EFFECT OF PLANT PRODUCTS AND STERILE INSECT TECHNIQUE IN THE MANAGEMENT OF RED PALM WEEVIL (*Rhynchophorus ferrugineus* Oliv.)

MAHESWARI, P.

Thesis submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2003

Department of Agricultural Entomology
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695522

DECLARATION

I hereby declare that this thesis entitled "**Effect of plant products and sterile insect technique in the management of red palm weevil (*Rhynchophorus ferrugineus* Oliv.)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
14-03-2003

MAHESWARI, P.
(2000-11-15)

CERTIFICATE

Certified that this thesis entitled "**Effect of plant products and sterile insect technique in the management of red palm weevil (*Rhynchophorus ferrugineus* Oliv.)**" is a record of research work done independently by Ms. Maheswari, P. (2000-11-15) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

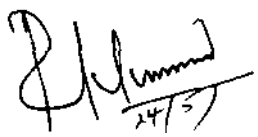
Vellayani,
14-03-2003

Dr R. Krishnakumar
(Chairman, Advisory Committee)
Assistant Professor
Department of Agricultural Entomology
College of Agriculture, Vellayani
Thiruvananthapuram.

Approved by

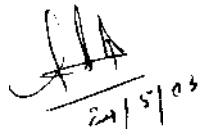
Chairman :

Dr. R. KRISHNAKUMAR
Assistant Professor,
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

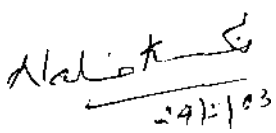


Members :

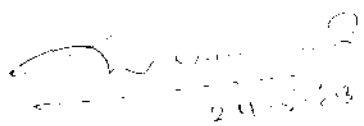
Dr. K. SARADAMMA
Professor and Head (Retired)
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.



Dr. T. NALINAKUMARI
Associate Professor and Head
Department of Agricultural Entomology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

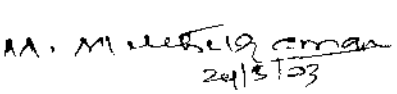


Dr. B.R. REGHUNATH
Associate Professor,
Department of Plantation Crops and Spices,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.



External Examiner :

Dr. M. MUTHURAMAN
Professor,
Department of Agricultural Entomology,
Tamil Nadu Agricultural University,
Coimbatore-641 003.



Dedicated to
Coconut Cultivators of Kerala

ACKNOWLEDGEMENT

I here to place the flowers of my gratitude and indebtedness on the feet of most respected chairman of my advisory committee, ***Dr. R. KRISHNAKUMAR*** *, Asst. Professor, Department of Entomology, College of Agriculture, Vellayani who came forward as a redeemer at the right juncture of my hard ship days by facilitating me to carryout my Masters degree programme along with the Junior Research Fellowship in the project. Words fail to express my deep and sincere obligation for his able guidance, persuasion, dedication, patience, sincerity, benevolence and affection shown through out the study period. His help in arriving at logical conclusion stood in good stead in the preparation of the manuscript with clarity and precision. The stimulation by his never ending flow of ideas contributed very significantly to my professional development. He was a source of strength and a beacon to my faltering steps in challenging work situations.*

I am highly grateful to Dr. K. SARADAMMA, Professor and head, Department of Entomology, College of Agriculture, Vellayani for the encouragement, scrutiny of the script, valuable suggestions and scientific support given during the entire period of this study.

I express my profound gratitude and obligation to Dr. T. NALINAKUMARI, Associate Professor, Department of Entomology, College of agriculture, Vellayani for her painstaking efforts in correcting the manuscript, valuable guidance and periodic suggestions at various stages of this investigation.

I express my sincere thanks to Dr. B.R. RAGHUNATH, Associate Professor, Department of Plantation crops and Spices, College of agriculture, Vellayani for his valuable suggestions and scrutiny of the script.

I am extremely grateful to Dr. R.. Vikraman Nair, Former Dean, College of Agriculture, Vellayani for his incessant encouragement, valuable advices and for sanctioning all the facilities necessary to carryout the study effectively.

I am highly thankful to Dr. Vijaya Raghava Kumar for his immense help in the statistical analysis of the data and Ajith Kumar, Programmer for his co-operation in the statistical analysis.

My special thanks are due to Dr. S. Suresh Nair, Associate Professor and Head, Department of Animal Husbandry, College of agriculture, Vellayani and Mrs. Suresh Nair for their unbound affection and moral support rendered to me through out the study period.

I sincerely thank Dr. C. A. Mary, Associate Professor, Department of Plant Pathology, and Asst. Warden Ladies Hostel, College of agriculture, Vellayani for her inestimable co-operation regarding my stay in the hostel and Mrs. K.S. Pramila, Asst. Professor, Department of Entomology for her moral support.

With ardent gratitude I remember the whole hearted co-operation bestowed on me by all the members of the teaching staffs especially my course teachers of Department of Entomology, College of agriculture, Vellayani.

I also thank Dr. S. Purushothaman Nair, Prof. and Head, Coconut Research Station, Balaramapuram for navigating me to the right path in the right time.

I should specially mention Mrs. T.S. Annie Bernice, my friend who was there in my need and led me to the right place.

My thanks to Miss. G. Sudha, SRF, BARC- DAE project for her help in the needy time and Mr.C. Dasayan, Technical assistant, BARC- DAE project for his unbound affection and help.

I sincerely thank to my bosom friend Miss. Manu. C. R, for her love and affection and for being my companion in all the ups and downs during these college days and my thanks are due to all my friends and colleagues who had added colours to my life.

My sincere thanks to Mr. Biju, ARDRA, for formatting the manuscript neatly and legibly.

I owe immeasurable indebtedness to my parents and my brother N. Hari Prasad for their unbound love, affection and blessings through out the period of my study.

Above all, I bow my head in front of that Almighty God who had given me the innate spirit to go through all the adversities in life with positive attitude.

Maheswari, P.

CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	Per cent
CD	Critical difference
cm	Centimetre
et al.	And others
Fig.	Figure
h	Hour
Krad	Kilo radians
ml	Millilitre
sec.	Second
spp.	Species
viz.	Namely
WCT	West Coast Tall

INTRODUCTION

1. INTRODUCTION

The "struggle for existence" between man and insects affecting his crops has been continuing from time immemorial. Man has fought war with insects for centuries. With few exceptions, man has been on defensive. Neither side has won the war but both have won the battles. With the world population attaining the seven billion mark, the urgency of increasing quality food production and reducing the insect attack without affecting the fragile environment is of paramount importance. The losses currently experienced in agricultural production due to insect pests and insect vectors are very high in developed and developing countries.

The present status of heavy reliance on chemical pesticides to control these insect pests can not be sustained in the future. Interestingly there is pesticide resistance in the target pests as well as the emergence of new pests as a result of the elimination of their natural enemies by insecticides. Furthermore, the public concerns have grown considerably as a result of widespread environmental pollution, contamination of underground water and presence of pesticide residues in food and fibre. In view of this unsustainable reliance on chemical pesticides and growing public concerns, new and more environment friendly techniques, approaches and strategies are getting much importance than the conventional methods of pest control. Obviously the last two decades of pest management were seem to give more emphasize on usage of botanicals instead of harmful chemicals as the former being safer to environment and sustainable.

Another new area in the pest management scenario is the 'sterile insect technique' (SIT). It has proven effectiveness against many key pests in controlling or even eradicating them. Unlike pesticides which generally have a broad spectrum lethal activity, the sterile insect technique is insect specific; it affects exclusively the reproduction of target insect and not other useful insects. Mass reared sterile insects are released on a sustained and regular basis in to the

target areas leading to substantial reduction in fertile mating. As a result SIT is highly compatible with other types of pest control. In developing countries the use of SIT is highly attractive because it reduces the need of expending hard currency for pesticide inputs and meets labour opportunities in mass rearing facilities. Being area wide integrated pest management in nature, SIT provides economic and environmental benefits equally for large commercial cultivators and small and poor subsistence farmers and the population at large.

The red palm weevil *Rhynchophorus ferrugineus* Oliv. is one of the most devastating pests of palms especially coconut in India (Ghosh, 1911), Ceylon (Brand,1917), and Phillippines (Viado and Bigornia, 1949). This weevil is distributed within 35° North and 15° South latitudes. The pest is strictly an internal feeder and hence its infestation can be identified only at the later stage of attack when the palm collapses. There are many methods of pest management in practice but nothing is effective due to the concealed nature of the pest. The traditional Integrated Pest Management (IPM) against red palm weevil with the dominant role played by chemical insecticides is not attractive due to the environmental hazards brought about by the harmful chemicals. Hence the modern IPM with the dominant role assigned to botanicals will be a right choice if the ideal botanical to contain red palm weevil is identified. Taking into account of the habitat of the red palm weevil, SIT can be considered as one of the method of containing it. Hence, the current study was in aim with containing red palm weevil using botanicals and SIT. The objectives of the study were

1. To collect the information on the pests of coconut and the management practices adopted by the cultivators, level of infestation by red palm weevil and presence of natural enemies through a survey conducted in Thiruvananthapuram District.

2. To evaluate the effect of plant products against red palm weevil.

3. To assess the effect of irradiation on male insect of red palm weevil.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 PEST STATUS

The weevils of genus *Rhynchophorus*, Sub family Rhynchophorinae of Curculionidae are major pests of palms especially coconut all over the world (Stebbing, 1903; Banks, 1906; Green, 1906; Lefroy, 1906; Ghosh, 1911; Henry, 1911; Fletcher, 1914; Brand, 1917; Buxton, 1920; Copeland, 1931; Corbett, 1932; Viado and Bigornia, 1949; Salgado, 1952; Nirula *et al.*, 1953; Wattanapongsiri, 1966). The red palm weevil *Rhynchophorus ferrugineus* Oliv. is a serious pest throughout South and South East Asia where they are important pests of coconut, oil palm and date palm (Viado and Bigornia, 1949; Salgado, 1952; Nirula *et al.*,1953; Wattanapongsiri, 1966). In Florida *Rhynchophorus cruentatus*. L is a major pest of sabal palm, the stake tree and a popular ornamental (Hagley, 1963). The weevil *Rhynchophorus palmarum* (L.) is a major pest in the neotropical region by vectoring the ring disease (Griffith, 1967). The Asiatic palm weevil, *Rhynchophorus schah* (Oliv.) is one of the most destructive pests of coconut in Philippines, Malaysia and Indonesia (Pacumbaba, 1972). The weevil *R. palmarum* is the primary vector of the red ring nematode *Radinaphelenchus* (*Bursaphelenchus*) *cocophilus* Baujard (Cobb, 1922; Tidman, 1951; Martyn, 1953; Hagley, 1963; Griffith, 1967, 1968, 1987). In Africa *Rhynchophorus phoenicis* L. causes losses in oil palm and coconut palms used as shade trees in cocoa in Papua New Guinea (Oehlschlager, 1993).

2.1.1 Nature and Extent of Damage and Symptoms due to Red Palm Weevil

The red palm weevil is a serious pest of coconut in Kerala (Kunjanpillai, 1919; Nirula *et al.*, 1953; Menon and Pandalai, 1958; Nair, 1978; Thampan, 1993; Rajan and Nair, 1997). The damage caused by the pest is 5-10 per cent in younger plantations (Nirula, 1956; Nair, 1978). Palms in the age group of 5 to 20 years are more susceptible to this pest attack (Vidyasagar and Kesavabhat, 1991). The incidence and abundance

of red palm weevil on various cultivars of date palms was reported by Baloch *et al.*, (1995) which ranged from 6.16 to 24.41 percent. The extent of damage by *R. ferrugineus* ranged from 6 to 34 per cent in Coimbatore, Tamil Nadu state, India (Rajamanickam *et al.*, 1995). The insect remain right inside the trunk feeding on the central tissue and the growing part resulting in the death of the tree (Rajamanickam *et al.*, 1995). The infestation by red palm weevil in date palms was higher during June-July and November- December (Vidyasagar *et al.*, 2000)

The weevil infestation in coconut and oil palms were not detected until the fronds wilt and the crown collapses (Sivapragasam *et al.*, 1990). Nair (1978) and Thampan (1993) reported that the mother weevil scoops out small holes on healthy tender parts of young palms upto seven years old and the eggs were laid in these holes. They also recorded that yellowing of inner leaf whorls and trunk with holes and oozing of fluids from these holes were the initial symptoms of attack and at the final stage the palm will collapse. Nair (1978) reported three types of infestation by red palm weevil in coconut *viz.* infestation of the crown, stem infestation and bole infestation.

The rate of red ring infection in oil palm plantations has been correlated with seasonal variations in weevil populations (Hagley, 1963; Blair, 1970a, b; Schuiling and Van Dinther, 1981). In the tropical America cumulative losses due to red ring disease caused by the combined attack of weevil and nematode *R. cocophilus* can reach 15 per cent in commercial oil palm plantations (Chinchilla, 1988).

2.2 DISTRIBUTION

The red palm weevil, *R. ferrugineus* is distributed all over the world but in most severe forms in Philippines (Banks, 1906; Copeland, 1931; Viado and Bigornia, 1949, Cendana, 1963), Ceylon (Green, 1906; Henry, 1917; Paul, 1929; Hudson, 1933; Salgado, 1952; Goonewardena and Velu, 1958, Kirthisinghe, 1966), India (Lefroy, 1906; Kunjanpillai, 1919;

Mackenna, 1919; Nirula *et al.*, 1953; Menon and Pandalai, 1958; Nair, 1978), Iraq (Buxton, 1920), Vestal (1956) recorded the presence of red palm weevil in Thailand. Lever (1969) reported its presence in New Guinea. Cox (1993) reported *R. ferrugineus* as a major pest on date palms in Egypt.

Shantappa *et al.* (1979) reported that *R. ferrugineus* is more severe in coastal areas of Kerala and Karanataka than in mid and high ranges. A survey conducted in Perinad village in the Kollam district of Kerala, showed that all the respondents knew about the pest status of red palm weevil and only 65.7 per cent were aware of the government recommendations for its control (George, 1977).

2.3 PLANT PRODUCTS IN PEST MANAGEMENT

2.3.1 On Red Palm Weevil

An oil derived from garlic (*Allium sativum* L.) and the synthetic oil containing the active ingredient diallyl disulphide were having insecticidal properties and were toxic to *R. ferrugineus* (Murthy and Amonkar, 1974). Chandrikamohan and Nair (1996) observed that 30-50 percent mortality of red palm weevil adults were obtained with seed extract of custard apple (*Annona squamosa* L.). The seed extract of neem, *Azadirachta indica* Juss. caused only below 50 percent mortality on the seven day old larvae of red palm weevil (Barranco *et al.*, 1998). Kurian and Mathen (1971) reported that one percent pyrethrum-piperonyl butoxide mixture was very effective against red palm weevil. Chandrikamohan *et al.* (2001) recorded that Azadiractin and Annona extract were effective against red palm weevil in the lab studies.

2.3.2 On Other Coleopteran Pests

2.3.2.1 Cledodendrum infortunatum L.

Several compounds which were reported to be isolated from *Cledodendrum* spp. like mycoside (Cooper *et al.*, 1980), clerodendrin A, B and clerodim (Antonious and Saito, 1981) and clerodin (Beek and Groot,

1986) showed antifeedant activity. Rajamma (1986) observed that the chopped leaves of *C. infortunatum* when incorporated into the soil, the infestation by *Cylas formicarius* F. was considerably reduced. Petroleum ether extracts of *Clerodendrum inerme* L. gave 93 percent protection of cowpea seeds against pulse beetle *Callasobruchus chinensis* F. (El Ghar and El Sheikh, 1987). They also reported the reduction in fecundity of pulse beetle *C. chinensis* when treated with *C. infortunatum*. The deterrency exhibited by *C. infortunatum* on *Henosepilachna vigintioctopunctata* F. was noticed by Saradamma (1989). Lily (1995) noticed the high antifeedant activity of flowers of *C. infortunatum* to *H. vigintioctopunctata*. The insecticidal and insect growth regulatory activity of *C. infortunatum* on grubs of rhinoceros beetle, *Oryctes rhinoceros* L. was observed by Chandrikamohan and Nair (2000).

2.3.2.2 Bougainvillea glabra Chois

Janardhanan *et al.* (1992) and Rao *et al.* (1992) observed that petroleum ether extracts of leaves of *B. glabra* at 0.5 percent concentration gave cent percent protection against *H. vigintioctopunctata*.

2.3.2.3 Azadirachta indica Juss.

'Thionemone' a compound extracted from neem seed kernel was reported as a repellent against *Aulocophora foevicollis* (Lucas) in cucurbits (Chakravarthy *et al.*, 1970). Ascher *et al.* (1980) found that 0.05 percent emulsion of methanol extract of neem had antifeedant activity against *Epilachna varivestis* Mostant. Kraus *et al.* (1980) reported that nine compounds from the seeds of *A. indica viz.*, nimbolin-B, nimbolidid A and B and ohchinolid A and B compounds exhibited antifeedant activity. Ladd (1980) observed the feeding deterrency exhibited by neem seed extracts over Japanese beetle (*Popillia japonica* F.). Pronounced malformations were observed in larval, pupal and adult stages in *E. varivestis* treated with *A. indica* (Rembold *et al.*, 1981). Feeding of *T. granarium* with neem extracts caused significant larval mortality

(Siddigi, 1981). Antifeedant activity of crude ethanol/ methanol extract of neem seeds were reported against Colorado potato beetle, *Leptinotarsa decemlineata* Say. (Jacobson *et al.*, 1983). Non emergence of adults from larvae treated with leaf and seed extracts of neem was reported in *P. japonica.* (Jacobson *et al.*, 1983). Singh and Singh (1985) observed that deoiled neem seed kernel extract was very effective in containing *T. granarium.* Newly hatched to twelve days old larvae of *Tribolium castaneum* Herbst. exposed to volatile substances from crushed seeds of neem failed to develop further (Maheswaran and Ganesalingam, 1988). Saradamma (1989) observed the feeding deterrency of *A. indica* to *H. viginctioctopunctata.* Inhibition of chlorinesterase activity was noticed in *Coccinella spp.* on treatment with neem extract (Naqvi *et al*, 1998). Considerable mortality of *Epilachna dodecastigma* Weideman was observed on treatment with neem oil 2 percent (Karmarkar and Bhole, 2000). Misra (2000) observed that applications of 3 percent dried leaf powder of *A. indica* on black gram seeds reduced the fecundity of *C. chinensis.*

2.3.2.4 Thevetia neriifolia Juss.

The effectiveness of *Thevetia* powders on a variety of insect species was reported by Indoo (1945); Jacobson (1958); Deshmukh and Borle (1975). Gattefosse (1949) attributed the insecticidal activity of *T. neriifolia* to the glycoside 'thevetin' and to another unidentified material of even greater toxicity. Reed *et al* (1982) reported the antifeedant activity of neriifolin isolated from *T. neriifolia* against striped cucumber beetle and Japanese beetle. Saradamma (1989) noticed the deterrent effect of leaf extracts of *T. neriifolia* to *H. viginctioctopunctata.* Ethanol extracts of leaves and fruits of *T. neriifolia* exhibited good antifeedant activity against the grubs of *H. viginctioctopunctata* (KAU, 1993). Bai (1996) reported that seed extracts of *T. neriifolia* was an effective antifeedant leading to larval starvation in *Epilachna* beetle. Dwivedi and Amitakumari (2000) observed that acetone extract of *T. neriifolia* leaves

reduced the egg hatching of *H. viginctioctopunctata* to 57 percent and that in petroleum ether extract caused 52 percent reduction in hatching.

2.3.2.5 Annona squamosa L.

Islam (1993) reported the antifeedant activity of *A. squamosa* against rice hispa, *Dicladispa armigera* (Oliv.) and rice weevil, *Sitophilus oryzae* L. and pulse beetle *C. chinensis*. Reddy *et al.* (1990) reported that the petroleum ether extract of *A. squamosa* was effective in reducing *H. viginctioctopunctata* in the field. Oshawa *et al.* (1990) observed that the ether extracts of seeds of *A. squamosa* caused feeding deterrency of grubs of *H. viginctioctopunctata* (Rao and Chitra, 1990). Santhoshbabu *et al.* (1996) reported that hexane extract of leaf and chloroform extract of seeds of *A. squamosa* showed effective antifeedant activity against pollu beetle (*Longitarsus nigripennis* Mots.). Kardinam and Wikardi (1997) reported that the application of seed extracts of *A. squamosa* at 1% (W/W) on *Callosobruchus analis* F. affected its mortality and oviposition. Mixing of foods of rhinoceros grubs with shade dried leaf powder of *A. squamosa* caused 40 percent mortality of rhinoceros grubs (CPCRI, 1998). According to Dharmasena *et al.* (2001) acetone and ethanol extracts made from fresh and stored leaves of *A. squamosa* decreased the number of adults of *Callosobruchus maculatus* F. emerging from cowpea seeds. Foliar extracts of *A. squamosa* was found to be effective against *C. chinensis*. Kolkar *et al.* (2002) observed that the foliar extracts of *A. squamosa* was very effective against *C. chinensis*

2.4 USE OF STERILE INSECT TECHNIQUE IN PEST MANAGEMENT

The use of sexually sterile males for the control of insect pests was first advocated by Knipling (1955). This approach has since been evaluated for its effectiveness in the case of a number of insect pests of agricultural and public health importance, with varying degrees of success (Proverbs and Newton, 1969) and they reported that the performance depends on the mating ability. Von Bosstel (1960) found that overall

competitiveness of sterile males would depend not only on their ability to mate, but also on their ability to produce and transfer adequate quantities of sperm and the ultimate competition would be at the level of sperm. Among the agricultural pests, sterilization by irradiation has been applied to the fruit flies more than to any other group (Steiner *et al*, 1962). Control and eradication of the cockchafer (*Melolonthus vulgaris* F) was achieved in a 30 hectare area of grassland in north-western Switzerland by Horber (1963). Some attempts to control the cotton boll weevil (*Anthonomus grandis* F) by the release of irradiated insects have been made by Davich (1969). The red palm weevil has typical chromosome for a curculionid, n = 11 and most also showed the Xyp male heterogametry (Takenouchi, 1965). Topical application of Matepa was also found to be effective in sterilizing red palm weevil (Nagayama and Nagasawa, 1966). Spielman *et al.* (1967) and Harwalkar and Rahalkar (1973) reported that the polygamous female were functionally monogamous. The radiation induced sterility in the males may be the result of either aspermia, sperm inactivation or induction of dominant lethal mutation in the sperm (La Chance, 1967) but in red palm weevil is only due to dominant lethal mutation (Rahalkar *et al.*, 1973) as the female red palm weevil is polygamous (Nirula, 1956). Ticheler (1971) reported a mass rearing technique enabling the production of 15 000 pupae of onion fly (*Hyemya antique* F.) by one man per week for irradiation. Noordink (1971) showed that pupae irradiated 1-3 days before eclosion at 3000 r produced fully sterile females and males. The competitive value between male and female would help to determine the number of sterile males required for release (Fried, 1971). Release of sterile female along with sterile male is not advantageous as greater reduction in reproduction potential of red palm weevil females was observed when the irradiated females were not released with irradiated males (Rananaware *et al.*, 1975). Competition between 10 sterile and one normal male was adequate for appreciable suppression of progeny production by a female (Rahalkar *et al.*, 1982).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 SURVEY OF INFESTATION OF RED PALM WEEVIL IN THIRUVANANTHAPURAM DISTRICT

A survey was conducted in the four administrative taluks of Thiruvananthapuram district viz., Neyyattinkara, Nedumangad, Chirayinkil and Thiruvananthapuram to judge the extent of damage inflicted by the red palm weevil *Rhynchophorus ferrugineus* of coconut, presence of its natural enemies if any and the plant protection methods adopted by the coconut cultivators.

3.1.1 Mode of Survey

Two Krishibhavans from each taluk *viz.*, Kottukal and Vizhinjam ; Vidhura and Karakulam; Kadakkavur and Varkkala; and Thiruvallam and Kalliyoor were selected from Neyyattinkara, Nedumangad, Chirayinkil and Thiruvananthapuram taluks respectively. From each of the selected Krishibhavan fifteen coconut cultivators were identified at random and survey was conducted. Three visits in three seasons *viz.*, June, September and February were carried out in all the selected cultivator's fields. Observations were recorded based on a proforma prepared for this purpose (Appendix 1).

The methodology applied for recording observations were by interview with the cultivators and also by direct observations from the area selected. In each visit, the total number of palms present and the number of infested and collapsed palms was recorded leaving the number of collapsed palms which were counted in the previous visit.

3.1.2 Percentage Seasonal Infestation of Red palm weevil in the Different Krishibhavans and Taluks of Thiruvananthapuram District

From the total number of palms present in the cultivator's field and from the total number of palms infested, the percentage infestations were worked out based on the field observations from all the eight Krishibhavans. The percentage

infestations of the red palm weevil in the four taluks were found out by taking the mean infestation percentage observed in the different Krishibhavans of that taluk during survey.

3.1.3 Topography of Land and Infestation Percentage

The average percentage infestations of red palm weevil under the three types of lands, *viz.*, low land, middle land and upland in all the Krishibhavans were observed and the data was subjected to statistical analysis.

3.1.4 Variety of Palm and Percentage Infestation

The average percentage infestations of red palm weevil in the different varieties of palms located in the different Krishibhavans were assessed.

3.1.5 Destructive Sampling

3.1.5.1 Various Life Stages of Red Palm Weevil Observed in Infested Coconut Palms, in the Different Parts of the Collapsed Palm

Five palms each showing different types of infestation *viz.*, crown infestation, stem infestation and bole infestation were cut opened and the number of life stages present were counted.

3.1.5.2 Various Life Stages of Red palm weevil Observed in Infested Coconut Palm, Different Levels of Infestation

Palms (5 numbers) with different infestation level *viz.*, Yellowing of leaf stage, Stem with holes and oozing of fluids stage and palms in the collapsing stage were cut opened and the number of different stages of red palm weevil found inside were recorded.

Table 1 Details of plant products used for study

Sl. No.	Scientific Name	Common Name	Local Name	Conc. Used (%)	Parts used
1	*Andrographis paniculata.* (Burn.F.) Wall.ex. Nees.	Creap	*Kiriyath*	5 and 10	Whole plant
2	*Hyptis suaveolens* L.	English Basil	*Nattapoochedi*	5 and 10	Whole plant
3	*Bougainvillea glabra* Chois.	Bougainvillea	*Kadalasuchedi*	5 and 10	Whole plant
4	*Samadera indica* Guertn.	Gatep pait / rapus	*Karingotti*	2 and 4	Whole plant
5	*Clerodendrum infortunatum* L.	Clerodendrum	*Peruvalam*	5 and 10	Leaf
6	*Azadirachta indica* Juss.	Neem	*Arya veppu*	2 and 4	Seed
7	*Thevetia neriifolia* Juss.	Yellow oleander	*Manja arali*	5 and 10	Leaf
8	*Annona squamosa* L.	Custard apple	*Seetha pazham*	5 and 10	Seed
9	*Anacardium occidentale* L.	Cashew	*Cashu mavu*	5 and 10	Apple

3.2 LABORATORY STUDIES ON TOXICITY AND REPELLENCY OF PLANT PRODUCTS ON RED PALM WEEVIL

Laboratory study was conducted to assess toxicity and repellency of the following treatments on red palm weevil, *R. ferrugineus*. The experiment was laid out in completely randomized design with 20 treatments (Table 1) each replicated thrice.

T_1- Plant extract of *A. paniculata*.(5%)

T_2- Plant extract of *A. paniculata* (10%)

T_3- Plant extract of *H. suaveolens* (5%)

T_4- Plant extract of *H. suaveolens* (10%)

T_5- Leaf extract of *B. glabra* (5%)

T_6- Leaf extract of *B. glabra* (10%)

T_7- Seed oil of *S. indica* (2%)

T_8- Seed oil of *S. indica* (4%)

T_9- Leaf extract of *C. infortunatum* (5%)

T_{10} - Leaf extract of *C. infortunatum* (10%)

T_{11} - Seed oil of *A. indica* (2%)

T_{12} - Seed oil of *A. indica* (4%)

T_{13}- Leaf extract of *T. neriifolia* (5%)

T_{14}- Leaf extract of *T. neriifolia* (10%)

T_{15}- Seed extract of *A. squamosa* (5%)

T_{16}- Seed extract of *A. squamosa* (10%)

T_{17}- Apple extract of *A. occidentale* (5%)

T_{18}- Apple extract of *A. occidentale* (10%)

T_{19}- Carbaryl (1%)

T_{20}- Control

3.2.1 Rearing of the Test Insect

Initial culture of red palm weevil *R. ferrugineous* was raised by collecting adult weevils from the field by cut open the infested fronds of coconut. The adult weevils were kept in pairs in screw caped glass bottles (25x15 cm). Splitted coconut petioles of 10 cm length and 5 cm in width were kept inside the bottles as oviposition medium. The petioles were taken out from the bottles in alternate days and the adults were provided with new petiole pieces. The petioles, which were taken out from the bottles, were pealed off using a sharp knife and the larvae were taken out. These larvae were kept singly in plastic disposable cups (9.5x6.5 cm) and provided with fresh pieces of coconut petioles as feed material. Feed change was carried out by taking out the petioles from the cup and cut open it carefully using a knife. The larvae were again replaced in the cup and provided with coconut petioles of varying length depending on the stage of the larvae. Lower instars were provided with small petioles (7x4 cm) and the higher instars with larger petioles (10x4 cm). Feed change was continued till the larvae became full grown. The full grown larvae were entered the coconut petioles of 30 cm length and 6 cm breadth by piercing a hole on one side of it with a pointed knife and kept as such on the racks for 20 days for pupation. After 20 days the petioles were cut open, cocoons were collected and kept inside the glass bottles separately. The adults emerging from the cocoons and the larvae reared in the above said method were used for the experiment.

Contamination of the culture was minimized by maintaining good sanitation in rearing. Glasswares were sterilized by immersing them in 0.5 percent Sodium hypo chlorite solution for one day. They were then washed in distilled water and air dried in hot air oven.

3.2.2 *Preparation of the Spray Solution*

Different plant products required for the study were collected from near by areas of College of Agriculture, Vellayani except seed oil of *S. indica* and seed oil of *A. indica*, both of which were purchased from the local market. The details of plant species used for the present study are given in Table 1.

3.2.2.1 Plant Extracts and Leaf Extracts

Aqueous extracts of leaves or whole plants of the plants mentioned in Table1 were prepared freshly just before use. For this purpose, fresh material were taken, washed thoroughly with tap water. chopped them into small pieces and 100 and 200 gram each of the materials was homogenized with mixer grinder and extracted with distilled water. The extracts were squeezed through muslin cloth and made up to two litres using distilled water. Thus 5 percent and 10 percent extracts were prepared. To these plant extracts 0.5 percent of soap solution was added as emulsifier before spraying for toxicity studies.

3.2.2.2 Seed Extracts

For the preparation of seed extracts i.e. *A. squamosa* 5 percent and 10 percent, the dried seeds were powdered and 100 and 200 grams of the powdered materials were taken separately and soaked overnight in a little quantity of distilled water. Next day, the materials were squeezed through the muslin cloth. the residue was washed with distilled water and the volume of the extract was made upto 2 litres. To these seed extracts also 0.5 percent of soap solution was added as emulsifier before spraying for toxicity studies.

3.2.2.3 Seed Oils

Crude oil (100%) of *A. indica* and *S. indica* (20 ml and 40 ml each) were taken in 500 ml glass beakers. To this 100 ml of 0.5 percent soap solution was added. The mixture was stirred thoroughly using a glass rod. There after the contents were transferred into a measuring cylinder of 2 litres capacity and were made upto 2 litre by adding distilled water to get 2 percent and 4 percent solutions respectively.

3.2.2.4 Apple Extract

The crude extract (100 %) of *A. occidentale* was prepared by homogenizing the well ripened fruits of the same in a mixer grinder. From the crude extracts required concentrations were prepared by diluting with distilled water.

3.2.2.5 Carbaryl 1%

Carbaryl 50 WP (40 g) was weighed and mixed with small quantity of water and made upto 2 litres to get 1% solution.

3.2.2.6 Control

Water was used as a spray solution in all the control treatments.

3.2.3 Estimation of Mortality

Mortality was estimated by topical application method. Ten numbers of each instars of red palm weevil were taken in separate petridishes. Three such sets were taken for each instar. The extracts of respective concentration were sprayed on the larvae taken in the petridishes using an atomizer. The treated larvae were transferred individually in to the plastic cups and provided with small pieces of coconut petioles as mentioned in 3.2.1. Mortality was observed in every 2, 24 and 48 hours. In the same manner the treatments were applied on pre pupae and pupae of red palm weevil. For applying the treatments on the adults, the weevils were taken in screw caped glass bottles and proceeded as above.

3.2.4 Estimation of Repellency

Cut coconut petioles of 7cm length and 5cm breadth were taken and dipped in the extracts of respective concentration taken in a glass basin for 24 hours. The treated coconut petioles were taken out, air-dried and transferred separately in the plastic cups and 10 larvae each from each stage of red palm weevil were released into each cup. Three such sets were kept for each stage of the larvae and for each treatment. The number of larvae moved away from the treated petiole was counted as the number of larvae repelled. The percentage repellency was calculated based on the formula (B/A) x100, where A=Total number of larvae released; B=Total number of larvae repelled.

Water was used as control. The repellency was corrected using Abbot's formula (Abbot, 1925).

3.2.5 Comparative Efficiency of Cashew Apple Extract and Carbaryl on the Mortality of Different Stages of Red Palm Weevil.

Different concentrations of apple extract of *A. occidentale* viz., 2, 4 , 5, 10, 20, 40, 50 and carbaryl 1 percent were applied on different stages of red palm weevil as mentioned in 3.2.3 and the results were compared statistically.

3.3 STERILE INSECT TECHNIQUE

The male red palm weevils 1-2 days after their emergence from the cocoons were used for the irradiation purpose. The insects were localized in the irradiation field by confining them in a perforated plastic box. The irradiation source is "Gamma irradiation chamber". This produced a dose of 1 Krad./ 150 sec. Ten adult weevils were taken in each plastic container. They were irradiated at different doses of 1.5 Krad., 1.6 Krad., 1.7 Krad., 1.8 Krad. and 2.0 Krad. respectively by keeping the containers inside the irradiation chamber. The irradiated weevils were used for further experiments.

3.3.1 Effect of Different Doses of Co 60 Gamma Radiation on the Development of Different Life Stages of Red palm weevil

Five irradiated males were kept separately in five screw cap glass bottles having perforation in the cap. Each male is provided with 3 day old virgin female and scrapings of petioles of coconut as egg laying medium. The number of eggs laid by the females kept in all the bottles were observed and recorded separately. The whole experiment was repeated for all the tested radiation doses. The eggs were harvested on alternate days and placed on moist filter paper in petri dishes. The number of eggs hatched was counted and from that the percentage were worked out. The larvae that hatched out from the eggs of all the bottles were observed separately and the number of larvae died before attaining adult stage was recorded. From that, the percent larval mortality in each case was calculated. The number of adults emerged from each case was also noted separately. The adults emerged from each case were kept

separately in another set of screwcap glass bottles with perforated cap and provided with coconut petioles. The longevity of adults in days was also noted separately.

3.3.2 Evaluation of Efficiency of Normal and Irradiated Male Insects of Red palm weevil on the Basis of Percent Egg Hatch

3.3.2.1 Due to Repeated Mating

Male weevils irradiated at different doses were caged individually with virgin females. The females were removed at 48h interval and the males were provided with fresh females. This process was repeated till the male had the chance to mate with seven females. The females after removal from their mates were confined singly for oviposition and the viability of eggs was studied.

3.3.2.2 Due to Re Mating

The competitiveness of sperms from normal and irradiated males was evaluated with following mating combinations.

(1) Single female insect mated with an irradiated male for 36 days and then with normal male there after

(2) Single female insect mated with a normal male for 36 days and then with irradiated male there after

(3) Single female insect mated with a normal male continuously

(4) Single female insect mated with an irradiated male continuously and

(5) Single female insect mated with a normal male for 36 days and then deprived of the mate.

In group (1) and (2) the males were interchanged. For each of the above mating combinations, five replications were kept and the viability of eggs laid was assessed. The whole experiment was repeated for all the radiation doses tried.

3.3.2.3 Due to Recent Mating

In order to study the effect of recent mating on egg viability after the normal mating, five newly emerged virgin females of red palm weevil were taken in screw cap glass bottles separately and were crossed individually with freshly emerged normal males of red palm weevil. In another set, five newly emerged virgin females were crossed individually with irradiated males. The males in these two groups were interchanged after four days and were allowed to remain with their mates for another four days. Thereafter, the females were deprived of their mates and were provided with oviposition medium. In yet another set, five newly emerged virgin females were crossed individually with normal males for four days and then continuously with irradiated males by replacing the normal male. The fecundity and the viability of eggs laid by females in all the sets were recorded and the percentage of eggs hatched was also calculated. The entire experiment was repeated for all the tested radiation doses.

3.3.2.4 Due to Mating Competition

Newly emerged virgin females of red palm weevil were confined individually with one normal and varying number of irradiated males starting from 0 to 10. For each ratio, five replications were kept and the entire experiment was carried out for all the tested irradiation doses. The number of eggs per female and percentage hatching were observed individually.

RESULTS

4. RESULTS

4.1 SURVEY

4.1.1 Seasonal Infestation of Red palm weevil in the Different Taluks and Krishibhavans of Thiruvananthapuram District

The survey conducted to study the seasonal infestation of red palm weevil in the selected Krishibhavan areas of Thiruvananthapuram district is shown in Table2. The result indicated that, during June the percentage infestation was significantly higher in Kadakkavur (12.44) when compared with other areas such as Vithura (8.48), Varkkala (7.89), Karakulam (7.64), Kottukal (7.46), Kalliyoor (6.77), Vizhinjam (6.53) and Thiruvallam (5.15). The infestation percentage in Vithura was also significantly higher than that of Thiruvallam, but was on par with other areas *viz.*, Varkkala, Karakulam, Kottukal, Kalliyoor and Vizhinjam. During September also significantly higher infestation was found in Kadakkavur area (9.24) when compared to other areas with percentage infestation ranged from 6.98 to 3.44, but was found to be statistically on par with Vizhinjam, Vithura and Kottukal areas. Infestation percentages in Kottukal and Vizhinjam area were found to be significant only to that in Thiruvallam area, but was on par with that in other areas with infestation ranged from 6.32 to 3.44 percent. During February also maximum infestation was found in Kadakkavur area (6.16) and it was statistically superior to that in Varkkala (2.26) and Thiruvallam (0.83) areas and on par with infestation percentage in other areas. Infestation percentage in Kottukal area was statistically same to that in Vizhinjam, Vithura, Karakulam, Varkkala and Kalliyoor areas and was significantly higher than that in Thiruvallam areas.

The results of the survey indicated that, of all the four taluks of the Thiruvananthapuram district surveyed, significantly higher percentage infestation during June was observed in Chirayinkil (10.21) when compared to other areas with the infestation range of 8.21 to 6.05 and was on par with that in Nedumangad

Table 2. Seasonal infestation of red palm weevil in the different Taluks and Krishibhavans of Thiruvananthapuram district

Taluks	Krishi bhavans	Mean percentage infestation during various seasons					
		June		September		February	
Neyyattinkara	Kottukal	7.46 (15.85)	6.89 (15.33)	6.98 (13.43)	5.12 (13.05)	4.94 (12.84)	3.92 (11.37)
	Vizhinjam	6.53 (14.80)		6.38 (12.68)		2.96 (9.90)	
Nedumangad	Vidhura	8.48 (16.92)	8.21 (16.48)	6.10 (14.62)	6.39 (14.46)	3.63 (10.98)	3.63 (10.98)
	Karakulam	7.64 (16.04)		4.82 (14.29)		3.45 (10.71)	
Chirayinkil	Kadakkavur	12.44 (20.65)	10.21 (18.48)	9.24 (17.69)	7.91 (16.50)	6.16 (14.36)	4.11 (11.51)
	Varkkala	7.89 (16.30)		4.26 (15.31)		2.26 (8.65)	
Thiruvananthapuram	Thiruvallam	5.15 (13.11)	6.05 (14.09)	3.44 (8.90)	2.92 (9.79)	0.83 (5.22)	2.12 (8.52)
	Kalliyoor	6.77 (15.08)		5.40 (10.68)		4.20 (11.82)	
CD (0.05)		(3.29)	(2.33)	(4.13)	(3.15)	(4.46)	(2.92)

Values in parentheses indicate transformed data: $\sqrt{x + 1}$

(8.21). The infestation in Nedumangad was significantly superior to that in Thiruvananthapuram (6.05), but was on par with that in Neyyattinkara. During September also significantly higher infestation was found in Chirayinkil area (7.91) than that in other areas and it was on par with infestation percentage in Nedumangad (6.39). The infestation percentage in Nedumangad was significantly higher than that in Thiruvananthapuram (2.92) and was on par with that in Neyyattinkara (5.12). During February, significantly higher infestation was found in Chirayinkil (4.11) and it was on par with infestation percentage in Nedumangad (3.63) and Neyyattinkara (3.92). The lowest infestation was recorded in Thiruvananthapuram (2.12).

Between seasons, the percentage infestation was significantly higher during June (Ranged from 14.09 to 18.48) when compared to that in September (2.92 to 7.91) and February (2.12 to 4.11) in all the four taluks.

4.1.2 Seasonal Infestation of Red palm weevil in Coconut under Different Topographical Situations and in Commonly Cultivated Coconut Varieties

The infestation level of red palm weevil in the different topographical situations and in commonly cultivated coconut varieties is mentioned in Table 3. The infestation level of red palm weevil in the different topographical situations *viz.*, low land, plain land and upland revealed that the significantly higher infestation was in low land or reclaimed paddy lands in all the three seasons (12.36, 8.73 and 3.77 during June, September and February respectively) followed by that in garden land (6.33, 4.43 and 2.21 respectively for June, September and February) and upland (2.73, 1.89 and 1.12 respectively for June, September and February).

The seasonal infestation in coconut varieties was significantly higher for Malayan Yellow dwarf (9.23 percentage) over that in West Coast Tall and was on par with that in Green Dwarf (8.83 percentage) . The same trend was observed during September and February months.

Table 3. Seasonal infestation of red palm weevil in coconut cultivated under different topographical situations and in commonly cultivated coconut varieties

Types of land	Mean percentage infestation		
	June	September	February
Low land	12.36(3.52)	8.73(2.96)	3.77(1.94)
Plain land	6.33(2.52)	4.43(2.11)	2.21(1.49)
Upland	2.73(1.65)	1.89(1.38)	1.12(1.06)
CD (0.05)	(0.5)	(0.25)	(0.24)
Varieties			
WCT	4.93(2.22)	4.10(2.03)	1.54(1.24)
Green dwarf	8.83(2.97)	7.85(2.80)	5.36(2.32)
Malayan yellow dwarf	9.23(3.04)	11.01(3.32)	8.09(2.85)
CD (0.05)	(0.52)	(0.42)	(0.31)

Values in parentheses indicate transformed values : $\sqrt{x + 1}$

4.1.3 The Life Stages of Red palm weevil Observed in the Different Parts of the Infested Collapsed Palms.

The different life stages like grubs, pupae and adults collected from the infested collapsed palms from the surveyed areas is shown in Table 4. The result denoted that the number of grubs per infested palm was observed to be higher significantly in palms in which the stem infestation was prominent (91.83) than that bole infestation (82.43) and crown infestation (69.66), but the number of grubs per infested palm in stems infestation and bole infestation was on par with each other. The number of pupae per infested palm was higher significantly in the case of crown infestation (29.91) than that in stem infestation (19.97) and in bole infestation (12.91). But the number of adults of red palm weevil per infested palm was significantly higher in the case of bole infestation than that in stem (3.75) and crown infestations (2.96) which were statistically on par with each other.

4.1.4 The Life Stages of Red palm weevil and the Symptoms of Infestations Observed in Infested Coconut Palms

The different life stages of red palm weevil collected from the infested palms is elucidated in Table 5. The result showed that the number of first to fifth instars of red palm weevil were higher significantly at yellowing of leaf stage (8.24, 14.13, 13.36, 18.36 and 14.44 numbers respectively) than that at stem with holes and oozing of fluids stage (4.90, 10.97, 11.81, 10.02 and 12.17 respectively) and at palm collapsing stage (1.04, 4.38, 3.75, 1.28 and 8.98 respectively). The number of sixth instars of red palm weevil was higher significantly at palm collapsing stage (10.56 number) and at yellowing of leaf stage (7.47) than that at stem with holes and oozing of fluids stage. The number of seventh instar of red palm weevil was also higher significantly at palm collapsing stage (12.54 numbers) than that at stem with holes and oozing of fluids stage (6.84). The instars seventh, eighth, ninth, pupae and adults of red palm weevil was not noticed at the yellowing of leaf stage of infestation. The higher instars (eighth and ninth instars), pupae and adults of red palm weevil were found only at palm collapsing stage (26.56, 9.96, 20.16 and 7.82 respectively)

Table 4.The life stages of red palm weevil observed in the different parts of the infested collapsed palm

Type of infestation	Grub	Pupa	Adult
Crown infestation	69.66 (8.41)	29.91(5.56)	2.96(1.99)
Stem infestation	91.83(9.63)	19.97(4.58)	3.75(2.18)
Bole infestation	82.43(9.13)	12.91(3.73)	6.18(2.68)
CD (0.05)	(0.63)	(0.43)	(0.28)

Table 5. The life stages of red palm weevil and the types of infestations observed in infested coconut palms

Type of infestation	I instar	II instar	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar	Pupa	Adult
Yellowing of middle leaf stage	8.24(3.04)	14.13(3.89)	13.36(3.79)	18.36(4.40)	14.44(3.93)	7.47(2.91)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)
Stem with wholes and oozing of fluids	4.90(2.43)	10.97(3.46)	11.81(3.58)	10.02(3.32)	12.17(3.63)	5.97(2.64)	6.84(2.80)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)
Palm collapsing stage	1.04(1.43)	4.38(2.32)	3.75(2.18)	1.28(1.51)	8.98(3.16)	10.56(3.40)	12.54(3.68)	26.56(5.25)	9.96(3.31)	20.16(4.6)	7.82(2.97)
CD (0.05)	(0.58)	(0.55)	(0.72)	(0.48)	(0.43)	(0.7)	(0.35)	(0.7)	(0.19)	(0.62)	(0.4)

Values in parentheses indicate transformed values : $\sqrt{x+1}$

4.2 LABORATORY STUDIES FOR EVALUATION OF PLANT PRODUCTS AGAINST RED PALM WEEVIL.

4.2.1 Effect of Plant Products on the Mortality of Different larval Stages of Red Palm Weevil

4.2.1.1 Two Hours after Treatment

The effect of plant products on the mortality of the larvae of red palm weevil recorded at two hours after treatment was depicted in Table 6. The results showed that in the case of first instars two hours after treatment, apple extract of *Anacardium occidentale* 10% and carbaryl 1% which had shown significantly higher level of mortality of 56.67 when compared to other treatments whose values ranges from 26.67 percent to 3.33 percent. But the mortality caused by apple extract of *A. occidentale* 10% and carbaryl 1% was statistically on par with the mortality caused by apple extract of *A. occidentale* 5% whose value was 46.67 percent. Seed extract of *Annona squamosa* 10%, seed extract of *A. squamosa* 5% with percent mortality of 26.67 was found to be statistically on par with that of apple extract of *A. occidentale* 5%. The mortality caused by seed extract of *A. squamosa* 10% was also found to be on par with that of leaf extract of *Thevetia neriifolia* 10%, seed oil of *Azadirachta indica* 4% and seed oil of *A. indica* 2% with percent mortalities of 16.31, 13.33 and 13.33 respectively. Mortality caused by seed oil of *A. indica* 4% was found to be on par with that by all other treatments except in the case of seed oil of *Samadera indica* 2% and plant extract of *Andrographis paniculata* 5%, with percent mortalities of 3.33. No mortality was observed in treatments with plant extract of *Hyptis suaveolens* 5 %.

When the same treatments were tried on second instars it was observed that 2 hours after treatment, apple extract of *A. occidentale* 10% and carbaryl 1% had shown significantly higher level of mortalities of 53.33 and 43.33 respectively. The mortality caused by carbaryl 1% was found to be on par with that caused by apple extract of *A. occidentale* 5% (36.67). Next highest mortality was caused by seed oil of *A. indica* 4% and leaf extract of *T. neriifolia* 10% (20.00 percent each) which was statistically on par with that caused by seed oil of *A. indica* 2%, seed

extract of *A. squamosa* 10%, seed extract of *A. squamosa* 5%, leaf extract of *T. neriifolia* 5%, leaf extract of *Bougainvillea glabra* 10% and plant extract of *H. suaveolens* 10% with percent mortalities of 20.00, 16.31, 16.31, 16.31, 13.33, 13.33, 13.33 and 10.00 respectively. Leaf extract of *B. glabra*5%, leaf extract *Clerodendrum infortunatum* 10%, leaf extract of *C. infortunatum* 5%. plant extract of *A. paniculata* 10% were also shown significant mortalities of 7.78. 7.78, 6.66, 6.66 and were on par with each other and with that of seed extract of *A. squamosa* 10%, seed extract of *A. squamosa* 5%, leaf extract of *T. neriifolia* 5%, leaf extract of *B. glabra* 10% and plant extract of *H. suaveolens* 10%. No mortality was observed in treatments applied with seed oil *of S. indica* 4%, plant extract of *A. paniculata* 5%, seed oil *of S. indica* 2% and in the control.

When the treatments were tried on the third instars the results indicated that two hours after treatment, the apple extract of *A. occidentale* 10% and carbaryl 1% showed significantly higher level of mortalities of 43.33 percentage and 40 percent respectively. Apple extract of *A. occidentale*5%, seed oil of *A. indica* 4%, seed extract of *A. squamosa* 10%, seed extract of *A. squamosa* 5%, seed oil of S. *indica* 4%, seed oil of *S. indica* 2%, plant extract of *H. suaveolens* 10%, and leaf extract of *T. neriifolia* 10% and plant extract of *H. suaveolens* 5% with percent mortalities of 13.33, 13.33, 10.00, 10.00, 10.00, 10.00, 10.00, 6.66 and 6.66 respectively and were also on par with each other. Other treatments were non significant.

The effect of the treatments on fourth instars two hours after treatment showed that, carbaryl1% and apple extract of *A. occidentale* 10% showed significantly higher levels of mortalities 40.00 and 36.67 respectively followed by apple extract of *A. occidentale*5% with mortality of 20.00 percent. Rest of the treatments were non significant.

The same for fifth instars showed that, carbaryl1%, apple extract of *A. occidentale* 10% and apple extract of *A. occidentale*5% showed significantly higher level mortalities 36.67, 26.67 and 23.33 respectively which were on par with each other. Rest of the treatments were non significant.

Table 6. Effect of plant products on the mortality of different larval stages of red palm weevil (2h after treatment)

Treatments	I instar	II instar	III Instar	IV Instar	V Instar
Plant extract of *A. paniculata* (5%)	3.33 (1.77)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)
Plant extract of *A. paniculata* (10 %)	6.66(2.54)	6.66(2.54)	3.33 (1.77)	3.33 (1.77)	0.00(1.00)
Plant extract of *H. suaveolens* (5%)	0.00(1.00)	3.33 (1.77)	6.66(2.54)	0.00(1.00)	0.00(1.00)
Plant extract of *H. suaveolens* (10%)	6.66(2.54)	10.00(3.31)	10.00(3.31)	6.66(2.54)	3.33 (1.77)
Leaf extract of *B. glabra* (5%)	6.66(2.54)	7.78(2.96)	0.00(1.00)	3.33 (1.77)	3.33 (1.77)
Leaf extract of *B. glabra* (10%)	6.66(2.54)	13.33(3.73)	0.00(1.00)	6.66(2.54)	3.33 (1.77)
Seed oil of *S. indica* (2%)	3.33 (1.77)	0.00(1.00)	10.00(3.31)	0.00(1.00)	0.00(1.00)
Seed oil of *S. indica* (4%)	6.66(2.54)	0.00(1.00)	10.00(3.31)	0.00(1.00)	3.33 (1.77)
Leaf extract of *C. infortunatum* (5%)	3.81(2.19)	6.66(2.54)	0.00(1.00)	0.00(1.00)	0.00(1.00)
Leaf extract of *C. infortunatum* (10%)	10.00(3.31)	7.78(2.96)	0.00(1.00)	0.00(1.00)	3.33 (1.77)
Seed oil of *A. indica* (2%)	13.33(3.73)	16.31(4.16)	0.00(1.00)	3.33 (1.77)	0.00(1.00)
Seed oil of *A. indica* (4%)	13.33(3.73)	20.00(4.58)	13.33(3.73)	3.33 (1.77)	3.33 (1.77)
Leaf extract of *T. neriifolia* (5%)	7.78(2.96)	13.33(3.73)	3.81(2.19)	0.00(1.00)	0.00(1.00)
Leaf extract of *T. neriifolia* (10%)	16.31(4.16)	20.00(4.58)	6.66(2.54)	0.00(1.00)	0.00(1.00)
Seed extract of *A. squamosa* (5%)	26.67(5.23)	13.33(3.73)	10.00(3.31)	6.66(2.54)	3.33 (1.77)
Seed extract of *A. squamosa* (10%)	26.67(5.23)	16.31(4.16)	10.00(3.31)	6.66(2.54)	6.66(2.54)
Apple extract of *A. occidentale* (5%)	46.67(6.89)	36.67(6.13)	13.33(3.73)	20.00(4.49)	23.33(4.91)
Apple extract of *A. occidentale* (10%)	56.67(7.59)	53.33(7.36)	43.33(6.65)	36.67(6.13)	26.67(5.23)
Carbaryl 1%	56.67(7.57)	43.33(6.65)	40.00(6.38)	40.00(6.40)	36.67(6.13)
CD (0.05)	(1.77)	(1.43)	(1.22)	(1.46)	(1.43)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

4.2.1.2 Twenty Four Hours after Treatment

Effect of plant products on the mortality of different larval stages of red palm weevil 24 hours after treatment is described in Table 7. The result showed that, apple extract of *A. occidentale* 10%, carbaryl1% , and apple extract of *A. occidentale* 5% had shown highest levels of mortalities 63.33, 58.90 and 50.00 respectively which were on par with each other. Mortality caused by carbaryl 1% and apple extract of *A. occidentale* 5% were statistically on par with that of seed extract of *A. squamosa* 10% with percent mortality of 36.67 which was significant and on par with that of seed extract of *A. squamosa* (5%). The other treatments *viz.* leaf extract of *T. neriifolia* (10 %), leaf extract of *C. infortunatum* (10%), seed oil of *S. indica* (4%), seed oil of *A. indica* (4%), seed oil of *A. indica* (2%), plant extract of *H. suaveolens* (10%) and leaf extract of *B. glabra* (10%) with percent mortalities of 16.31, 16.31, 13.33, 13.33, 13.33, 13.33 and 13.33 were significant and on par with each other and also on par with that of seed extract of *A. squamosa* 10% and seed extract of *A. squamosa* 5%. Rest of the treatments were non significant.

For second instars 24 hours after treatment, apple extract of *A. occidentale* (10%), carbaryl1% , and apple extract of *A. occidentale* (5%) showed significantly higher mortalities of 63.33, 53.33 and 50.00 respectively which were on par with each other. There were not much significant difference between other treatments and were all on par.

The effect of treatments on third instars 24 hours after treatment revealed that, apple extract of *A. occidentale* 10%, carbaryl1% and apple extract of *A. occidentale* 5% showed significantly higher level of mortalities 53.33, 50.00 and 33.33 respectively which were on par with each other. Next higher mortality was observed in the case of seed oil of *A. indica* (4%), plant extract of *H. suaveolens* (10%), and seed oil of *S. indica* (4%), leaf extract of *T. neriifolia* (10%), seed extract of *A. squamosa* (10%) , seed extract of *A. squamosa* (5%) , plant extract of *H. suaveolens* (5%), seed oil of S. indica (2%), leaf extract of *T. nerifolia* (5%), Seed oil of A. indica (2%), leaf extract of *C. infortunatum* (10%), leaf

Table 7. Effect of plant product on the mortality of different larval stages of red palm weevil (24h after treatment)

Treatments	I instar	II instar	III Instar	IV Instar	V Instar
Plant extract of *A. paniculata* (5%)	7.78(2.96)	13.33(3.73)	3.33 (1.77)	0.00(1.00)	3.33 (1.77)
Plant extract of *A. paniculata* (10 %)	10.00(3.31)	13.33(3.73)	6.66(2.54)	6.66(2.54)	6.66(2.54)
Plant extract of *H. suaveolens* (5%)	6.66(2.54)	7.78(2.96)	13.33(3.73)	6.66(2.54)	0.00(1.00)
Plant extract of *H. suaveolens* (10%)	13.33(3.73)	13.33(3.73)	16.31(4.16)	10.00(3.31)	0.00(1.00)
Leaf extract of *B. glabra* (5%)	10.00(3.31)	13.33(3.73)	3.33 (1.77)	6.66(2.54)	6.66(2.54)
Leaf extract of *B. glabra* (10%)	13.33(3.73)	13.33(3.73)	6.66(2.54)	10.00(3.31)	10.00(3.31)
Seed oil of *S. indica* (2%)	7.78(2.96)	10.00(3.31)	13.33(3.73)	0.00(1.00)	6.66(2.54)
Seed oil of *S. indica* (4%)	13.33(3.73)	13.33(3.73)	15.54(4.06)	0.00(1.00)	10.00(3.31)
Leaf extract of *C. infortunatum* (5%)	7.78(2.96)	13.33(3.73)	6.66(2.54)	0.00(1.00)	6.66(2.54)
Leaf extract of *C. infortunatum* (10%)	16.31(4.16)	16.31(4.16)	6.66(2.54)	3.33 (1.77)	10.00(3.31)
Seed oil of *A. indica* (2%)	13.33(3.73)	20.00(4.58)	7.80(2.96)	0.00(1.00)	6.66(2.54)
Seed oil of *A. indica* (4%)	13.33(3.73)	23.33(4.91)	16.31(4.16)	3.33 (1.77)	6.66(2.54)
Leaf extract of *T. neriifolia* (5%)	7.78(2.96)	13.33(3.73)	10.00(3.31)	0.00(1.00)	3.33 (1.77)
Leaf extract of *T. neriifolia* (10%)	16.31(4.16)	20.00(4.58)	13.33(3.73)	0.00(1.00)	3.33 (1.77)
Seed extract of *A. squamosa* (5%)	26.67(5.23)	13.33(3.73)	13.33(3.73)	6.66(2.54)	6.66(2.54)
Seed extract of *A. squamosa* (10%)	36.67(6.12)	20.00(4.48)	13.33(3.73)	10.00(3.31)	10.00(3.31)
Apple extract *A. occidentale* (5%)	50.00(7.14)	50.00(7.12)	33.33(5.85)	26.67(5.23)	26.67(5.23)
Apple extract *A. occidentale* (10%)	63.33(8.02)	63.33(8.02)	53.33(7.36)	43.33(6.65)	33.33(5.85)
Carbaryl 1%	58.90(7.74)	53.33(7.36)	50.00(7.12)	43.33(6.65)	46.67(6.89)
CD (0.05)	(1.64)	(1.22)	(1.66)	(1.24)	(1.59)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

extract of *C. infortunatum* (5%), leaf extract of *B. glabra* (10%) and plant extract of *A. paniculata* (10%), with percent mortalities of 16.31, 16.31, 15.54, 13.33, 13.33, 13.33, 13.33, 13.33, 10.00 , 7.80, 6.66, 6.66, 6.66 and 6.66 which were all on par with each other. Rests of the treatments were non significant.

When the same treatments were applied on fourth instars, apple extract of *A. occidentale* 10% and carbaryl 1% had caused significantly higher level of mortality of 43.33 for both the cases when compared to other treatments. Apple extract of *A. occidentale*5% was also shown significant percent mortality of 26.67. The other treatments were not significant.

The effect of treatments on fifth instars 24 hours after treatment implied that, carbaryl1% and apple extract of *A. occidentale* 10% showed significantly higher level of mortalities, 46.67 and 33.33 respectively followed by apple extract of *A. occidentale* 5% with percent mortalities of 26.67. The other treatments were not significant.

4.2.1.3 Fourty Eight Hours After Treatment

Effect of plant products on the mortality of different larval stages of red palm weevil 48 hours after treatment was indicated in Table 8. The result revealed that in the case of first instar 48 hours after treatment, carbaryl1% and apple extract of *A. occidentale* 10% had shown significantly higher levels of mortalities (72.22 percent) when compared with other treatments such as seed extract of *A. squamosa* 10% (36.67), seed extract of *A. squamosa* 5% (29.44), leaf extract of *T. neriifolia* 10% (16.31), leaf extract of *C. infortunatum* 10% (16.31), seed oil of *A. indica* 4% (16.31), seed oil of *A. indica* 2% (16.31), leaf extract of *T. neriifolia* 5% (13.33), seed oil of *S. indica* 4% (13.33), leaf extract of *B. glabra* 10% (13.33), leaf extract of *C. infortunatum* 5% (13.33), plant extract of *H. suaveolens* 10% (13.33), plant extract of *A. paniculata* 10% (10.00), plant extract of *H. suaveolens* 5% (10.00), leaf extract of *B. glabra*5% (10.00), plant extract of *A. paniculata* 5% (7.78) and seed oil of *S. indica* 2% (7.78). But the mortality caused by carbaryl1% and apple extract of *A. occidentale* 10% were on par with that of apple extract of *A. occidentale*5% (53.33 percent). Seed extract of *A.*

squamosa 10% with a percent mortality of 36.67 was significantly higher than that of other treatments whose values ranged from 16.31 percent to 7.78 percent. But it was on par with that of apple extract of *A. occidentale*5% and seed extract of *A. squamosa* 5%. Seed extract of *A. squamosa* 5% was also statistically superior to the treatments whose values ranged from 13.33 to 7.78 percent and was on par with leaf extract of *T. neriifolia* 10%, leaf extract of *C. infortunatum* 10%, seed oil of *A. indica* 4% and seed oil of *A. indica* 2% with the percentage mortality of 16.31 in each of the cases.

The plant products when applied on second instar 48 hours after treatment indicated that, apple extract of *A. occidentale* 10%, carbaryl1% and apple extract of *A. occidentale* 5% showed significantly higher level of mortalities, 73.33, 66.67 and 53.33 respectively in comparison with other treatments such as seed oil of *A. indica* 4%, seed extract of *A. squamosa* 10%, seed oil of *A. indica* 2%, leaf extract of *T. neriifolia* 10%, plant extract of *A. paniculata* 10%, plant extract of *A. paniculata* 5%, leaf extract of *C. infortunatum* 10%, seed extract of *A. squamosa* 5%, leaf extract of *T. neriifolia* 5%, leaf extract of *C. infortunatum* 5%, seed oil of *S. indica* 4%, plant extract of *H. suaveolens* 10%, leaf extract of *B. glabra* 10%, leaf extract of *B. glabra* 5%, seed oil of *S. indica* 2% and plant extract of *H. suaveolens* 5% with a percent mortality of 23.33, 20.00, 20.00, 20.00, 16.31, 16.31, 16.31, 13.33, 13.33, 13.33, 13.33, 13.33, 13.33, 13.33, 13.33, 10.00 and 7.78 respectively and apple extract of *A. occidentale* 10%, carbaryl1% and apple extract of *A. occidentale*5% were statistically on par with each other. Mortality caused by seed oil of *A. indica* 4% was significantly higher than that of plant extract of *H. suaveolens* 10%, but was on par with other treatments whose values ranged from 20.00 percent to 10.00 percent.

The effect of plant products 48 hours after application on third instars implied that, apple extract of *A. occidentale* 10%, carbaryl 1% and apple extract of *A. occidentale* 5% were shown significantly higher level of mortalities 53.33, 50.00 and 36.67 respectively as against other treatments such as seed oil of *A. indica* 4%, seed oil of *A. indica* 2%, plant extract of *H. suaveolens* 10%, plant

extract of *H. suaveolens* 5%, seed extract of *A. squamosa* 10% , seed oil of *S. indica* 4%, seed oil of *S. indica* 2%, seed extract of *A. squamosa* 5%, leaf extract of *T. neriifolia* 10% , plant extract of A. paniculata 10%, leaf extract of *T. neriifolia* 5%, leaf extract of *C. infortunatum* 10%, leaf extract of *C. infortunatum* 5%, plant extract of *A. paniculata* 5%, leaf extract of *B. glabra* 10% and leaf extract of *B. glabra* 5% with percent mortalities of 16.31, 16.31, 16.31, 16.31, 16.31, 15.54, 13.33, 13.33, 13.33, 10.00, 7.78, 7.78, 6.66, 6.66, 6.66 and 6.66 respectively. Apple extract of *A. occidentale* 10%, carbaryl 1% and apple extract of *A. occidentale* 5% were on par statistically. Rest of the treatments was not significant.

The effect of the same treatments on fourth instars 48 hour after application indicated that, apple extract of *A. occidentale* 10% and carbaryl 1% showed higher level of mortalities 53.33 and 50.00 respectively followed by apple extract of *A. occidentale* 5% with percent mortality of 33.33 and they were all statistically superior to other treatments such as seed extract of *A. squamosa* 10% (13.33), seed extract of *A. squamosa* 5%, leaf extract of *B. glabra* 10% and plant extract of *H. suaveolens* 10, leaf extract of *B. glabra* 5% with percent mortalities of 10.00 percent in each case, plant extract of *A. paniculata* 10% (6.66), plant extract of *H. suaveolens* 5% (6.66), leaf extract of *C. infortunatum* 10% (3.33) and plant extract of *A. paniculata* 5% (3.33). Rests of the treatments were not significant.

The treatments when applied on fifth instar, the mortality after 48 hours denoted that, apple extract of *A. occidentale* 10%, carbaryl1% and apple extract of *A. occidentale*5% showed significantly higher level of mortalities of 56.67, 50.00 and 36.67 respectively while comparing with other treatments such as seed extract of *A. squamosa* 10%, leaf extract of *C. infortunatum* 10%, seed oil of *S. indica* 4%, and leaf extract of *B. glabra* 10% with percent mortality of 10.00 percent, seed oil of *A. indica* 4%, seed oil of *A. indica* 2%, leaf extract of *B. glabra*5%, seed oil of *S. indica* 2%, seed extract of *A. squamosa* 5%, plant extract of *A. paniculata* 10%, leaf extract of *C. infortunatum* 5%, plant extract of

Table 8. Effect of plant product on the mortality of different larval stages of red palm weevil (48h after treatment)

Treatments	I instar	II instarI	III Instar	IV Instar	V InstarI
Plant extract of *A. paniculata* (5%)	7.78(2.96)	16.31(4.16)	6.66(2.54)	3.33 (1.77)	6.66(2.54)
Plant extract of *A. paniculata* (10 %)	10.00(3.31)	16.31(4.16)	10.00(3.31)	6.66(2.54)	6.66(2.54)
Plant extract of *H. suaveolens* (5%)	10.00(3.31)	7.78(2.96)	16.31(4.16)	6.66(2.54)	0.00(1.00)
Plant extract of *H. suaveolens* (10%)	13.33(3.73)	13.33(3.73)	16.31(4.16)	10.00(3.31)	3.33 (1.77)
Leaf extract of *B. glabra* (5%)	10.00(3.31)	13.33(3.73)	6.66(2.54)	10.00(3.31)	6.66(2.54)
Leaf extract of *B. glabra* (10%)	13.33(3.73)	13.33(3.73)	6.66(2.54)	10.00(3.31)	10.00(3.31)
Seed oil of *S. indica* (2%)	7.78(2.96)	10.00(3.31)	13.33(3.73)	0.00(1.00)	6.66(2.54)
Seed oil of *S. indica* (4%)	13.33(3.73)	13.33(3.73)	15.54(4.07)	0.00(1.00)	10.00(3.31)
Leaf extract of *C. infortunatum* (5%)	13.33(3.73)	13.33(3.73)	6.66(2.54)	0.00(1.00)	6.66(2.54)
Leaf extract of *C. infortunatum* (10%)	16.31(4.16)	16.31(4.16)	7.78(2.96)	3.33(1.77)	10.00(3.31)
Seed oil of *A. indica* (2%)	16.31(4.16)	20.00(4.58)	16.31(4.16)	0.00(1.00)	6.66(2.54)
Seed oil of *A. indica* (4%)	16.31(4.16)	23.33(4.91)	16.31(4.16)	0.00(1.00)	6.66(2.54)
Leaf extract of *T. neriifolia* (5%)	13.33(3.73)	13.33(3.73)	7.78(2.96)	0.00(1.00)	3.33 (1.77)
Leaf extract of *T. neriifolia* (10%)	16.31(4.16)	20.00(4.58)	13.33(3.73)	0.00(1.00)	3.33 (1.77)
Seed extract of *A. squamosa* (5%)	29.44(5.52)	13.33(3.73)	13.33(3.73)	10.00(3.31)	6.66(2.54)
Seed extract of *A. squamosa* (10%)	36.67(6.13)	20.00(4.48)	16.31(4.16)	13.33(3.73)	10.00(3.31)
Apple extract of *A. occidentale* (5%)	53.33(7.36)	53.33(7.34)	36.67(6.12	33.33(5.85)	36.67(6.12)
Apple extract of *A. occidentale* (10%)	72.22(8.56)	73.33(8.62)	53.33(7.36)	53.33(7.36)	56.67(7.59)
Carbaryl 1%	73.33(8.62)	66.67(8.22)	50.00(7.12)	50.00(7.12)	50.00(7.12)
CD (0.05)	(1.40)	(1.23)	(1.68)	(1.08)	(1.67)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

A. paniculata 5% with percent mortality of 6.66 percent, leaf extract of *T. neriifolia* 10%, leaf extract of *T. neriifolia* 5% and plant extract of *H. suaveolens* 10% with percent mortality of 3.33 percent. Apple extract of *A. occidentale* 10%, carbaryl 1% and apple extract of *A. occidentale* 5% were statistically on par with each other.

4.2.2 Repellant Effect of Different Plant Products on Various Larval Instars of Red Palm Weevil

4.2.2.1 Two Hours After Treatment

The repellant effect of different plant products on various larval instars of red palm weevil two hours after treatment was denoted in Table 9. The result indicated that for first instar, leaf extract of *T. neriifolia* 10% with percent repellency of 43.33 was found to be statistically superior to other treatments such as seed oil of *S. indica* 2% (23.33), seed oil of *S. indica* 4% (23.33), apple extract of *A. occidentale* 10% (20.00) (Plate 1), seed extract of *A. squamosa* 10% (20.00), apple extract of *A. occidentale*5% (16.67), seed extract of *A. squamosa* 5% (16.67), leaf extract of *B. glabra*5% (16.67), plant extract of *H. suaveolens* 10% (13.33), leaf extract of *C. infortunatum* 10% (10.47), leaf extract of *C. infortunatum* 5% (6.66), plant extract of *A. paniculata* 10% (6.66), leaf extract of *B. glabra* 10% (3.33), plant extract of *A. paniculata* 5% (3.33), plant extract of *H. suaveolens* 5% (3.33) and carbaryl1% (3.33). But the repellency caused by leaf extract of *T. neriifolia* 10% was not statistically significant to seed oil of *A. indica* 4%, leaf extract of *T. nerifolia* 5% and seed oil of *A. indica* 2% with the percent repellencies of, 40.00, 36.67 and 30.00. The repellency caused by seed oil of *A. indica* 4% was also significantly higher than those treatments whose values ranged from 16.67 to3.33 percent and was found to be not significant to the repellency caused by leaf extract of *T. neriifolia* 5%, seed oil of *A. indica* 2%, seed oil of *S. indica* 2% and seed oil of *S. indica* 4% .The repellency due to seed oil of *A. indica* 2% was found to be significantly superior to those treatments whose values ranged from 3.73 to 3.33 and were non significant to seed oil of

S. indica 2% (23.33), seed oil of *S. indica* 4% (23.33) and leaf extract of *B. glabra* 5%. Rest of the treatments were not significant.

The same treatments when applied on second instar, the repellency of larvae after two hours showed that leaf extract of *T. neriifolia* 10% with the percent repellency of 29.44 percent was statistically superior to other treatments such as apple extract of *A. occidentale* 10% (10.00), leaf extract of *C. infortunatum* 5% (10.00), plant extract of *A. paniculata* 10% (10.00), seed extract of *A. squamosa* 5% (7.8), plant extract of *H. suaveolens* 10% (7.8), carbaryl1%(7.8), seed extract of *A. squamosa* 10% (6.66), leaf extract of *C. infortunatum* 10% (6.66), leaf extract of *B. glabra* 10% (6.66), plant extract of *A. paniculata* 5% (6.66), apple extract of *A. occidentale*5% (3.81), plant extract of *H. suaveolens* 5% (3.80) and leaf extract of *B. glabra* 5% (3.33). But the repellency caused by leaf extract of *T. neriifolia* 10% was not statistically significant to seed oil of *S. indica* 2% (26.67), seed oil of *S. indica* 4% (23.33), leaf extract of *T. neriifolia* 5% (16.67), seed oil of *A. indica* 4% (13.33) and seed oil of *A. indica* 2% (13.33) and were on par with each other. The repellency caused by seed oil of *S. indica* 2% and seed oil of *S. indica* 4% was found to be significant to those treatments whose values ranged from 6.66 to 3.33, and was on par with those treatments whose values ranged from 16.67 to 10.00 percent. The repellency caused due to leaf extract of *T. neriifolia* 5% was significantly higher than those treatments with the repellency rate of 3.33 percent and was on par with those treatment with repellency range of 13.33 to 6.66 percent. Rest of the treatments were non significant.

The repellant effect on third instars of red palm weevil two hours after treatment implied that seed oil of *S. indica* 4% and seed oil of *S. indica* 2% has recorded significantly higher repellency of 40.00 and 36.67 percent when compared to other treatments whose values ranged from 13.33 to 3.33 percent. The repellency caused due to seed oil of *S. indica* 4% and seed oil of *S. indica* 2% was found to be statistically on par with that of leaf extract of *T. neriifolia* 10% (20.00). Also the repellent effect of leaf extract of *T. neriifolia* 10% was found to be superior to those treatments with repellency value of 3.33 percent and was on

Table 9. Repellant effect of different plant products on various larval instars of red palm weevil (2h after treatment)

Treatments	I instar	II instar	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar
Plant extract of *A. paniculata* (5%)	3.33 (1.77)	6.66(2.54)	0.00(1.00)	3.33 (1.77)	0.00(1.00)	3.33 (1.77)	0.00(1.00)	13.33(3.73)	6.66(2.54)
Plant extract of *A. paniculata* (10 %)	6.66(2.544)	10.00(3.31)	3.33 (1.77)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	6.66(2.54)	3.33 (1.77)
Plant extract of *H. suaveolens* (5%)	3.33 (1.77)	3.80(2.19)	10.00(3.31)	0.00(1.00)	7.80(2.96)	6.66(2.54)	3.33(1.77)	7.80(2.96)	0.00(1.00)
Plant extract of *H. suaveolens* (10%)	13.33(3.73)	7.80(2.96)	3.81(2.19)	7.80(2.96)	6.66(2.54)	10.00(3.31)	0.00(1.00)	3.81(2.19)	10.00(3.31)
Leaf extract of *B. glabra* (5%)	16.67(4.16)	3.33 (1.77)	3.33 (1.77)	10.00(3.31)	7.80(2.96)	7.80(2.96)	7.80(2.96)	0.00(1.00)	7.80(2.96)
Leaf extract of *B. glabra* (10%)	3.33(1.77)	6.66(2.54)	13.33(3.73)	13.33(3.73)	3.33 (1.77)	6.66(2.54)	5.36(2.5)	6.66(2.54)	13.33(3.73)
Seed oil of *S. indica* (2%)	23.33(4.91)	26.67(5.24)	36.67(6.13)	36.67(6.13)	10.00(3.31)	0.00(1.00)	10.00(3.30)	20.00(4.49)	5.36(2.5)
Seed oil of *S. indica* (4%)	23.33(4.91)	23.33(4.91)	40.00(6.38)	36.67(6.13)	10.00(3.31)	13.33(3.73)	13.33 (3.73)	5.36(2.5)	10.00(3.30)
Leaf extract of *C. infortunatum* (5%)	6.66(2.54)	10.00(3.31)	10.00(3.31)	6.66(2.54)	5.36(2.5)	0.00(1.00)	7.80(2.96)	7.80(2.96)	10.00(3.31)
Leaf extract of *C. infortunatum* (10%)	10.47(3.80)	6.66(2.54)	3.33 (1.77)	3.81(2.19)	3.33 (1.77)	0.00(1.00)	3.33 (1.77)	10.47(3.80)	6.66(2.54)
Seed oil of *A. indica* (2%)	30.00(5.57)	13.33(3.73)	3.81(2.19)	5.36(2.5)	6.66(2.54)	10.00(3.31)	6.66(2.54)	15.54(4.07)	3.33(1.77)
Seed oil of *A. indica* (4%)	40.00(6.38)	13.33(3.73)	6.66(2.54)	10.00(3.30)	6.66(2.54)	6.66(2.54)	10.00(3.31)	6.85(2.80)	3.81(2.19)

Table 9. Continued

Treatments	I instar	II instarI	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar
Leaf extract of *T. neriifolia* (5%)	36.67(6.13)	16.67(4.16)	10.00(3.31)	20.00(4.49)	43.33(6.65)	46.67(6.82)	50.00(7.12)	53.33(7.36)	40.00(6.38)
Leaf extract of *T. neriifolia* (10%)	43.33(6.65)	29.44(5.52)	20.00 (4.49)	22.22(4.82)	40.00(6.40)	50.00(7.12)	53.33(7.36)	53.33(7.36)	46.67(6.89)
Seed extract of *A. squamosa* (5%)	16.67(4.16)	7.80(2.96)	6.66(2.54)	6.66(2.544)	3.33 (1.77)	6.66(2.54)	7.80(2.96)	13.33(3.73)	10.47 (3.38)
Seed extract of *A. squamosa* (10%)	20.00(4.49)	6.66(2.54)	0.00(1.00)	3.33 (1.77)	6.66(2.54)	3.81(2.19)	5.36(2.5)	13.33(3.73)	10.00(3.30)
Apple extract of *A. occidentale* (5%)	16.67(4.16)	3.81(2.19)	7.80(2.96)	3.33 (1.77)	0.00(1.00)	3.33 (1.77)	10.00(3.30)	3.33 (1.77)	10.00(3.31)
Apple extract of *A. occidentale* (10%)	20.00(4.58)	10.00(3.31)	13.33(3.73)	6.66(2.54)	3.33(1.77)	6.66(2.54)	10.00(3.30)	6.66(2.54)	7.80(2.96)
Carbaryl 1%	3.33(1.71)	7.80(2.96)	3.33(1.77)	3.33(1.77)	7.80(2.96)	3.33 (1.77)	16.67(4.16)	13.33(3.73)	23.33(4.91)
CD (0.05)	(1.59)	(2.04)	(2.02)	(2.35)	(2.09)	(1.86)	(2.57)	(2.50)	(2.52)

Values in parentheses indicate transformed values : $\sqrt{x + 1}$

a) *Samadera indica* Guertn.

b) *Thevetia neriifolia* Juss.

c) *Anacardium occidentale* L.

Plate.1. Plants found effective in the Study

par with those treatments with percentage repellency ranged from 13.33 to 6.66 percent. Rest of the treatments were non significant.

Against fourth instars of red palm weevil two hours after treatment seed oil of *S. indica* 4% (36.67) and seed oil of *S. indica* 2% (36.67) was found to be significantly superior to those treatments whose values ranged from 13.33 to 3.33 and was insignificant to the repellency caused by leaf extract of *T. neriifolia* 10%, and leaf extract of *T. neriifolia* 5% with the repellency rate of 22.22 and 20.00. The repellency shown by leaf extract of *T. neriifolia* 5% was significantly higher to those treatments whose values ranged from 7.80 to 3.33 percent and were on par with those treatments which showed a repellency range of 13.33 to 10.00 percent.

The results also indicated that in the case of fifth instar, leaf extract of *T. neriifolia* 10% and leaf extract of *T. neriifolia* 5% has recorded significantly higher repellency of 43.33 and 40.00 over all other treatments whose values ranged from 10.00 percent to 3.33. All other treatments were found to be non significant.

In the case of sixth instar, leaf extract of *T. neriifolia* 10% (50.00) and leaf extract of *T. neriifolia* 5% (46.67) had shown significant repellency when compared to other treatments with the percentage repellency ranged from 3.33 to10.00. The rest of the treatments were non significant.

Statistically the same trend was observed in the case of seventh, eighth and ninth instars.

4.2.2.2 Twenty Four Hours After Treatment

The repellant effect of different plant products on various larval instars of red palm weevil is presented in Table 10. The result revealed that for first instar, leaf extract of *T. neriifolia* 10% (60.00), seed oil of *A. indica* 4% (55.95) and leaf extract of *T. neriifolia* 5% (50.00), seed oil of *A. indica* 2% (46.67) and seed oil of *S. indica* 4% (46.67) had shown significantly higher repellency while considering other treatments with values ranging from 6.13 to 3.33. The repellency caused by

seed oil of *S. indica* 4% was also significantly higher than other treatments with values ranging from 5.09 to 3.33 but was found to be on par with the repellent effect of seed oil of *S. indica* 2% (6.13). Leaf extract of *C. infortunatum* 10% with the percent repellency of 24.96 was also significantly higher than those treatments with repellency rate ranging from 10.00 to 3.33 but it was on par with that of leaf extract of *B. glabra*5% (20.00), plant extract of *H. suaveolens* 10% (21.72), leaf extract of *C. infortunatum* 5% (20.00), apple extract of *A. occidentale* 5% (23.33), apple extract of *A. occidentale* 10% (20.00), Seed extract of *A. squamosa* 10% (20.00) and seed extract of *A. squamosa* 5% (20.00). Rest of the treatments were non significant.

The effect of the same plant products on second instar indicated that seed oil of *A. indica* 4% and seed oil of *A. indica* 2% had recorded significantly higher repellency of 56.67. Seed oil of *S. indica* 2%, seed oil of *S. indica* 4%, leaf extract of *C. infortunatum* 10%, leaf extract of *T. neriifolia* 5%, leaf extract of *C. infortunatum* 5% and plant extract of *A. paniculata* 10%, with the percent repellency of 33.33, 29.44, 20.00, 20.00, 20.00 and 16.67 were on par with each other and were superior to rest of the treatments.

When the treatments were applied on third instar, seed oil of *S. indica* 4% and seed oil of *S. indica* 2% had recorded significantly higher repellency of 43.33 over all other treatments. Rest of the treatments were found to be non significant.

The effect of treatments after 24 hours when applied on fourth instars showed that seed oil of *S. indica* 4% and seed oil of *S. indica* 2% had recorded significantly higher repellency of 56.67 and 53.33 which were on par. Leaf extract of *T. neriifolia* 10%, leaf extract of *T. neriifolia* 5%, seed oil of *A. indica* 4%, leaf extract of *B. glabra* 10% and plant extract of *H. suaveolens* 10% with the percent repellency of 22.22, 22.22, 20.00, 16.67 and 16.67 were on par and significantly superior over all other treatments. Other treatments were non significant.

In the case of fifth, sixth, seventh, eighth and ninth instar, leaf extract of *T. neriifolia* 10% and leaf extract of *T. neriifolia* 5% only shown significant

Table 10. Repellant effect of different plant products on various larval instars of red palm weevil (24 h after treatment)

Treatments	I instar	II instarI	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar
Plant extract of *A. paniculata* (5%)	6.66(2.544)	7.80(2.96)	6.66(2.54)	13.33(3.73)	3.33 (1.77)	3.81(2.19)	3.33 (1.77)	16.67(4.16)	10.00(3.31)
Plant extract of *A. paniculata* (10 %)	13.33(3.73)	16.67(4.16)	6.66(2.54)	6.66(2.54)	6.66(2.54)	6.66(2.54)	3.33 (1.77)	13.33(3.73)	10.00(3.31)
Plant extract of *H. suaveolens* (5%)	10.00(3.31)	13.33(3.73)	13.33(3.73)	6.66(2.54)	7.80(2.96)	10.00(3.31)	10.00(3.31)	12.82(3.72)	6.66(2.54)
Plant extract of *H. suaveolens* (10%)	21.72(4.77)	13.33(3.73)	6.66(2.54)	16.67(4.16)	7.80(2.96)	10.00(3.31)	3.33 (1.77)	3.81(2.19)	13.33(3.73)
Leaf extract of *B. glabra* (5%)	20.00(4.58)	7.80(2.96)	7.80(2.96)	13.33(3.73)	13.33(3.73)	10.47(3.80)	10.47(3.80)	3.81(2.19)	13.33(3.73)
Leaf extract of *B. glabra* (10%)	22.22(4.82)	10.00(3.31)	13.33(3.73)	16.67(4.16)	10.00(3.31)	10.00(3.31)	10.00(3.30)	13.33(3.73)	16.67(4.16)
Seed oil of *S. indica* (2%)	36.67(6.13)	33.33(5.85)	43.33(6.65)	53.33(7.34)	10.00(3.31)	10.00(3.31)	5.36(2.5)	20.00(4.49)	5.36(2.5)
Seed oil of *S. indica* (4%)	46.67(6.89)	29.44(5.52)	43.33(6.65)	56.67(7.59)	10.00(3.31)	16.67(4.16)	10.00(3.31)	10.00(3.30)	10.00(3.30)
Leaf extract of *C. infortunatum* (5%)	20.00(4.49)	20.00(4.58)	10.00(3.31)	10.00(3.31)	13.33(3.73)	15.54(4.07)	10.47(3.80)	20.00(4.49)	13.33(3.73)
Leaf extract of *C. infortunatum* (10%)	24.96(5.09)	20.00(4.49)	6.66(2.54)	13.33(3.73)	6.66(2.54)	12.82(3.72)	10.00(3.31)	12.82(3.72)	7.80(2.96)
Seed oil of *A. indica* (2%)	46.67(6.89)	56.67(7.59)	6.66(2.54)	5.36(2.5)	6.66(2.54)	13.33(3.73)	15.54(4.07)	20.00(4.49)	7.80(2.96)
Seed oil of *A. indica* (4%)	55.95(7.55)	56.97(7.79)	6.66(2.54)	20.00(4.49)	16.67(4.16)	16.67(4.16)	13.33(3.73)	11.76(3.57)	6.66(2.54)

Table 10.Continued

Treatments	I instar	II instarI	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar
Leaf extract of *T. neriifolia* (5%)	50.00(7.12)	56.67(7.79)	3.33 (1.77)	22.22(4.82)	60.00(7.81)	53.33(7.36)	56.67(7.59)	60.00(7.81)	40.00(6.38)
Leaf extract of *T. neriifolia* (10%)	60.00(7.81)	29.14(5.52)	20.00(4.49)	22.22(4.82)	63.33(8.02)	55.95(7.55)	60.00(7.81)	63.33(8.02)	50.00(7.14)
Seed extract of *A. squamosa* (5%)	20.00(4.58)	7.80(2.96)	13.33(3.73)	10.00(3.31)	7.80(2.96)	10.00(3.31)	10.47(3.80)	16.67(4.16)	10.47(3.38)
Seed extract of *A. squamosa* (10%)	20.00(4.58)	6.66(2.54)	6.66(2.54)	6.66(2.54)	7.80(2.96)	7.80(2.96)	10.00(3.30)	16.67(4.16)	10.00(3.30)
Apple extract of *A. occidentale* (5%)	23.33(4.91)	7.80(2.96)	13.33(3.73)	6.66(2.54)	6.66(2.54)	13.33(3.73)	10.00(3.31)	7.80(2.96)	13.33(3.73)
Apple extract of *A. occidentale* (10%)	20.00(4.58)	13.33(3.73)	13.33(3.73)	10.00(3.31)	7.80(2.96)	16.67(4.16)	15.54(4.07)	13.33(3.73)	7.80(2.96)
Carbaryl 1%	3.33(1.77)	16.67(4.16)	6.66(2.54)	5.36(2.5)	7.80(2.96)	6.66(2.54)	16.67(4.16)	13.33(3.73)	23.33(4.91)
CD (0.05)	(1.49)	(1.81)	(2.11)	(1.83)	(2.21)	(2.03)	(2.39)	(2.38)	(2.41)

Values in parentheses indicate transformed values : $\sqrt{x + 1}$

repellency of 63.33, 60; 55.95, 53.33; 60.00, 56.67; 63.33, 60.00 and 50.00, 40.00 percent respectively for fifth, sixth, seventh, eighth and ninth instars. Rest of the treatments were found to be non significant.

4.2.2.3 Fourty Eight Hours After Treatment

Repellent effect of different plant products on various larval instars of red palm weevil 48 hours after treatment is described in Table 11. The result revealed that the percentage repellency for first instars of red palm weevil was found to be significantly higher for leaf extract of *T. neriifolia* 10%, seed oil of *A. indica* 4%, leaf extract of *T. neriifolia* 5%, seed oil of *A. indica* 2% and seed oil of *S. indica* 4% (63.33, 55.95, 53.33, 46.67 and 43.33 respectively) and were on par with each other. Seed oil of *S. indica* 2%, *A. occidentale* 5%, and *C. infortunatum* 10%, leaf extract of *B. glabra* 10% and Apple extract of *A. occidentale*10% with the percentage repellency of 36.67, 23.33, 24.96 and 20.00 were also significant and were on par. Rest of the treatments were not effective.

The effect of the treatments applied after 48 hours on the second instar of red palm weevil revealed that, seed oil of *A. indica* 4% and seed oil of *A. indica* 2% with the percent repellency of 56.97 and 56.67 were found to be the best repellents. Seed oil of *S. indica* 2%, seed oil of *S. indica* 4%, leaf extract of *T. neriifolia* 10%, leaf extract of *T. neriifolia* 5%, leaf extract of *C. infortunatum* 5% and leaf extract of *C. infortunatum* 10% with the percent repellency of 33.33, 29.44, 29.44, 20.00, 20.00, and 20.00 were also significant and on par with each other. Rest of the treatments showed no significant repellency.

The treatments when tried on third and fourth instar, seed oil of *S. indica* 4% and Seed oil of *S. indica* 2% has recorded highest repellency of 43.33, 43.33 and 56.67, 53.33 both on par with each other. All other treatments were found to be non significant.

The repellent effect of treatments on fifth, sixth, seventh, eighth and ninth instars of red palm weevil 48 h after treatment implied that leaf extract of *T.*

Table 11. Repellant effect of different plant products on various larval instars of red palm weevil (48 h after treatment)

Treatments	I instar	II instarl	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar
Plant extract of *A. paniculata* (5%)	13.33(3.73)	13.33(3.73)	6.66(2.54)	13.33(3.73)	10.00(3.31)	7.80(2.96)	7.80(2.96))	16.67(4.16)	10.00(3.31)
Plant extract of *A. paniculata* (10 %)	13.33(3.73)	16.67(4.16)	7.80(2.96)	6.66(2.54)	13.33(3.73)	7.80(2.96)	7.80(2.96)	13.33(3.73)	10.00(3.31)
Plant extract of *H. suaveolens* (5%)	10.00(3.31)	13.33(3.73)	13.33(3.73)	6.66(2.54)	13.33(3.73)	13.33(3.73)	10.00(3.31)	12.82(3.72)	7.80(2.96)
Plant extract of *H. suaveolens* (10%)	21.72(4.77)	13.33(3.73)	13.33(3.73)	16.67(4.16)	16.67(4.16)	10.00(3.31)	7.80(2.96)	3.81(2.19)	13.33(3.73)
Leaf extract of *B. glabra* (5%)	20.00(4.58)	7.80(2.96)	13.33(3.73)	13.33(3.73)	13.33(3.73)	10.47(3.80)	10.47(3.80)	7.80(2.96)	13.33(3.73)
Leaf extract of *B. glabra* (10%)	22.22(4.82)	10.00(3.31)	13.33(3.73)	16.67(4.16)	13.33(3.73)	13.33(3.73)	10.00(3.30)	20.00(4.49)	16.67(4.16)
Seed oil of *S. indica* (2%)	36.67(6.13)	33.33(5.85)	43.33(6.65)	53.33(7.34)	10.00(3.31)	13.33(3.73)	10.00(3.30)	20.00(4.49)	10.00(3.30)
Seed oil of *S. indica* (4%)	43.33(6.65)	29.44(5.52)	43.33(6.65)	56.67(7.59)	13.33(3.73)	16.67(4.16)	10.00(3.31)	10.00(3.30)	10.00(3.30)
Leaf extract of *C. infortunatum* (5%)	20.00(4.49)	20.00(4.58)	10.00(3.31)	13.33(3.73)	10.00(3.30)	20.00(4.49)	10.47(3.80)	20.00(4.49)	13.33(3.73)
Leaf extract of *C. infortunatum* (10%)	24.96(5.09)	20.00(4.49)	6.66(2.54)	13.33(3.73)	16.67(4.16)	12.82(3.72)	10.00(3.31)	12.82(3.72)	7.80(2.96)
Seed oil of *A. indica* (2%)	46.67(6.89)	56.67(7.59)	7.80(2.96)	13.33(3.73)	16.67(4.16)	13.33(3.73)	15.54(4.07)	20.00(4.49)	13.33(3.73)
Seed oil of *A. indica* (4%)	55.95(7.55)	56.97(7.79)	6.66(2.54)	20.00(4.49)	16.67(4.16)	16.67(4.16)	13.33(3.73)	20.00(4.49)	7.80(2.96)

Table 11. Continued

Treatments	I instar	II instarI	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar
Leaf extract of *T. neriifolia* (5%)	53.33(7.36)	20.00(4.58)	13.33 (3.72)	22.22 (4.82)	60.00(7.81)	53.33(7.36)	56.67(7.59)	60.00(7.81)	46.67(6.89)
Leaf extract of *T. neriifolia* (10%)	63.33(8.02)	29.44(5.52)	20.00(4.49)	30.00(5.62)	63.33(8.02)	55.95(7.55)	60.00(7.81)	63.33(8.02)	50.00(7.14)
Seed extract of *A. squamosa* (5%)	20.00(4.58)	7.80(2.96)	7.80(2.96)	10.00(3.31)	10.00(3.31)	10.00(3.31)	10.47(3.80)	23.33(4.91)	13.33(3.73)
Seed extract of *A. squamosa* (10%)	23.33(4.91)	7.80(2.96)	7.80(2.96)	10.00(3.31)	20.00(4.49)	7.80(2.96)	15.54(4.07)	16.67(4.16)	15.54(4.07)
Apple extract of *A. occidentale* (5%)	23.33(4.91)	7.80(2.96)	13.33(3.73)	10.00(3.31)	10.00(3.31)	13.33(3.73)	13.33(3.73)	13.33(3.73)	13.33(3.73)
Apple extract of *A. occidentale* (10%)	29.44(5.52)	16.67(4.16)	13.33(3.73)	10.00(3.31)	10.00(3.31)	16.67(4.16)	15.54(4.07)	13.33(3.73)	7.80(2.96)
Carbaryl 1%	7.80(2.96)	16.67(4.16)	6.66(2.54)	7.80(2.96)	10.00(3.31)	7.80(2.96)	16.67(4.16)	13.33(3.73)	23.33(4.91)
CD (0.05)	(1.51)	(1.67)	(1.98)	(1.80)	(2.21)	(1.96)	(2.21)	(3.38)	(2.25)

Values in parentheses indicate transformed values : $\sqrt{x + 1}$

neriifolia 10% and leaf extract of *T. neriifolia* 5% only shown significant percent repellency of 63.33, 60.00; 55.95, 53.33; 60.00, 56.67; 63.33, 60.00 and 50.00, 46.67 respectively and all other treatments were found to be non significant.

4.2.3 Comparative Efficiency of Cashew Apple Extract and Carbaryl on the Mortality of Different life Stages of Red Palm Weevil

4.2.3.1 Two Hours After Treatment

The result of studies on comparative efficiency of cashew apple extract and carbaryl on the mortality of different life stages of red palm weevil 2 hours after treatment is showed in Table 12. The result denoted that cashew apple extract 50% and cashew apple extract 40% has caused significantly higher percentage mortality of first instars of red palm weevil (96.67 and 93.28 respectively) which were on par with each other, followed by cashew apple extract 20% with a mortality rate of 73.25 percent. The mortality caused by cashew apple extract 20% was on par with that of cashew apple extract 10% (56.56 percent) and that of carbaryl 1% (56.30). The mortality caused by cashew apple extract 10% was on par with that of carbaryl 1% and that of cashew apple extracts 5% (6.90 percent) and was significantly superior to that of cashew apple extract 4% and 2%. Rest of the treatments were non significant.

The effect of the same treatments on second instar showed that cashew apple extract 50% and cashew apple extract 40% has caused significantly higher mortality of second instar, having a mortality percentage of 93.28 for both the case followed by cashew apple 20% with a mortality rate of 66.58 % which was found to be on par with that at 10 %. Next significantly higher mortality rate was produced by cashew apple 10% (53.22 percent) which was found to be on par with that at carbaryl 1% (43.20 percent).

In the case of third instars, cashew apple extract 50% and cashew apple extract 40% has caused significantly higher percentage mortality of 83.27 and 73.25 respectively which were on par with each other followed by cashew apple 20% with a percentage mortality rate of 63.25 which again was on par with that at

Table 12. Comparative efficiency of apple extract of *A. occidentale* and carbaryl on the mortality of different life stages of red palm weevil (2 h after treatment)

Dose	I Instar	II Instar	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar	Prepupa	Pupa	Adult
2%	16.31(4.17)	13.33(3.74)	6.66(2.54)	0.00(1.00)	6.66(2.54)	0.00(1.00)	0.00(1.00)	0.00(1.00)	0.00(1.00)	9.96(3.31)	0.00(1.00)	0.00(1.00)
4%	16.31(4.17)	16.31(4.17)	13.33(3.73)	6.66(2.54)	13.33(3.73)	6.66(2.54)	6.66(2.54)	3.33(1.77)	6.66(2.54)	13.33(3.73)	0.00(1.00)	0.00(1.00)
5%	45.54(6.90)	16.31(4.17)	13.33(3.73)	20.00(4.48)	23.11(4.91)	6.66(2.54)	6.66(2.54)	6.66(2.54)	16.31(4.17)	20.00(4.58)	0.00(1.00)	0.00(1.00)
10%	56.56(7.59)	53.22(7.36)	43.20(6.65)	36.51(6.13)	26.67(5.24)	33.33(5.84)	6.66(2.54)	26.67(5.24)	36.51(6.13)	33.33(5.84)	9.96(3.31)	13.33(3.74)
20%	73.25(8.62)	66.58(8.22)	63.25(8.02)	66.58(8.22)	36.51(6.13)	50.00(7.12)	43.20(6.65)	40.00(6.37)	50.00(7.12)	76.59(8.81)	53.22(7.36)	60.00(7.81)
40%	93.28(9.71)	93.28(9.71)	73.25(8.62)	73.25(8.62)	63.25(8.02)	63.25(8.02)	50.00(7.12)	45.54(6.90)	56.56(7.59)	70.00(8.41)	60.00(7.81)	63.25(8.02)
50%	96.67(9.88)	93.28(9.71)	83.27(9.18)	76.59(8.81)	56.56(7.59)	63.25(8.02)	53.22(7.36)	50.00(7.14)	56.56(7.59)	83.27(9.18)	63.25(8.02)	66.58(8.22)
1% carbaryl	56.30(7.57)	43.20(6.65)	40.00(6.37)	40.00(6.40)	36.51(6.13)	23.11(4.91)	23.11(4.91)	28.55(5.43)	30.00(5.52)	33.33(5.84)	45.54(6.90)	13.33(3.73)
CD (0.05)	(0.91)	(0.85)	(1.13)	(1.16)	(1.18)	(1.13)	(0.91)	(1.41)	(1.25)	(0.76)	(0.41)	(0.70)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

40%. The insecticide carbaryl 1% caused 43.20 percent mortality which was on par with cashew apple 10 % that recorded a mortality rate of 43.20 percent.

When the treatments were applied on fourth instar, significantly higher mortality was recorded by cashew apple extract 50% and cashew apple extract 40% followed by cashew apple 20% with mortality percentage of 76.59, 73.25 and 66.58 respectively and were on par with each other. Carbaryl 1% caused 40.00 percent mortality which was on par with cashew apple 10% with a mortality percentage of 36.51. Other treatments were non significant.

In the case of fifth instar, cashew apple extract 50% and cashew apple extract 40% has caused significantly higher mortality percentage of 63.25 and 56.56 respectively which were on par with each other followed by cashew apple 20% with a mortality rate of 63.25 percent, which was on par with carbaryl 1% (36.51 percent mortality) and cashew apple 10% that recorded a mortality rate of 26.67 percent.

in the case of sixth, seventh, eight and ninth instar, prepupae, pupae and adult stages, significantly higher mortality was recorded by cashew apple extract 50% and cashew apple extract 40% followed by cashew apple 20%. In all the cases the mortality caused by spraying insecticide carbaryl 1% was on par with the mortality rate caused by spraying cashew apple 10%.

4.2.3.2 Twenty Four Hours after Treatment

Comparative efficiency of cashew apple extract and carbaryl on the mortality of different life stages of red palm weevil twenty four hours after treatment is depicted in Table 13. The result showed that cashew apple extract 50% and cashew apple extract 40% had caused cent percent mortality of first instar which was significantly superior to other treatments followed by cashew apple 20% which caused a mortality rate of 76.59 percent which was on par with the carbaryl 1% and cashew apple 10% (63.25 in both cases). Next significantly higher mortality rate was produced by cashew apple extract 5 % (50.00).

For the second instar, cashew apple extract 50% and cashew apple extract 40% has caused 100 percent mortality followed by cashew apple 20% with a mortality rate of 70.00 percent which was on par with carbaryl 1% and cashew apple 10% that caused the same mortality percentage of 63.25.

The treatments when tried on third instar cashew apple extract 50% and cashew apple extract 40% has caused significantly higher mortality of third instars with percentage mortality equal to 93.28 and 86.60 respectively which were on par with each other followed by cashew apple 20% with a mortality rate of 73.25 percent. Carbaryl 1% caused 50.00 percent mortality which was on par with cashew apple 10% that recorded mortality rate of 53.22 percent.

When the same treatments were applied on fourth instar of red palm weevil cashew apple extract 50% and cashew apple extract 40% has caused significantly higher mortality percentage of 96.67 and 93.28 respectively which were on par with each other followed by cashew apple 20% with a mortality rate of 76.59 percent. Carbaryl 1% caused 43.20 percent mortality which was equal to the mortality caused by cashew apple 10%.

The effect of treatments on fifth instar of red palm weevil indicated that cashew apple extract 50% and cashew apple extract 40% has caused significantly higher mortality (93.28 and 86.19 respectively) which was on par with each other followed by cashew apple 20% with a mortality rate of 56.56 percent. Carbaryl 1% caused 45.54 percent mortality which was on par with cashew apple extract 20%. Cashew apple 10% which caused the percent mortality of 33.33 was also on par with cashew apple 5 % (26.67).

In the case of sixth, seventh, and ninth instars, prepupae, pupae and adult stages, significantly higher mortality was recorded by cashew apple extract 50% and cashew apple extract 40% followed by cashew apple 20% . In all the cases the mortality caused by spraying carbaryl 1% was on par with the mortality rate caused by spraying cashew apple 10%.

Table 13. Comparative efficiency of apple extract of *A. occidentale* and carbaryl on the mortality of different life stages of red palm weevil (24 h after treatment)

Dose	I instar	II Instar	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar	Prepupa	Pupa	Adult
2%	23.11(4.91)	13.33(3.73)	10.00(3.31)	3.33 (1.77)	10.00(3.31)	10.00(3.31)	6.66(2.54)	3.33 (1.77)	3.33 (1.77)	13.33(3.73)	0.00(1.00)	0.00(1.00)
4%	23.11(4.91)	16.31(4.17)	16.31(4.17)	13.33(3.73)	16.31(4.17)	16.31(4.17)	20.00(4.58)	10.00(3.31)	10.00(3.31)	16.31(4.17)	0.00(1.00)	0.00(1.00)
5%	50.00(7.14)	50.00(7.12)	33.33(5.84)	26.67(5.24)	26.67(5.24)	30.00(5.57)	36.51(6.13)	36.51(6.13)	31.90(5.79)	25.92(5.19)	0.00(1.00)	7.79(2.96)
10%	63.25(8.02)	63.25(8.02)	53.22(7.36)	43.20(6.65)	33.33(5.84)	53.22(7.36)	45.54(6.90)	50.00(7.14)	43.20(6.65)	40.00(6.37)	16.31(4.17)	20.00(4.58)
20%	76.59(8.81)	70.00(8.42)	73.25(8.62)	76.59(8.81)	56.56(7.59)	73.25(8.62)	70.00(8.42)	53.22(7.36)	56.30(7.57)	83.27(9.18)	70.00(8.41)	66.58(8.22)
40%	100.00(10.05)	100.00(10.05)	86.60(9.36)	93.28(9.71)	86.19(9.34)	76.59(8.81)	76.59(8.81)	70.00(8.41)	70.00(8.42)	86.60(9.36)	66.58(8.22)	90.00(9.53)
50%	100.00(10.05)	100.00(10.05)	93.28(9.71)	96.67(9.88)	93.28(9.71)	83.27(9.18)	80.00(9.00)	73.25(8.62)	73.25(8.62)	86.60(9.36)	70.00(8.42)	86.60(9.36)
1% carbaryl	63.25(8.02)	63.25(8.02)	50.00(7.12)	43.20(6.65)	45.54(6.90)	56.56(7.59)	50.00(7.14)	50.00(7.07)	36.51(6.13)	40.00(6.37)	53.22(7.36)	26.67(5.24)
CD (0.05)	(0.69)	(0.83)	(0.78)	(1.11)	(0.91)	(0.66)	(0.93)	(1.22)	(1.22)	(1.18)	(0.66)	(1.24)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

In the case of eighth instar, cashew apple extract 50% and cashew apple extract 40% recorded significantly higher mortality rates which were on par with each other followed by cashew apple extract 20%, cashew apple extract 10% and carbaryl 1% which were also on par.

4.2.3.3 Fourty Eight Hours After Treatment

Comparative efficiency of cashew apple extract and carbaryl on the mortality of different life stages of red palm weevil 48 hours after treatment is indicated in Table 14. The result denoted that cashew apple extract 50% and cashew apple extract 40% has caused 100 percent mortality of first instars which was on par with cashew apple 20% with a mortality rate of 86.42 percent. Carbaryl 1% caused 73.25 percent mortality which was on par with cashew apple 10% that recorded a mortality rate of 72.22 percent.

The effect of these treatments on second instars of red palm weevil revealed that cashew apple extract 50% and cashew apple extract 40% has caused 100 percent mortality and cashew apple 20% and cashew apple 10% caused the mortality of 73.25 percent which was on par with carbaryl 1% that caused 66.58 percent mortality. Next significantly higher mortality rate was produced by cashew apple 5 % (52.89 percent).

Cashew apple extract 50% and cashew apple extract 40% has caused 100 percent mortality of third instar, followed by cashew apple 20% with a mortality rate of 76.59 percent. Carbaryl 1% caused 50.00 percent mortality which was on par with cashew apple 10% which recorded a mortality rate of 53.22 percent.

In the case of fourth instar, significantly higher mortality was recorded by cashew apple extract 50% and cashew apple extract 40% followed by cashew apple 20% having a mortality percentage of 100, 96.67 and 80 respectively which were on par with each other. Carbaryl 1% caused 50.00 percent mortality which was on par with cashew apple 10% which recorded a mortality rate of 53.22 percent.

When the treatments were applied on fifth instar, cashew apple extract 50% and 40% has caused significantly higher mortality percentage of 100 and 96.67 respectively which were on par with each other followed by cashew apple 20% with a mortality rate of 63.25 percent which was on par with cashew apple 10% that recorded a mortality rate of 56.56 percent. Carbaryl 1% has recorded a mortality rate of 50.00 percent.

The effect of same treatments on sixth instar showed that cashew apple extract 50% has caused significantly higher mortality percentage (100) followed by cashew apple extract 40% and cashew apple extract 20% with a mortality rate of 83.27 and 80 respectively which were on par with each other. Cashew apple 10% which recorded a mortality rate of 56.56 percent was on par with carbaryl 1% that recorded a mortality rate of 56.97 percent.

The same treatments on seventh instar revealed that significantly higher mortality was recorded by cashew apple extract 50% and cashew apple extract 40% followed by cashew apple 20% with a mortality percentage of 100, 93.28 and 80.27 respectively which were on par with each other. Carbaryl 1% caused 53.22 percent mortality which was on par with cashew apple 10% that recorded a mortality rate of 56.56 percent.

Cashew apple extract 50% and 40% had caused significantly higher mortality of eighth instars, having a mortality percentage of 86.60 percent followed by cashew apple 20% and cashew apple 10%, with a mortality rate of 62.74 and 56.56 respectively which were on par with carbaryl 1% that caused 50.00 percent mortality.

In the case of ninth instar, significantly higher mortality was recorded by cashew apple extract 50%, cashew apple extract 40% followed by cashew apple 20% having a mortality percentage of 80, 73.25 and 70 respectively which were on par with each other. Carbaryl 1% caused 52.89 percent mortality which was on par with cashew apple 10% which recorded a mortality rate of 45.54 percent.

Table 14. Comparative efficiency of apple extract *A. occidentale* of and carbaryl on the mortality of different life stages of red palm weevil (48 h after treatment)

Dose	I instar	II Instar	III Instar	IV Instar	V Instar	VI Instar	VII Instar	VIII Instar	IX Instar	Prepupa	Pupa	Adult
2%	23.11(4.91)	16.31(4.17)	10.00(3.31)	6.66(2.54)	13.33(3.73)	13.33(3.73)	6.66(2.54)	10.00(3.31)	6.66(2.54)	16.31(4.17)	0.00(1.00)	0.00(1.00)
4%	30.00(5.56)	20.00(4.58)	16.31(4.17)	13.33(3.73)	23.11(4.91)	20.00(4.58)	20.00(4.58)	13.33(3.73)	23.11(4.91)	20.00(4.583	0.00(1.00)	0.00(1.00)
5%	53.22(7.36)	52.89(7.34)	36.51(6.13)	33.33(5.84)	36.51(6.13)	33.33(5.84)	33.33(5.84)	36.51(6.13)	40.00(6.37)	33.33(5.84)	0.00(1.00)	13.33(3.73)
10%	72.22(8.56)	73.25(8.62)	53.22(7.36)	53.22(7.36)	56.56(7.59)	56.56(7.59)	56.56(7.59)	56.56(7.59)	45.54(6.90)	45.54(6.90)	16.31(4.17)	23.11(4.91)
20%	86.42(9.35)	73.25(8.62)	76.59(8.81)	80.00(9.00)	63.25(8.02)	80.00(9.00)	83.27(9.18)	62.74(7.98)	70.00(8.41)	90.00(9.53)	76.59(8.81)	83.27(9.18)
40%	100.00(10.05)	100.00(10.05)	100.00(10.05)	96.67(9.88)	96.67(9.88)	83.27(9.18)	93.28(9.71)	86.60(9.36)	73.25(8.62)	93.28(9.71)	80.00(9.00)	90.00(9.53)
50%	100.00(10.05)	100.00(10.05)	100.00(10.05)	100.00(10.05)	100.00(10.05)	100.00(10.05)	90.00(9.54)	86.60(9.36)	80.00(9.00)	96.67(9.88)	86.60(9.36)	96.67(9.88)
1% carbaryl	73.25(8.62)	66.58(8.22)	50.00(7.12)	50.00(7.12)	50.00(7.12)	24.97(7.79)	53.22(7.36)	50.00(7.07)	52.89(7.34)	43.20(6.65)	53.22(7.36)	33.33(5.84)
CD (0.05)	(0.99)	(0.76)	(0.76)	(1.11)	(0.85)	(0.73)	(0.96)	(1.12)	(1.23)	(0.69)	(0.58)	(0.69)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

The treatments when applied on prepupae, significantly higher mortality was recorded by cashew apple extract 50% and cashew apple extract 40% followed by cashew apple 20% having a mortality percentage of 96.67, 93.28 and 90 respectively which were on par with each other. Carbaryl 1% caused only 43.20 percent mortality which was on par with cashew apple extract 10% which recorded a mortality rate of 45.54 percent.

In the case of pupae, significantly higher mortality was recorded by cashew apple extract 50% and cashew apple extract 40% followed by cashew apple 20% that recorded a mortality percentage of 86.60, 80 and 76.59 respectively which were on par with each other. Carbaryl 1% caused 3.22 percent mortality followed by cashew apple 10% which recorded a mortality rate of 16.31 percent.

The adults of red palm weevil when treated with the same treatments, significantly higher mortality was recorded by cashew apple extract 50% and cashew apple extract 40%, followed by cashew apple 20% having a mortality percentage of 96.67, 90 and 83.27 respectively which are on par with each other. The insecticide carbaryl 1% caused only 33.33% mortality followed by cashew apple 10% which recorded a mortality percentage of 23.11.

4.3 STERILE INSECT TECHNIQUE

4.3.1 Effect of Different Doses of Co 60 Gamma Radiation on the Development of Different Life Stages of Red Palm Weevil

Development of different life stages of irradiated red palm weevil when the males were subjected to different doses of Co 60 radiation is indicated in Table 15. The number of eggs laid was significantly lower at 2.0 Krad. (76.03) in comparison with other treatments followed by 1.8 Krad. (89.55) which was statistically superior to that at 1.5 Krad. (100.4) and control. The treatments 1.8 Krad., 1.7 Krad. (94.39) and 1.6 Krad. (98.60) stood statistically in the same position. Also the number of eggs laid by the female mated with the males irradiated at 1.5 Krad.was statistically superior to the control. The highest number of eggs (128.82) laid was noticed in control, *i.e.* without any radiation treatment

Table 15. Effect of different doses of Co 60 gamma radiation on the development of different life stages of red palm weevil

Radiation dose (Krad)	Number of eggs laid	Percentage egg hatch	Percentage larval mortality	Number of adults emerged	Percentage mortality (egg-adult)	Adult longevity (days)
0	128.82(11.40)	85.48(9.30)	24.00(5.00)	55.49(7.52)	50.64(7.19)	107.52(10.42)
1.5	100.40(10.07)	11.14(3.48)	70.84(8.48)	4.06(2.25)	95.18(9.81)	100.4(10.07)
1.6	98.60 (9.98)	8.58(3.09)	76.44(8.80)	3.43(2.11)	96.39(9.87)	83.76(9.21)
1.7	94.389(9.77)	6.62(2.76)	78.72(8.93)	0.36(1.17)	99.60(10.03)	75.94(8.77)
1.8	89.55 (9.52)	3.71(2.17)	81.67(9.09)	0.36(1.17)	99.60(10.03)	50.86(7.20)
2.0	76.03 (8.78)	1.25(1.5)	86.02(9.33)	0.00(1.00)	99.99(10.05)	41.90(6.55)
CD (0.05)	(0.54)	(0.24)	(0.290	(0.50)	(0.30)	(0.38)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

The percentage egg hatch was significantly lower at 2.0 Krad. (1.25) than that of other treatments followed by 1.8 Krad. (3.71), 1.7 Krad. (6.62), 1.6 Krad. (8.58), and 1.5 Krad. (11.4) respectively. The highest percentage egg hatch was noticed in control (85.48).

The percentage larval mortality was significantly higher at 2.0 Krad (86.02) followed by 1.8 Krad. (81.67) and both were on par with each other. The percentage larval mortality at 1.8 Krad was significantly higher than that at 1.5 Krad. (70.84) and at 0 Krad. (24.00), but was on par with that at 1.7 Krad. (78.12) and 1.6 Krad. (76.44). Similarly the percentage larval mortality at 1.7 Krad. was on par with that at 1.6 Krad. The treatment 1.5 Krad. was also statistically superior to the control.

There were no adults found to be emerged at 2.0 Krad. which was on par with 1.8Krad. and 1.7 Krad. with the number of adults emerged equal to 0.36. The number of adults emerged was highest in the case of control (55.49).

The percentage mortality, (egg - adult) at 2.0 Krad., 1.8 Krad., 1.7 Krad., 1.6 Krad. and 1.5 Krad. were statistically on par with each other and they were all superior to control (50.64).

The adult longevity recorded was statistically higher in control (107.52 days) followed by 1.5Krad. (100.4 days), but both were on par with each other. The adult longevity was lowest at 2 Krad. (41.90 days).

4.3.2 Evaluation of Normal and Irradiated Male Insects of Red Palm Weevil on the Basis of Percentage Egg Hatch

4.3.2.1 Due to Repeated Mating

The efficiency of irradiated male insect of red palm weevil by repeated mating with female insects is indicated in Table 16. The result showed that at 1.5 Krad., 1.6 Krad. and 1.7 Krad. the percent egg hatch reached nil when the males were exposed to sixth female and hence statistically lower percentage egg hatch obtained at sixth female level when compared to other treatments. Significantly higher percentage egg hatch was reported when the males were exposed to first

Table 16. Efficiency of irradiated male insects of red palm weevil by repeated mating with female insects before release in the field

Sequence of females supplied irradiated male	Percentage egg hatch under varying level of irradiation (Krad)				
	1.5	1.6	1.7	1.8	2.0
First female (1-2 days)	14.18(3.90)	12.32(3.65)	10.96(3.46)	8.64(3.10)	7.30(2.88)
Second female (3-4 days)	9.50(3.24)	7.41(2.90)	9.80(3.29)	7.44(2.90)	3.53(2.13)
Third female (5-6 days)	0.77(1.33)	0.68(1.30)	0.65(1.28)	0.37(1.17)	0.22(1.10)
Fourth female (7-8 days)	0.77(1.33)	0.66(1.29)	0.18(1.09)	0.11(1.05)	0.00 (1.00)
Fifth female (9-10 days)	0.54(1.24)	0.36(1.17)	0.11(1.05)	0.00 (1.00)	0.00 (1.00)
Sixth female (11-12 days)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
CD (0.05)	(0.11)	(0.11)	(5.83)	(0.16)	(0.12)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

female, 14.18, 12.32 and 10.96 percent respectively at 1.5 Krad., 1.6 Krad. and 1.7 Krad.. The males irradiated at 1.8 Krad. when mated repeatedly with females, nil egg hatches was observed at fifth female level onwards and significantly higher percentage egg hatch was at first female level, 8.64 percent. The males irradiated at 2.0 Krad. when coupled repeatedly with female, no eggs were found to hatch from third female level onwards and significantly higher percentage egg hatch was noticed at first female level, 7.30 percent.

4.3.2.2 Due to Remating

The viability of eggs laid by female mated with male red palm weevil irradiated at different doses due to re mating is presented in Table17. The result indicated that at 1.5 Krad. among all the treatments the percent hatch of eggs laid during first 36 days of oviposition was significantly higher for 'female treated with normal male for 36 days and subsequently with irradiated male', 'Female treated with normal males continuously' and for 'female treated with normal male for 36 days and then deprived of male' with 81.28, 80.04 and 80.04 percent respectively which were on par with each other. The percent egg hatch of the eggs laid during first 36 days of oviposition was least for 'female treated with irradiated male for 36 days and subsequently with normal male' and for 'female treated with irradiated male continuously' with the percent hatch of 7.04 in both the cases. But at 1.5 Krad. among all the treatments the percent hatch of eggs laid during 3760 days of oviposition was significantly higher for 'female treated with normal males continuously' and for 'female treated with normal male for 36 days and then deprived of male' with 76.53 and 75.41 percent respectively which were on par with each other followed by 'female treated with irradiated male for 36 days and subsequently with normal male'. In this case the percent egg hatch for 'female treated with normal male for 36 days and subsequently with irradiated male' was significantly less than 'female treated with normal males continuously' and 'female treated with normal male for 36 days and then deprived of male. The percent egg hatch of the eggs laid during 3760 days of oviposition was nil for 'female treated with irradiated male continuously'.

Table 17. Evaluation of normal and irradiated male insects of red palm weevil due to remating on the basis of percentage egg hatch

Treatments	Percentage of egg hatch under varying levels of irradiation (Krad)									
	1.5		1.6		1.7		1.8		2.0	
	Eggs laid during first 36 days	Eggs laid from 37-60 days	Eggs laid during first 36 days	Eggs laid from 37-60 days	Eggs laid during first 36 days	Eggs laid during first 36 days	Eggs laid from 37-60 days	Eggs laid from 37-60 days	Eggs laid during first 36 days	Eggs laid from 37-60 days
Female treated with irradiated male for 36 days and subsequent with normal male	7.04(2.84)	67.19(8.25)	6.35(2.71)	69.44(8.39)	4.76 (2.40)	8.76(3.12)	71.87(8.54)	73.18(8.61)	3.72(2.17)	72.44(8.56)
Female treated with normal male for 36 days and subsequent with irradiated male	81.28(9.07)	50.37(7.17)	81.12(9.06)	33.45(5.87)	78.88(8.94)	74.76(8.70)	50.70(7.19)	45.03(6.78)	79.47(8.97)	36.39(6.11)
Female treated with normal male continuously	80.04(9.00)	76.53(8.80)	80.66(9.04)	76.57(8.80)	76.33(8.79)	81.39(9.08)	78.88(8.93)	75.54(8.75)	80.15(9.01)	81.14(9.06)
Female treated with irradiated male continuously	7.04(2.84)	0.00(1.00)	5.55(2.56)	0.00(1.00)	5.34(2.52)	3.24(2.06)	0.00(1.00)	0.00(1.00)	3.44(2.11)	0.00(1.00)
Female treated with normal male for 36 days and then deprived of male	81.28(9.07)	75.41(8.74)	80.66(9.04)	80.38(9.02)	81.92(9.10)	84.41(9.24)	83.54(9.19)	80.61(9.03)	81.44(9.08)	80.36(9.02)
CD (0.05)	(0.32)	(0.35)	(0.18)	(0.65)	(0.28)	(0.39)	(0.38)	(0.20)	(0.34)	(0.41)

Figures in parentheses are transformed values : $\sqrt{x+1}$

At 1.6 Krad., the percent hatch of eggs laid during first 36 days of oviposition was significantly higher for 'female treated with normal male for 36 days and subsequently with irradiated male', 'female treated with normal males continuously' and for 'female treated with normal male for 36 days and then deprived of male' with 81.12, 80.66 and 80.66 percent respectively which were on par with each other. The percent egg hatch of the eggs laid during first 36 days of oviposition was significantly lesser for 'female treated with irradiated male continuously' and for 'female treated with irradiated male for 36 days and subsequently with normal male' with the percent hatch of 5.55 and 6.35 respectively. Also in this case the percent hatch of the eggs laid during 3760 days was significantly higher for 'female treated with normal male for 36 days and then deprived of male', female treated with normal males continuously' and 'female treated with irradiated male for 36 days and subsequently with normal male' which were on par with each other. Percent egg hatch was significantly lesser for 'female treated with normal male for 36 days and subsequently with irradiated male' and nil for 'female treated with irradiated male continuously'.

At 1.7 Krad., the percent hatch of eggs laid during first 36 days of oviposition was significantly higher for 'female treated with normal male for 36 days and then deprived of male' with the percent hatch of 81.92 followed by 'female treated with normal male for 36 days and subsequently with irradiated male' and 'female treated with normal males continuously' (78.88 and 76.33 respectively) which were on par with each other. In this case the percent egg hatch of the eggs laid during first 36 days of oviposition was significantly lesser for 'female treated with irradiated male for 36 days and subsequently with normal male' and 'female treated with irradiated male continuously' with the percent hatch of 4.76 and 5.34 respectively which were also on par with each other. Also in this case the percent hatch of the eggs laid during 3760 days was significantly higher for 'female treated with normal male for 36 days and then deprived of male' and 'female treated with normal males continuously' which were on par followed by 'female treated with irradiated male for 36 days and subsequently with normal male'. Percent egg hatch was significantly less for 'female treated with normal male for 36

days and subsequently with irradiated male' and nil for 'Female treated with irradiated male continuously'.

At 1.8 Krad, among all the treatments the percent hatch of eggs laid during first 36 days of oviposition was significantly higher for 'female treated with normal male for 36 days and then deprived of male', 'female treated with normal males continuously' and 'female treated with normal male for 36 days and subsequently with irradiated male' with the percent hatch of 81.44, 80.15 and 79.47 respectively which were on par with each other and significantly lower for 'female treated with irradiated male for 36 days and subsequently with normal male' and 'female treated with irradiated male continuously' which were also on par with each other. The percent hatch of the eggs laid during 37-60 days at 1.8 Krad. was significantly higher for 'female treated with normal male for 36 days and then deprived of male' and 'female treated with normal males continuously' which were on par followed by 'female treated with irradiated male for 36 days and subsequently with normal male'. Percent egg hatch was lesser significantly for 'female treated with normal male for 36 days and subsequently with irradiated male' and nil for 'female treated with irradiated male continuously'.

At 2.0 Krad, the percent hatch of eggs laid during first 36 days of oviposition was significantly higher for 'female treated with normal male for 36 days and then deprived of male' and 'female treated with normal males continuously' with the percent hatch of 84.41 and 81.39 which were on par with each other followed by 'female treated with normal male for 36 days and subsequently with irradiated male' with the percent hatch of 74.76. The percent hatch was lesser significantly for 'female treated with irradiated male for 36 days and subsequently with normal male' and nil for 'female treated with irradiated male continuously'. The percent hatch of the eggs laid during 37-60 days at 2.0 Krad. was significantly higher for 'female treated with normal male for 36 days and then deprived of male' followed by 'female treated with normal males continuously', 'female treated with irradiated male for 36 days and subsequently with normal male' and 'female

treated with normal male for 36 days and subsequently with irradiated male' and nil for 'female treated with irradiated male continuously'.

4.3.2.3 Due to Recent Mating

The viability of eggs laid by the female red palm weevil due to the effect of recent mating is shown in Table 18. The result indicated that in all radiation doses *viz.*, 1.5 Krad.,1.6 Krad.,1.7 Krad.,1.8 Krad. and at 2.0 Krad. the hatching percentage was significantly lower for 'virgin female treated with normal male for 4 days and then continuously with irradiated male' (Ranged from 12.25 to 4.04 percent) followed by the treatment 'virgin female treated with normal male for 4 days and then with irradiated male for another 4 days and then deprived of males', values being in the range of 26.52 to 13.39 percentage. Significantly higher hatching percentage was found in the treatment 'virgin female treated with irradiated male for 4 days and then with normal male for another 4 days and then deprived of males', percentage of hatching being in the range of 73.11 to 67.12 respectively for 1.5 Krad. to 2.0 Krad.

4.3.2.4 Due to Mating Competition

The mating competition of normal male and sterile male (at different concentration) at different ratios is presented in Table 19. The result indicated that the males when irradiated at 1.5 Krad. and kept at different ratios of normal male: irradiated male: normal female, the number of eggs per female were significantly less in the treatments 1:8:1 , 1:3:1 , 1:6:1, 1:4:1, and 1:5:1 and were on par with each other, values ranged from 124.9 to 130.47. The hatching percentage of eggs laid by females exposed to different ratios of normal and irradiated males were significantly less for 0:1:1, 1:10:1 and 1:9:1 with percentage hatch equal to 16.48 in each case when compared to other treatments. Significantly higher hatching percentage was observed for 1:0:1 with the percentage hatch of 83.42 over all other treatments.

When males were irradiated at 1.6 Krad. and kept at different ratios of normal male: irradiated male: normal female, the number of eggs per female were

Table 18. Evaluation of viability of eggs laid by red palm weevil due to the different combinations of sterile and normal insects

Treatments	Percentage of egg hatch under varying levels of irradiation (Krad)				
	1.5	1.6	1.7	1.8	2.0
Virgin female treated with irradiated male for 4 days and then with normal male for another 4 days and then deprived of males	73.11(8.60)	69.68(8.40)	64.79(8.11)	67.68(8.28)	67.12(8.25)
Virgin female treated with normal male for 4 days and then with irradiated male for another 4 days and then deprived of males	26.52(5.25)	25.47(5.14)	21.68(4.76)	19.98(4.58)	13.39(3.79)
Virgin female treated with normal male for 4 days and then continuously with irradiated male	12.25(3.64)	10.55(3.39)	8.89(3.14)	5.28(2.51)	4.04(2.25)
CD (0.05)	(0.24)	(0.24)	(0.31)	(0.23)	(0.35)

Figures in parentheses are transformed values : $\sqrt{x+1}$

significantly less in the treatment 1:10:1 (112.16) when compared to other treatments except that at 1:5:1 (113.36), 1:4:1 (116.17), 1:2:1 (117.76) and at 1:8:1 (127.44) which were all on par with each other. The treatments 1:4:1 was found to be on par with that at 1:2:1, 1:8:1 and 0:1:1 and were significant too. All other treatments have shown significantly higher number of eggs per female. The hatching percentage of eggs laid by females exposed to different ratios of normal and irradiated males were significantly less for the treatments 0:1:1 and 1:10:1 with the percent hatch of 14.21 and 14.30 both on par, followed by 1:9:1, 1:8:1 and 1:7:1 with percentage hatch equal to 16.19, 17.54 and 18.89 respectively which were also on par with each other. The hatching percentage was significantly less in all the treatments when compared with that at 1:0:1 (83.45)

At 1.7 Krad.the number of eggs per female was significantly lower for 0:0:1 over that at 1:7:1, 1:1:1 and 1:0:1 and was found to be on par with that of other treatments. The hatching percentage at 1.7 Krad. was significantly less for 0:1:1 (10.42) and 1:10:1 (10.42) followed by 1:9:1 (16.37). All other treatments were insignificant.

At 1.8 Krad.and at different ratios, the number of eggs per female was lower significantly for 1:3:1 which was found to be on par with that at 1:2:1 and at 1:6:1. In all other treatments number of eggs per female were significantly higher. The hatching percentages at 1.8 Krad. were significantly less for 0:1:1 (8.11), 1:10:1 (8.11) and 1:9:1 (9.29) and were found to be on par. All other treatments had shown significantly higher hatching percentage.

At 2.0 Krad.and at different ratios, the numbers of eggs per female was lower significantly for 1:7:1 followed by 1:8:1, 1:9:1, 1:10:1 and 0:1:1 and were all on par. In all other treatments numbers of eggs per female were significantly higher. The hatching percentages at 2.0 Krad, were less significantly for 0:1:1 (3.00) and 1:10:1 (3.79) and were found to be on par with each other followed by 1:9:1 (6.33) and 1:8:1 (7.42) both were also on par. All other treatments had shown significantly higher hatching percentages.

Table 19 Evaluation of mating competition of irradiated males with normal males at different ratios and at different radiation doses

Ratio of normal male: Sterile male: fertile female	Doses of irradiation (Krad)									
	1.5		1.6		1.7		1.8		2.0	
	Eggs/ female	Hatching percentage	Eggs/ female	Hatching percentage	Eggs/ female	Hatching percentage	Eggs/ female	Hatching percentage	Eggs/ female	Hatching percentage
1:0:1	155.88 (12.53)	83.42 (9.19)	160.74 (12.72)	83.45 (9.18)	164.36 (12.86)	82.57 (9.14)	156.36(12.54)	83.35 (9.13)	144.34 (12.06)	81.93 (9.11)
1:1:1	151.71 (12.36)	72.30 (8.56)	143.70 (12.03)	69.62 (8.40)	116.16 (10.82)	69.25 (8.38)	76.90 (8.83)	67.27 (8.26)	76.50 (8.80)	59.06 (7.75)
1:2:1	151.06 (12.33)	51.32 (7.23)	117.76 (10.90)	53.45 (7.38)	89.39 (9.51)	49.34 (7.10)	69.76 (8.41)	45.25 (6.80)	79.05 (8.95)	41.12 (6.49)
1:3:1	126.47 (11.29)	48.61 (7.04)	133.99 (11.62)	46.56 (6.90)	89.32 (9.50)	50.52 (7.18)	64.12 (8.07)	39.33 (6.35)	84.03 (9.22)	38.33 (6.27)
1:4:1	128.81 (11.39)	40.87 (6.47)	116.17 (10.82)	47.75 (6.98)	92.31 (9.66)	48.69 (7.05)	91.12 (9.60)	30.95 (5.65)	70.75 (8.47)	21.40 (4.73)
1:5:1	130.47 (11.47)	30.93 (5.65)	113.36 (10.69)	31.46 (5.70)	94.93 (9.79)	30.59 (5.62)	100.08(10.05)	27.89 (5.37)	80.72 (9.04)	15.43 (4.05)
1:6:1	128.50 (11.38)	22.91 (4.89)	151.51 (12.35)	20.39 (4.63)	95.10 (9.80)	23.53 (4.95)	74.38 (8.68)	18.95 (4.47)	76.60 (8.81)	12.37 (3.66)
1:7:1	133.40 (11.59)	19.16 (4.49)	124.28 (11.19)	18.38 (4.40)	101.05 (10.10)	19.43 (4.52)	77.01 (8.83)	16.97 (4.2)	54.69 (7.46)	9.40 (3.22)
1:8:1	124.90 (11.22)	18.89 (4.46)	127.44 (11.33)	17.54 (4.31)	88.21 (9.45)	18.23 (4.39)	86.03 (9.33)	11.51 (3.54)	60.86 (7.87)	7.42 (2.90)
1:9:1	143.93 (12.04)	16.48 (4.18)	140.14 (11.88)	16.19 (4.15)	86.81 (9.37)	16.37 (4.17)	84.40 (9.24)	9.29 (3.21)	63.04 (8.000	6.33 (2.71)
1:10:1	140.83 (11.91)	16.48 (4.18)	112.16 (10.64)	14.30 (3.91)	93.24 (9.71)	10.42 (3.38)	83.35 (9.18)	8.11 (3.02)	59.14 (7.75)	3.79 (2.19)
0:1:1	146.08 (12.13)	14.21 (3.90)	129.94 (11.44)	14.21 (3.90)	82.29 (9.13)	10.42 (3.38)	78.04 (8.89)	8.11 (3.02)	59.68 (7.79)	3.00 (2.00)
CD (0.05)	(1.00)	(0.23)	(0.73)	(0.20)	(0.80)	(0.18)	(0.71)	(0.22)	(1.05)	(0.21)

Figures in parentheses are transformed values : $\sqrt{x + 1}$

DISCUSSION

5. DISCUSSION

The red palm weevil is the most fatal pest of coconut leading to permanent debility of the palms. Most of the available methods are curative in nature wherein early and timely detection and adoption of preventive measures can save the palms to an extent. Detection of the weevil attack at later stages will not help in saving the palms from collapsing. Therefore, it has become imperative to develop alternative and cost effective methods of pest management to contain this pest. In this context, the idea of employing male insects of red palm weevils by sterilizing them and releasing in the infested fields so that these insects will mate with wild populations leading to population elimination can be an ideal solution for this problem. But the major hurdles in advocating the sterile insect technique is the requirement of a vast number of individual insects for irradiation, identifying the susceptible stage for irradiation and prompt field release. Before implementing SIT, the primary step to be undertaken is to bring down the pest population to a manageable level by adopting other methods of pest management and then try for SIT. For this purpose the generally suggested method is to apply insecticides to reduce insect population in the field. But due to the ill effects caused by the injudicious use of persistent toxic chemicals to the environment, trial on the effect of different botanical insecticides on this insect is also important. Hence the current study conducted was in aim with containing the population of red palm weevil below manageable level using bio pesticides and also by SIT.

5.1 SURVEY

5.1.1 Seasonal Infestation of Red Palm Weevil in Different Taluks and Krishibhavans of Thiruvananthapuram District

The results of the survey conducted between June 2001- February 2002 revealed that the infestation of red palm weevil was higher during

June in all the eight Krishibhavans surveyed, followed by that in September (Fig. 1). This result was in conformity by the study conducted by Vidyasagar *et al.* (2000) which indicated that the percentage infestation by red palm weevil in date palm were more during the months of June and July and November and December. The infestation was least during February, which may be due to high temperature during the summer season. Also the rainy seasons (June and September) cause collapsing of infested palms and hence infestation could be noticeable in these periods than during summer months. Also the percentage infestation of red palm weevil was higher in Kadakkavur Krishibhavan area in all the seasons and that may be due to its nearness to sea which is in accordance with the reports by Shantappa *et al.* (1979) that *R. ferrugineus* is more severe in coastal areas of Kerala than in mid land and high ranges. The percentage of infestation was least in Thiruvallam Krishibhavan area in all the three seasons.

The percentage infestation of red palm weevil in the four taluks of Thiruvananthapuram district showed that the infestation level was significantly higher in Chirayinkil taluk in all the seasons followed by that in Nedumangad taluk during June and September and that in Neyyattinkara taluk during February (Fig. 2). The infestation level was lower significantly in Thiruvananthapuram taluk with 6.05 percent during June, 2.92 percent during September and 2.12 percent during February months. The percentage of infestation was in agreement with the earlier reports of Ganapathy *et al.* (1992) who reported that the extent of infestation by red palm weevil was from 6 to 34 percent in Coimbatore area of Tamilnadu state.

Of the various topographical situation surveyed, the infestation by red palm weevil was found to be higher significantly in low lands (Reclaimed paddy lands) in all the three seasons with the highest of 12.36 percentage during June. The infestation by red palm weevil was lowest in

Fig.1. Seasonal infestation of red palm weevil in different Krishibhavans surveyed

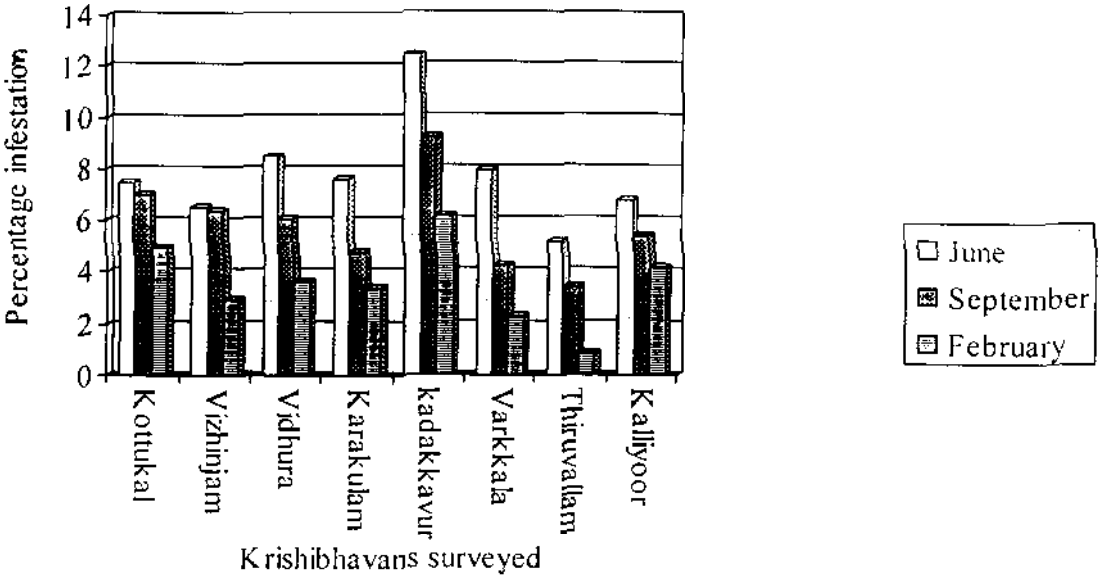
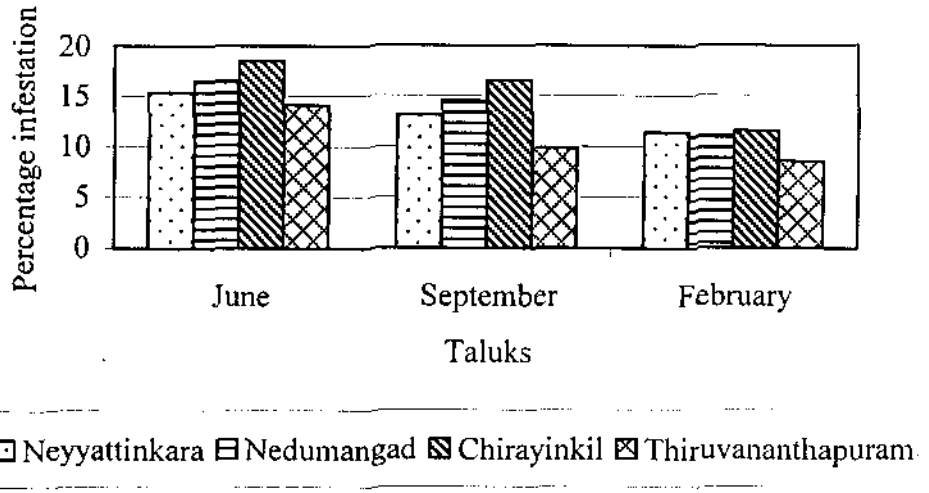


Fig. 2. Seasonal infestaton of red palm weevil in the different taluks of Thiruvananthapuram district



upland. Of the total area infested by red palm weevil, 55 percent of the area comes under low land, 29 percent area under garden land and only 16 percent of the area under upland (Fig. 3). Similar findings were also reported by Mazumdar (1995).

The survey revealed that in Kottukal Krishibhavan area, only 26.67 percent of the surveyed farmers were aware of the symptoms of infestation caused by red palm weevil and the rest 73.33 percentage of the farmers could realize its attack only after collapsing of the palm. In the other Krishibhavans surveyed only 13.33 percent of the surveyed farmers has got adequate knowledge about the symptoms of red palm weevil attack and the others 86.67 could find it only after the palms succumbed to death (Fig.4).

It was observed from the results of the survey that 50 percent of the surveyed farmers could identify the grubs of red palm weevil, 16.67 percent identified both the grubs and pupae of the pest, only 14.99 percent knew about the pupal stages and 13.33 percent of them told that they had seen the adults and only 5 percent of the surveyed farmers know about all the stages of red palm weevil (Fig.5).

The infestation observed was highest in young palms below seven years old and was less in palms of more than 14 year old (Fig.6). This was in accordance with the earlier reports by Vidyasagar and Kesavabhat (1991).

Of the surveyed farmers, only 40 percent of the farmers of Vizhinjam and Thiruvallam Krishibhavan and 60 percent of the farmers of Kalliyoor Krishibhavan were having knowledge about the use of pheromone traps against red palm weevil and the other were totally unaware of such traps. Also none of the farmers in the surveyed area was heard about the use of SIT in pest management (Appendix II).

Fig.3. Percent seasonal infestaston of red palm weevil in different topographical situations

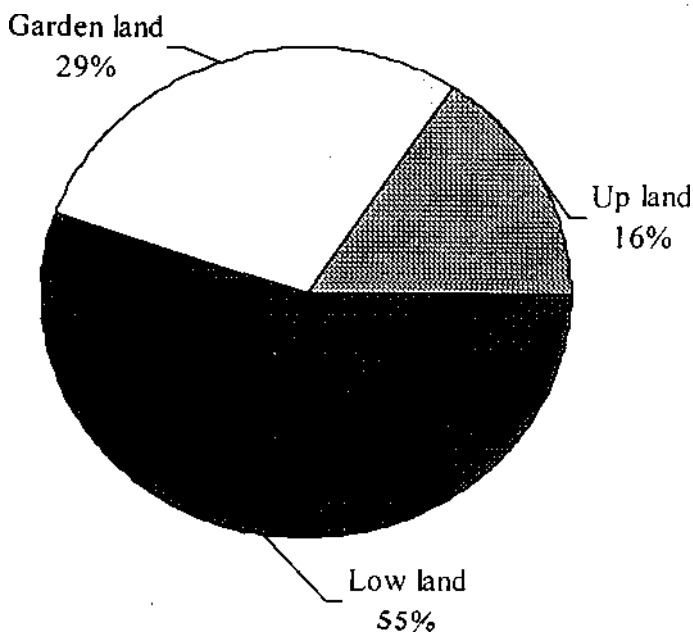


Fig.4. Method adopted in detection of infestation caused by red palm weevil by the farmers under various krishibhavans

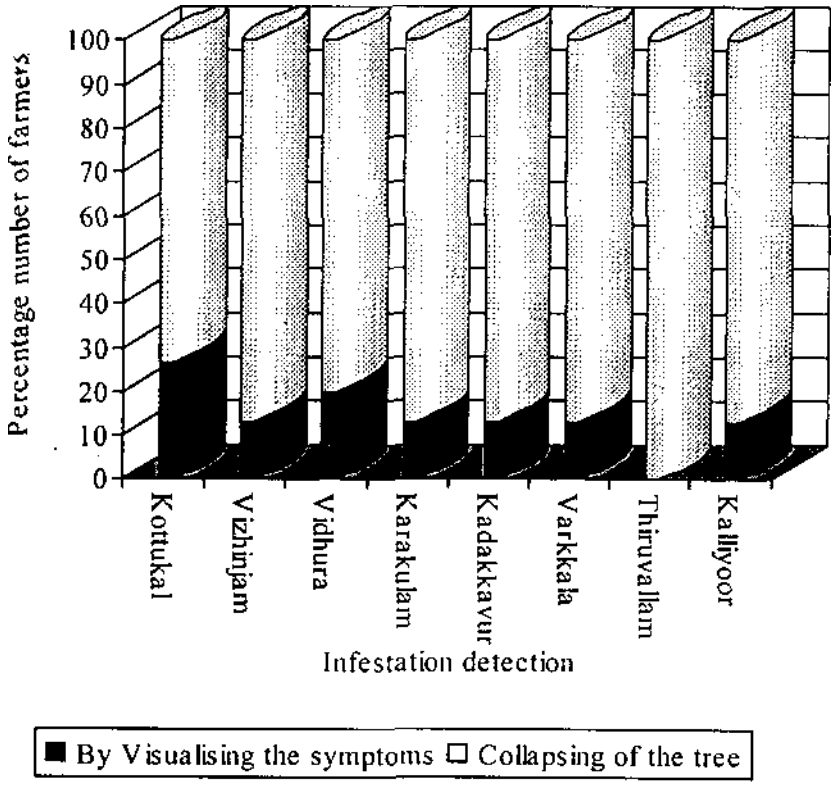


Fig.5. The life stages of red palm weevil observed in the different parts of infested collapsed palms

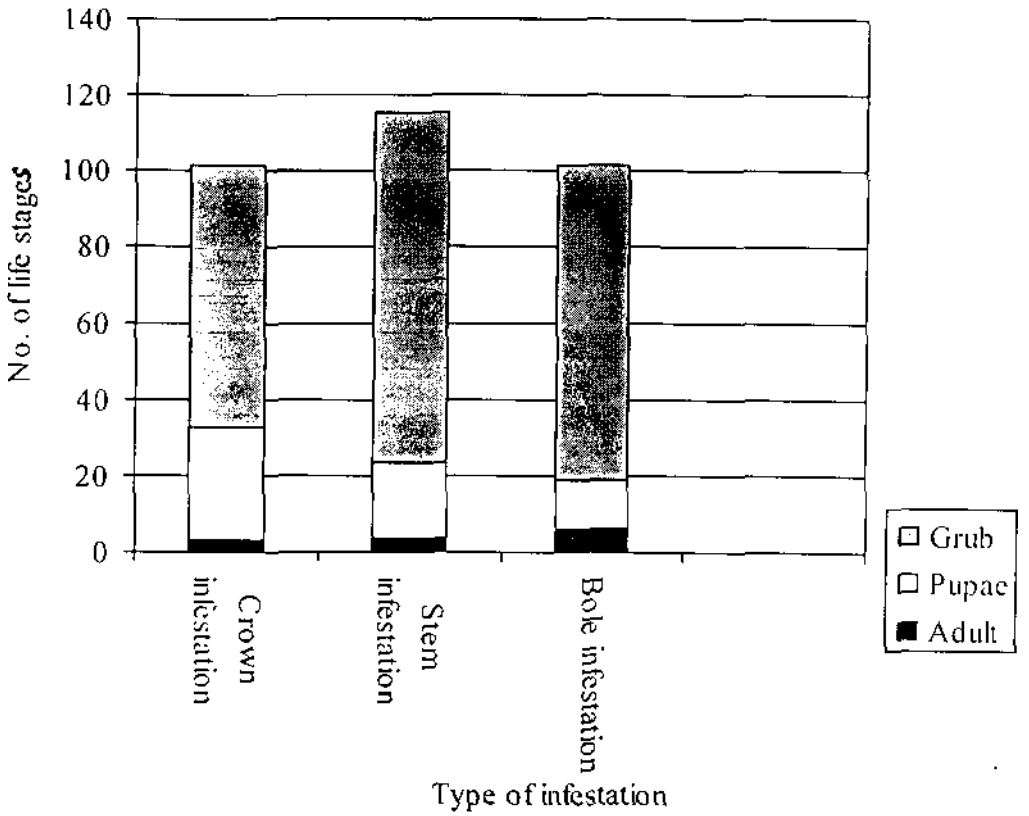
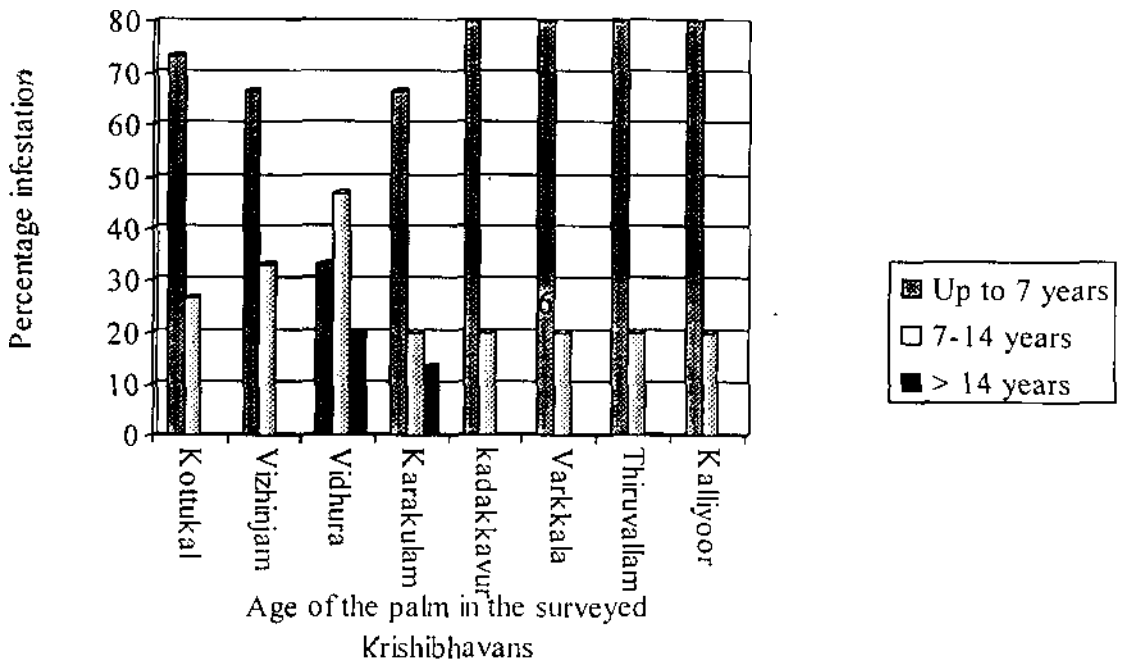


Fig.6. Age of the palm and percentage infestation



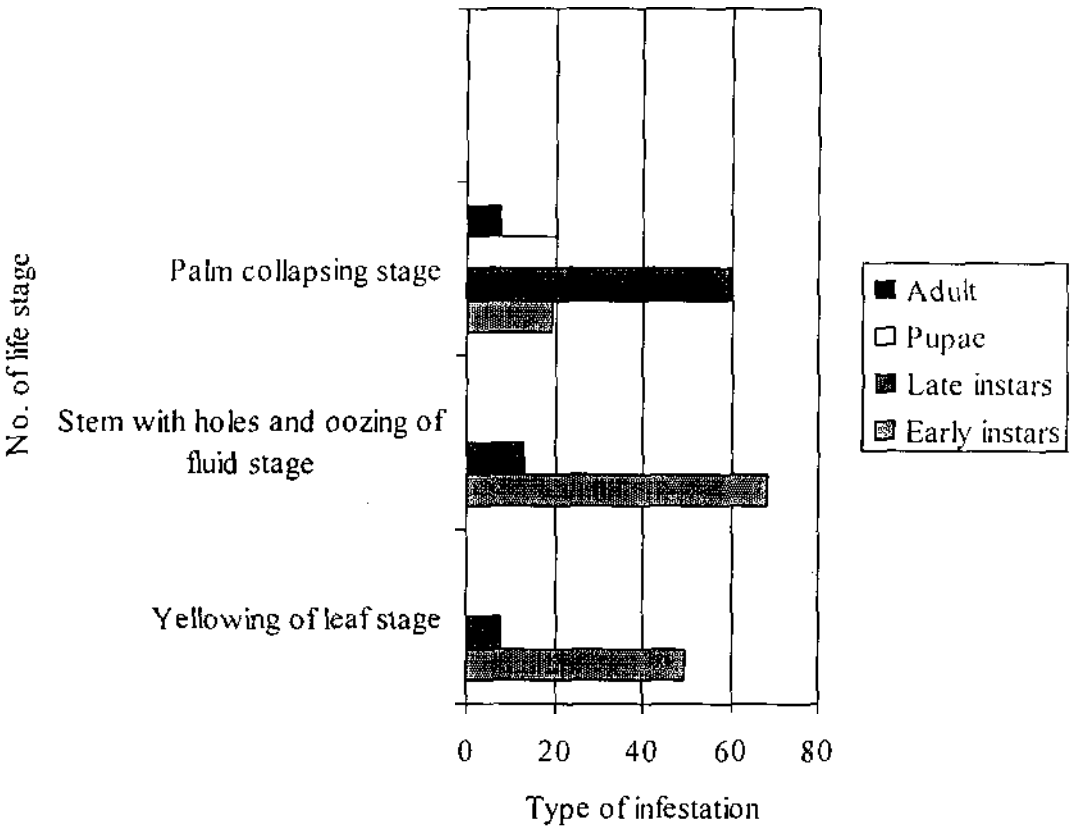
5.1.2 The Life Stages of Red Palm Weevil Observed in the Different Parts of the Infested Collapsed Palms

The results described in para 4.1.2 denoted that the number of grubs per infested palm was observed to be higher significantly in palms in which the stem infestation was prominent than that bole infestation and crown infestation and the number of grubs per infested palm in stem infestation and bole infestation was on par with each other. This may be due to the delay in collapsing of palm in this type of infestation and there may be enough food for the development of grubs. The number of pupae per infested palm was higher significantly in the case of crown infestation than that in stem infestation and in bole infestation. But the number of adults of red palm weevil per infested palm was significantly higher in the case of bole infestation than that in stem and crown infestations.

5.1.3 The Life Stages of Red Palm Weevil and the Symptoms of Infestations Observed in Infested Coconut Palms

At yellowing of middle leaf stage of infestation, only early instars (upto fifth instars) of red palm weevil were seen and there were no later instars, pupae and adult. During the stage of stems with holes and oozing of fluids, up to seventh instars were seen. At palm collapsing stage all the life stages of the weevils were present (Table 5). This corroborate with the earlier findings of Nair (1978) that the initial symptom of red palm weevil attack was yellowing of middle leaves of the palm and the subsequent symptoms were stems with holes and oozing of fluids and at the final stage of infestation the palm will collapse (Fig.7).

Fig.7. The life stages of red palm weevil and the type of infestations observed in infested coconut palms



5.2 LABORATORY STUDIES FOR EVALUATION OF PLANT PRODUCTS AGAINST RED PALM WEEVIL

5.2.1 Effect of Plant Products on the Mortality of Different Larval Stages of Red Palm Weevil

The results of the effect of plant products on the mortality of different larval stages of red palm weevil 2 hours, 24 hours and 48 hours after treatment explained in para 4.2.1 revealed that apple extract of *Anacardium occidentale* 10% had shown significantly higher level of mortality of larvae of red palm weevil up to fifth instar followed by carbaryl 1%, which in most of the cases was on par with that of *A. occidentale* 5%. From sixth instar onwards only apple extract of *A. occidentale* 10% and carbaryl 1% were effective (Fig.8). This indicates the higher insecticidal activity of fruits of *A. occidentale*, which may be due to the presence of some active chemical components in the fruits having insecticidal properties about which no reviews are available.

5.2.2 Repellant Effect of Different Plant Products on Various Larval Instars of Red Palm Weevil

The results of the repellant effect of different plant products on various larval instars of red palm weevil 2 hours, 24 hours and 48 hours after treatment explained in para 4.2.2 indicated that in the case of first instars, leaf extract of *Thevetia neriifolia* 10% was found to be statistically superior to other treatments except that of seed oil of *Azadirachta indica* 4%, leaf extract of *T. neriifolia* 5% and seed oil of *A. indica* 2%. The repellency caused by seed oil of *A. indica* 4% was on par with that of leaf extract of *T. neriifolia* 5%, seed oil of *A. indica* 2%, seed oil of *Samadera indica* 2% and seed oil of *S. indica* 4%. Rest of the treatments were not significant. In the case of second instar, seed oil of *A. indica* 4% and seed oil of *A. indica* 2% were found to be the best repellents significantly followed by seed oil of *S. indica* 2%, seed oil of *S. indica* 4%, leaf extract of *T. neriifolia* 10% and leaf extract of *T. neriifolia* 5%. Thionemone' a compound extracted from neem seed kernel was reported considerably as a

Fig.8. Effect of plant products on the mortality of different larval stages of red palm weevil

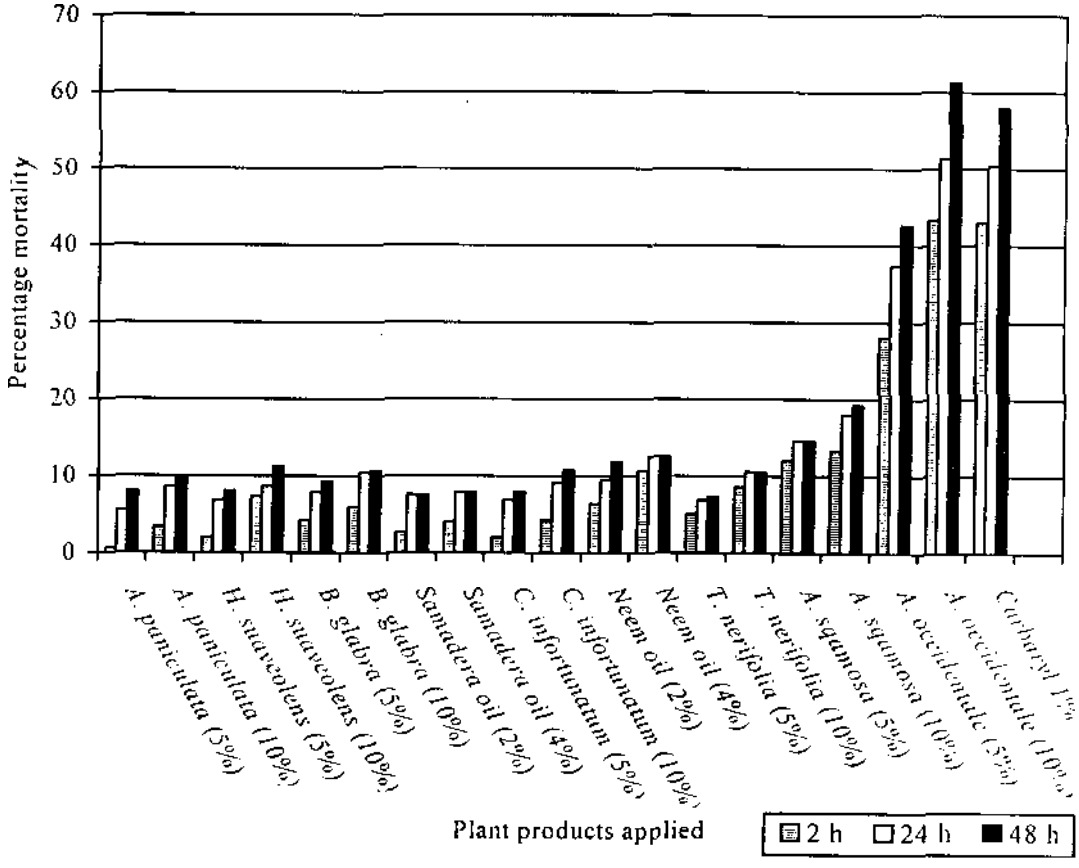
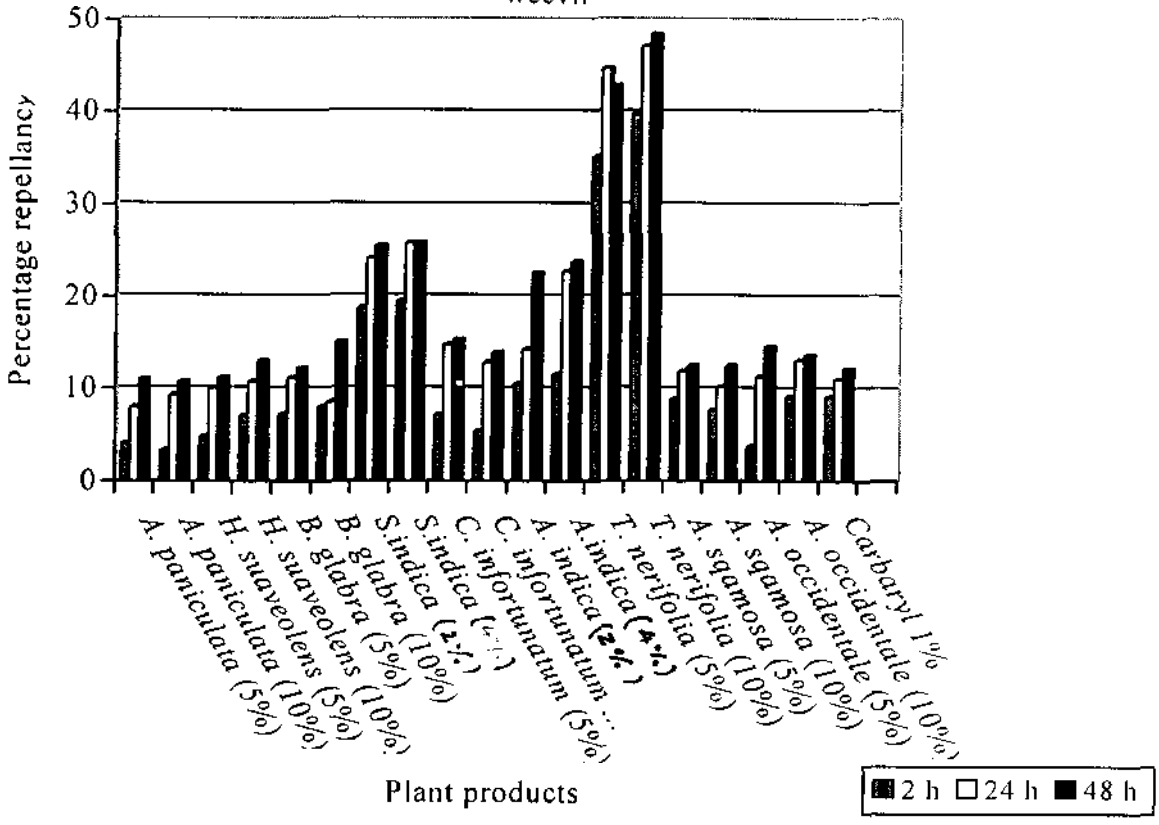


Fig.9. Repellant effect of different plant products on the larval stages of red palm weevil



repellent against coleopterans by Chakravarthy *et al.* (1970). The repellant effect on third and fouth instars implied that seed oil of *S. indica* 4% and seed oil of *S. indica* 2% has recorded significantly higher repellency when compared to other treatments which were on par with that of leaf extract of *T. neriifolia* 10%. In the case of fifth, sixth, seventh, eighth and ninth instars, leaf extract of *T. neriifolia* 10% and leaf extract of *T. neriifolia* 5% have only shown significant repellency (Fig.9). The repellent effects of *T. neriifolia* on coleopterans were already reported by Saradamma (1989).

5.2.3 Comparative Efficiency of Cashew Apple Extract and Carbaryl on the Mortality of Different Life Stages of Red Palm Weevil

The studies on mortality effect of different plant products on the larvae of red palm weevil showed that cashew apple extract is the most effective treatment. Hence a comparative study on the effectiveness of cashew apple extract over carbaryl on the different stages of red palm weevil was carried out to fix the dose of cashew apple extract so as to get maximum effect. The results of the study explained in para 4.2.3 indicated that in all the life stages of red palm weevil, the mortality caused by cashew apple extract 50%, 40% and 20 % was significantly higher than that of carbaryl 1 % and they were on par with each other and superior than cashew apple extract 10% (Fig. 10-13). The grubs treated with cashew apple extract (20%, 40% and 50%) showed feeding cessation, sluggishness, loss of clasping ability to the substratum, shrinkage of thoracic and terminal abdominal segments and death (Plate. 2). Since both 20 % and 50% extracts showed same effect on red palm weevil grubs, apple extract of *A. occidentale* 20 % can be recommended as the economical and effective concentration for field application against red palm weevil. Field trials should be under taken to recommend apple extract of *A. occidentale* 20% as a biopesticide in the Integrated pest management strategy of red palm weevil in coconut.

Fig.10. Comparative efficiency of cashew apple extract and carbaryl on the mortality of larvae of red palm weevil

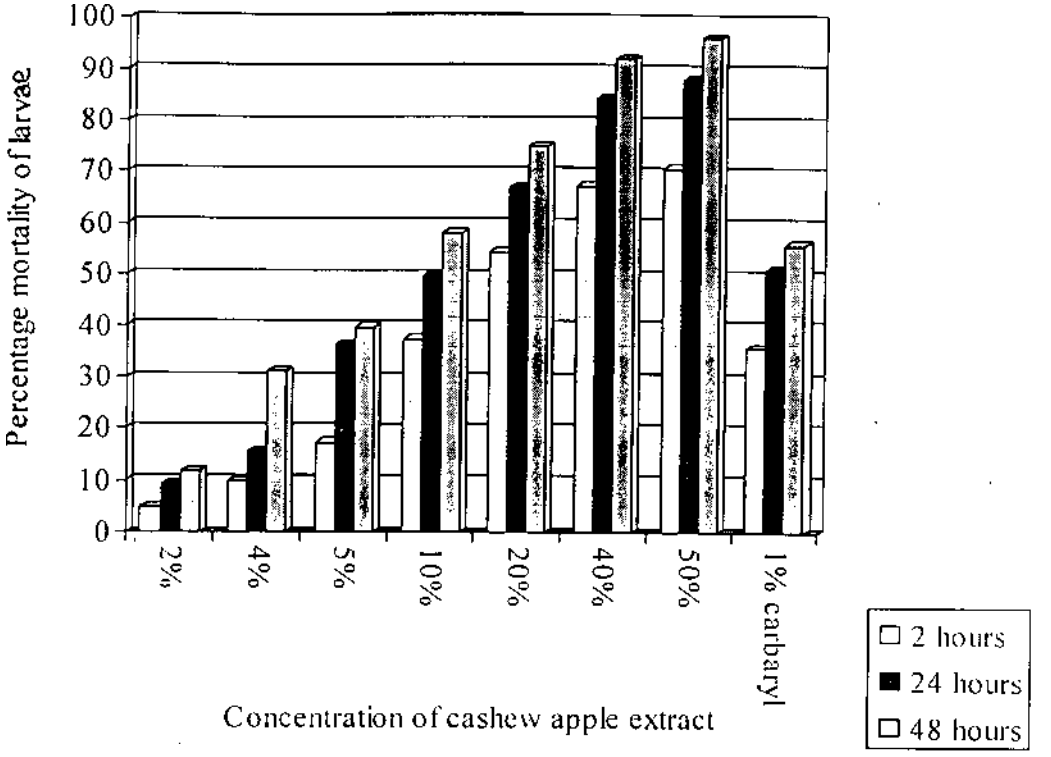


Fig.11. Comparative efficiency of Cashew apple extract and carbaryl on the mortality of prepupae of red palm weevil

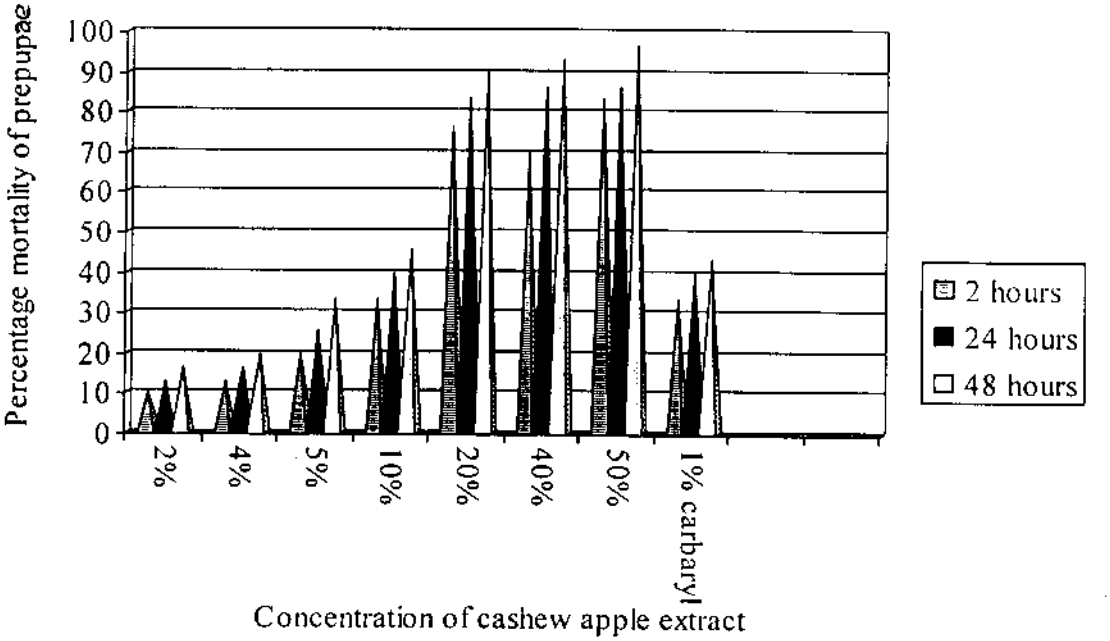


Fig.12. Comparative efficiency of Cashew apple extract and carbaryl on the mortality of pupae of red palm weevil

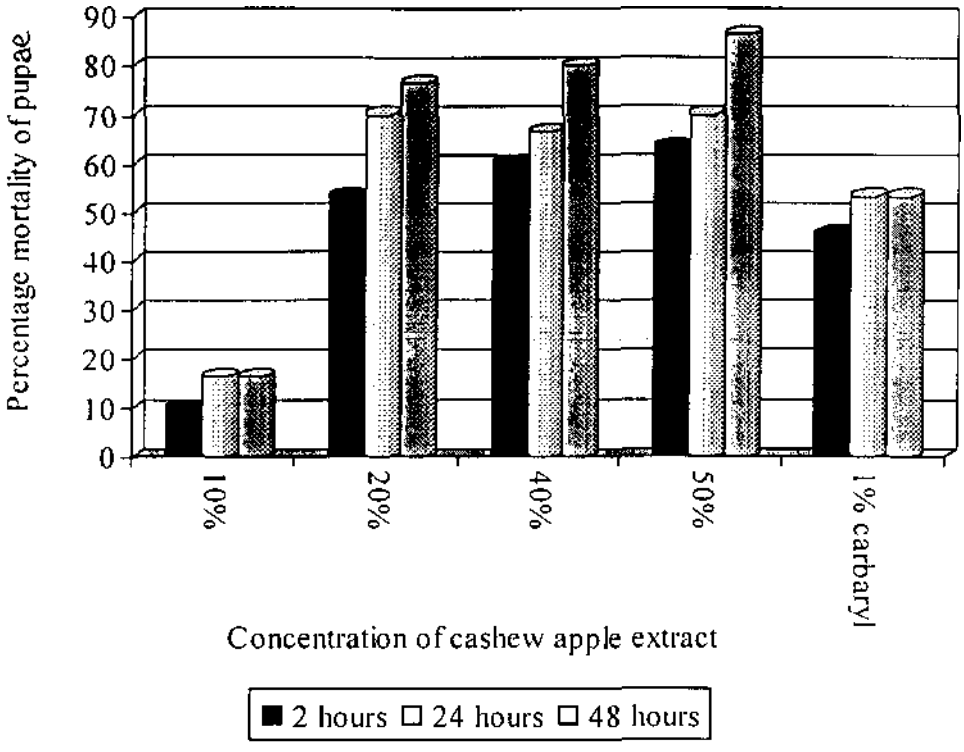
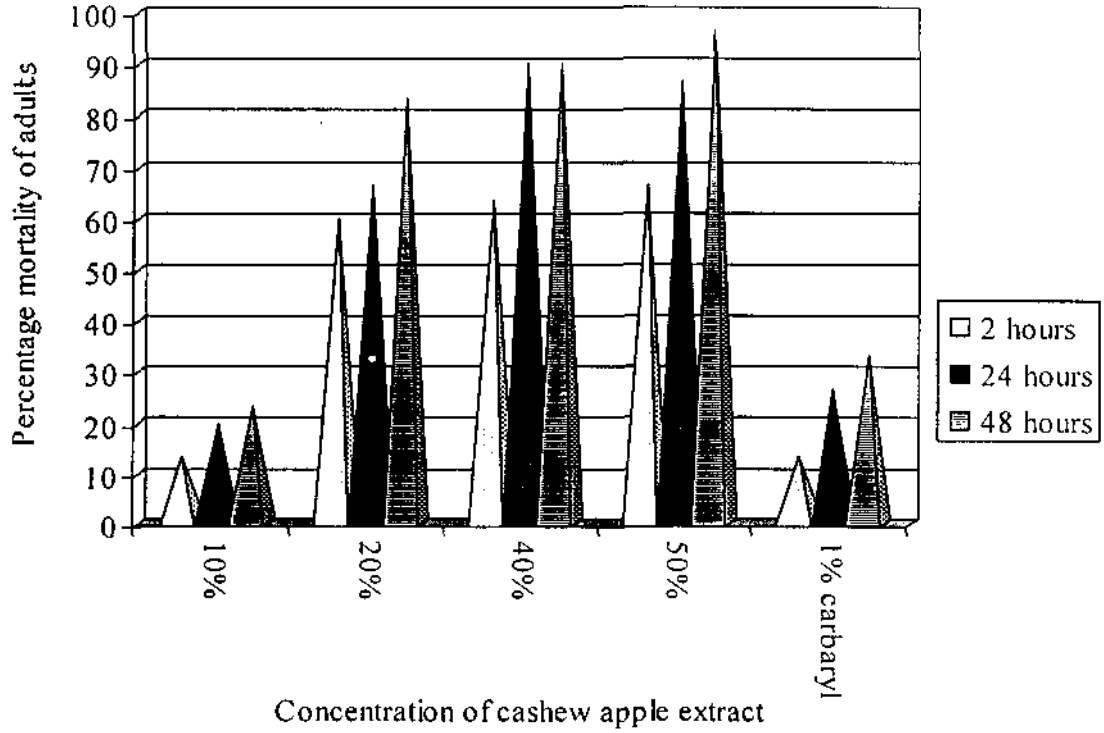


Fig.13. Comparative efficiency of Cashew apple extract and carbaryl on the mortality of adults of red palm weevil



a) Different instars of red palm weevil treated with apple extract of *A. occidentale*

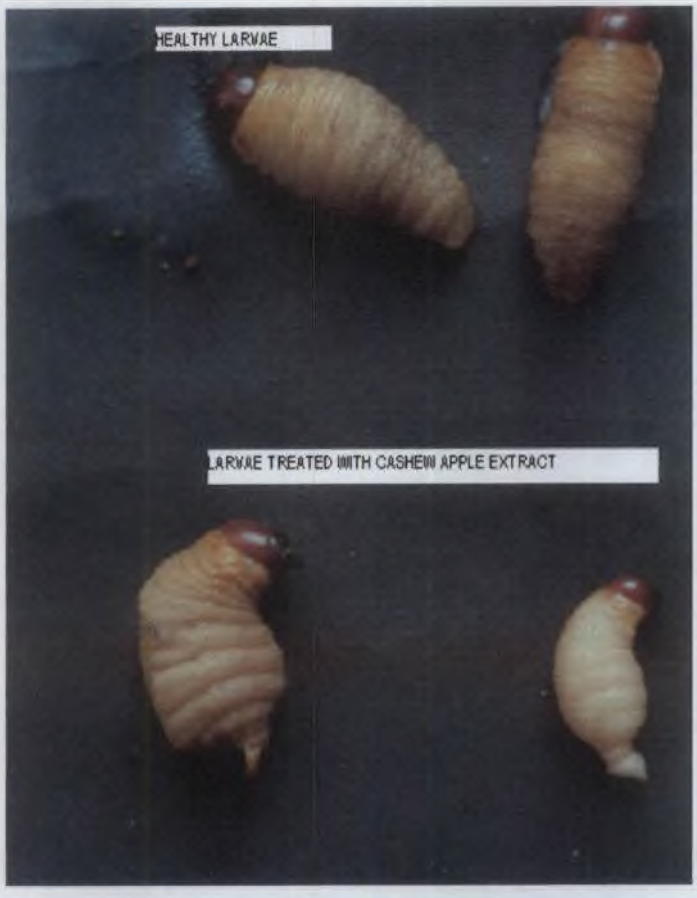


Plate.2. Larvae of red palm weevil treated with apple extract of *A. occidentale*

5.3 STERILE INSECT TECHNIQUE

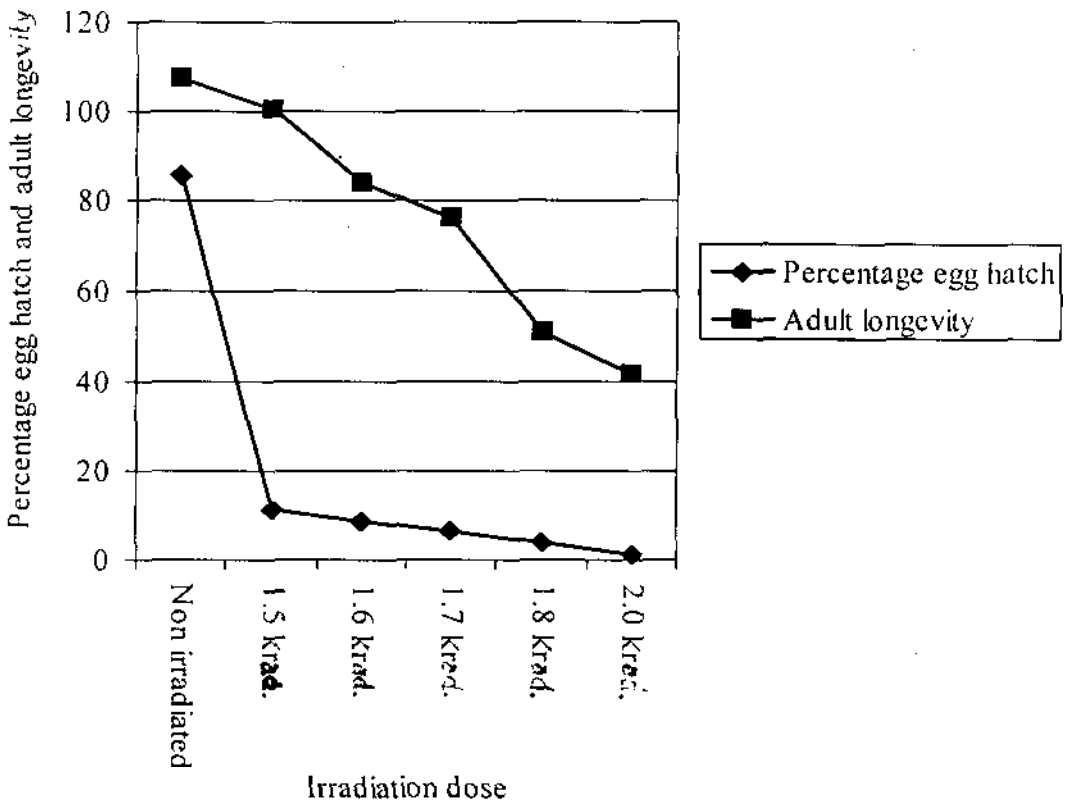
5.3.1 Effect of Different Doses of Co 60 Gamma Radiation on the Development of Different Life Stages of Red Palm Weevil

The results of study on the effect of different doses of Co 60 gamma radiation on the development of different life stages of red palm weevil explained in para 4.3.1 revealed that the number of eggs laid was significantly lower at 2.0 Krad. in comparison with other treatments followed by 1.8 Krad.which was statistically superior to that at 1.5 Krad. and control. The treatments 1.8 Krad.,1.7 Krad.and 1.6 Krad.were found statistically on par. Also the number of eggs laid by the female mated with the males irradiated at 1.5 Krad. was statistically superior to the control. This showed that there was certain impact due to irradiation on the number of eggs laid. This result was in contrary to the report by Rahalkar *et al.* (1973). The percentage egg hatch had shown a decreasing trend on increasing radiation with highest percent of 85.48 for the control and a lowest of 1.25 percent for 2.0 Krad. Percent larval mortality was highest at 2.0 Krad. and also the number of adults emerged was nil at 2.0 Krad. Percentage mortality (Egg- Adult) was also highest at 2.0 Krad.,But the adult longevity decreased considerably from 1.6 Krad. onwards (Fig.14). The adult longevity at 1.5 Krad. was on par with the control (without any radiation). Considering all these facts 1.5 Krad. was considered to the ideal dose of irradiation for red palm weevil. This result was in conformity with the findings of Rahalkar *et al.* (1973).

5.3.2 Evaluation of Normal and Irradiated Male Insect of Red Palm Weevil on the Basis of Percentage Egg Hatch

The results of study on efficiency of irradiated male insects of red palm weevil by repeated mating was explained in para 4.3.2. The results denoted that when the males, irradiated at 1.5 Krad.,1.6 Krad. and 1.7 Krad. were mated with virgin females, the unaffected sperms were completely eliminated from the male reproductive system through mating

Fig.14. Effect of different doses of Co 60 radiation on the hatching of eggs and adult longevity of red palm weevil



with six females over a period of 12 days (Fig. 15). But for those irradiated at 1.8 Krad.the complete removal of viable sperms had occurred from fifth exposure (after fourth female level) and for those irradiated at 2.0 Krad. the complete excision of impervious sperms was obtained when they are treated with third female (After 6 days).This result is also in concurrence with the reports of Rahalkar *et al.* (1973).

The data from para 4.3.2.2 pointed out that as the male age progressed the proportion of sperm carrying dominant lethal genes may be increased and most likely after a period of 36 days all sperms were affected. The competitiveness of these sperms was investigated through different mating combinations of normal and irradiated males with virgin female. The results revealed that, when the normal male was exchanged by an irradiated one (at 1.5 Krad), the egg hatch reduced from 81.28 percent to 50.37 and in the reverse case it increased from 7.04 percent to 67.19 percent. When the females were deprived of their unirradiated male after a period of 36 days, there was no significant reduction in egg hatch, thus suggesting that the female was sufficiently inseminated during previous mating. Therefore, in a cross where normal male was substituted by an irradiated male, the observed decrease in egg viability is a clear indication of sperm transfer by the irradiated male. Similar results were obtained at 1.6, 1.7, 1.8 and 2.0 Krad.. These results were in agreement with the earlier reports of Rahalkar *et al.* (1973).

The results expounded in para 4.3.2.1 indicated that 73.11 percent of the eggs were viable when an irradiated male (At 1.5 Krad) was replaced by the normal one and the reversal of mating sequence resulted in 26.52 percent egg hatch. Moreover when a female paired with a normal male for four days and then continuously with irradiated male, the egg viability was only 12.25 percent. These results indicated that the females were inseminated at each mating and there was predominant utilization of sperm transferred during recent mating. The same results were obtained

when males irradiated at 1.6, 1.7, 1.8 and 2.0 Krad. were used for the same experiment. These results corroborate with the previous results obtained by Rahalkar *et al.* (1973). Since the sperm transferred during recent matings were predominantly utilized, an egg hatch of zero percent would be expected.

The results of the study of mating competition of irradiated males with normal males at different ratios were depicted in para 4.3.2.4. The results revealed that, by increasing the ratio of sterile to normal male the egg hatch was progressively reduced (Fig. 16). It was observed that, when one normal male was allowed to compete with nine or ten males irradiated at 1.5 Krad. for mating with virgin female, the hatching percentage of eggs was found to be statistically on par with that of one irradiated male alone crossed with virgin female. Hence it was confirmed that to nullify the effect of wild males in the field the irradiated males to be released in the field should be of ten fold than that of normal males so as to make appreciable suppression of progeny production. The same result was obtained when the males irradiated at 1.6, 1.7, 1.8 and 2.0 Krad. were used for competition study. These results are in conformity with the reports by Rahalkar *et al.* (1973).

The results of the present study revealed that the infestation of red palm weevil was highest in coastal areas than that in inland areas. The highest infestation was noticed during June and lowest during February months. Also the infestation was higher in palms below 7 years of age. The study on the effect of some plant products to contain red palm weevil showed that apple extract of *A. occidentale* 10% was the best among the different treatments tried caused highest mortality of red palm weevil. Also leaf extract of *T. neriifolia,* seed oil of *A. indica* and seed oil of *S. indica* had shown considerable repellency of red palm weevil grubs under laboratory conditions. In the case of sterile insect technique, gamma radiation at 1.5 Krad. was found to be the best treatment as it caused

Fig.15. Efficiency of irradiated male insects of red palm weevil by repeated mating before release in the field

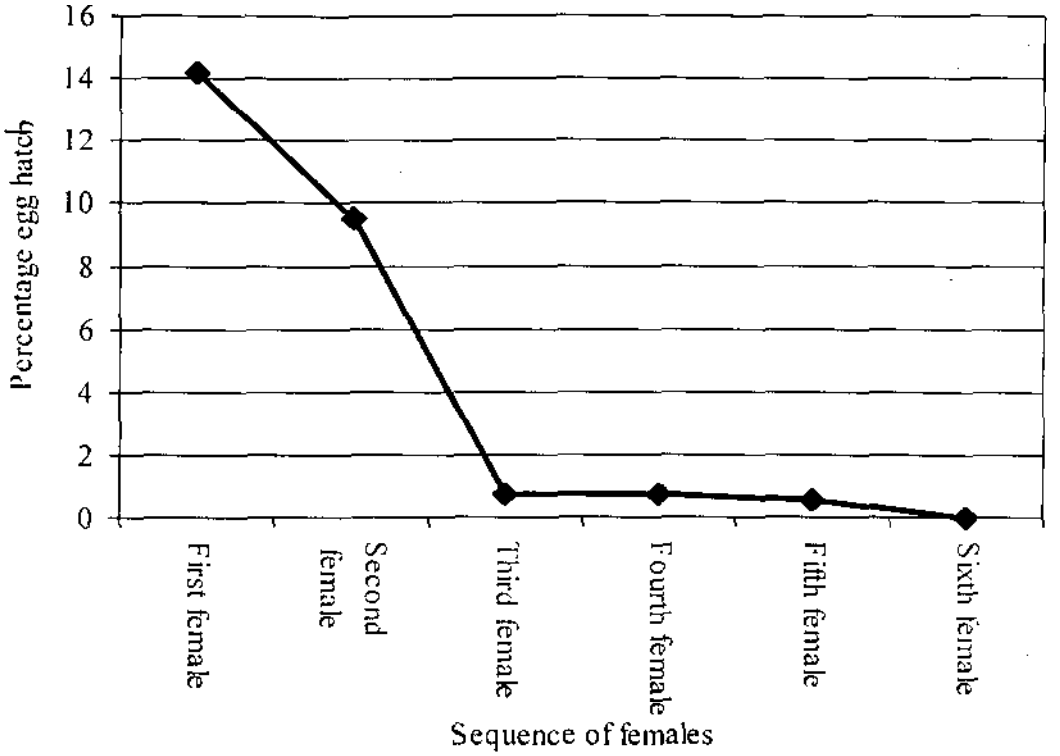
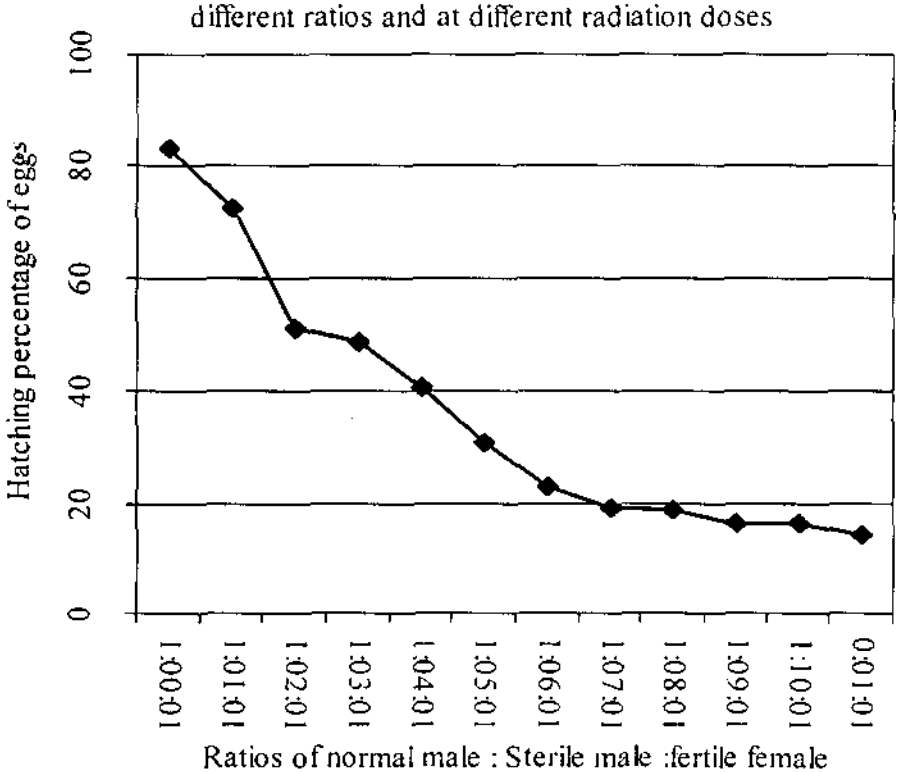


Fig.16. Mating competition of irradiated males with normal males at different ratios and at different radiation doses



highest sterility as well as higher longevity for the irradiated male insects. Hence further investigations have to be undertaken to confirm the effectiveness of the above mentioned plant products to contain red palm weevil under field conditions. Also field trials should be carried out to assess the effectiveness of sterile insect technique to manage red palm weevil so that it can be recommended as a safe component in integrated pest management strategies which is environmentally safe and sustainable.

SUMMARY

6. SUMMARY

The red palm weevil *Rhynchophorus ferrugineus* (Oliv.) is a serious threat to coconut cultivation all over the world wherever the crop is cultivated. This tissue borer is considered as the most serious pest of coconut in Kerala causing heavy damage more often leading to the annihilation of the palm in the prime of its youth. The increasing trend of cost of cultivation as well as cost of inputs and low availability of labour in the agriculture scenario of Kerala have necessitated search for newer techniques of pest management practices possessing desirable qualities and effective in field application. One such method is the sterile male technique for the control of red palm weevil which has already been evaluated for its effectiveness in the case of a number of pests of economic importance to man. with varying degrees of success. With these studies the effects of plants / plant products which are cheap and locally available showing insecticidal properties have to be identified and evaluated for the management of red palm weevil.

The survey conducted between June 2001- February 2002 showed that the infestation of red palm weevil was significantly higher during June in all the eight Krishibhavans surveyed, followed by that in September and least during February.

The infestation percentage of red palm weevil was higher significantly in Kadakkavur Krishibhavan area and was lower significantly in Thiruvallam Krishibhavan area. Also it could be observed that, of all the four surveyed taluks of Thiruvananthapuram district, the palms in Chirayinkil was most infested in all the seasons and that in Thiruvananthapuram taluk was least infested by red palm weevil. The infestation by red palm weevil was found to be significantly higher in low lands and was lower in upland. The attack by red palm weevil was found to be higher significantly in the variety Malayan yellow dwarf and the infestation level was least in WCT in all the three seasons. The infestation percentage was higher in young palms upto seven years old and was less in palms of more than 14 year old. The number of individuals of different stages of red palm weevil per

infested collapsed palm was found to be higher significantly in stem infestation type and was less in crown infestation and bole infestation. At yellowing of middle leaf stage of infestation, only early instars of red palm weevil were seen inside the infested palm. During stems with holes and oozing of fluids stage up to seventh instars were seen and at palm collapsing stage all the life stages of the weevils were present inside the collapsed palm. This reveals that the initial symptoms of red palm weevil attack was yellowing of middle leaf of the palm and the subsequent symptoms were stems with holes and oozing of fluids and at the final stage of attack the palm will collapse.

Of the various plant products tried on red palm weevil, apple extract of *Anacardium occidentale* 10% and apple extract of *Anacardium occidentale* 5% had shown significantly higher levels of mortalities of all the stages of red palm weevil and results were on par with the mortality rate caused by carbaryl 1%. Considerable repellent effect was seen only in the case of leaf extract of *Thevetia neriifolia* 10%, seed oil of *A. indica* 4%, leaf extract of *Thevetia nerifolia* 5%, seed oil of *A. indica* 2%, seed oil of *Samadera indica* 4% and seed oil of *Samadera oil* 2%. The study on comparative efficiency of apple extract of *Anacardium occidentale* and carbaryl shown that cashew apple extract 20 percent was the most economical and effective treatment in containing red palm weevil.

The effect of different doses of Co 60 gamma radiation on the development of different life stages of red palm weevil indicated that 1.5 Krad.was found to be the best treatment as it caused considerable sterility with highest adult longevity. The study on efficiency of irradiated male insect of red palm weevil by repeated mating denoted that when the males, irradiated at 1.5 Krad.were mated with virgin females, the unaffected sperms were completely eliminated from the male reproductive system through mating with six females over a period of 12 days. When the normal male was exchanged by an irradiated insect (1.5 Krad), the hatching percentage of eggs laid by already mated females reduced from 81.28 percent to 50.37 and in the reverse case it increased from 7.04 percent to 67.19 percent. Also the females were inseminated at each mating and there was

predominant utilization of sperm transferred during recent mating. The study of mating competition of irradiated males with normal males at different ratios revealed that, by increasing the ratio of sterile to normal male, the egg hatch was progressively reduced. It was observed that, when one normal male was allowed to compete with nine or ten males irradiated at 1.5 Krad.for mating with a virgin female, the hatching percentage of eggs was found to be statistically on par with that of one irradiated male alone crossed with a virgin female. Hence it was confirmed that to nullify the effect of wild males in the field the irradiated males to be released in the field should be of ten fold than that of normal males so as to make appreciable suppression of progeny production.

The results of the experiments revealed that, apple extract of *A. occidentale* can be utilized as a promising bio pesticide to contain the red palm weevil and also use of 1.5 Krad.gamma radiation from Co 60 is most efficient in sterilizing red palm weevil which can be utilized in the release of sterile insects in the SIT programme.

REFERENCES

7. REFERENCES

Abbot, W.S. 1925. A method for computing the effectiveness of an insecticide. *J. Econ. Ent.* 15: 265 - 267

Antonious, A.G. and Saito, T. 1981. Mode of action of antifeeding compounds in the larvae of the tobacco cutworm *Spodoptera litura* (F.) (Lepidoptera: Noctuidae). II. Sensory responses of the larval chemoreceptors to chlordimeform and clerodin. *Appl. Ent. Zool.* 18: 40

Ascher, K.R.S. 1980. Some physical solubility properties and biological sterilant for *Epilachna varivestis* females effects of a dried methanolic neem seed extract. *Proceedings of First International Neem Conference, Rottachegrern, June 16-18, 1980* (eds. Schmutterer, H, Ascher, K.R.S and Rembold, H). GTZ, Eschborn, pp. 63-64

Bai, H. 1996. Isolation of the bioactive principle of *Thevetia neriifolia* Juss. (Apocyanaceae) and determination of their biological activities. Ph.D thesis, Kerala Agricultural University, Thrissur, p.142

Baloch, H.B., Rustamani, M.A and Khuro, R.D. 1995. Incidence and abundance of date palm weevil in different cultivars of date palm. *Proceedings of Pakistan Congress of Zoology, Islamabad, June 25-30, 1995* (eds. Talpur, M.A., Hussain, T., Ahmad, M. and Shakoori, A. R.). National Publishing Com., Islamabad, pp. 445-447

*Banks, C.S. 1906. The principal insects attacking the coconut palm, *Philipp. J. Sci.* 1: 143-167

*Barranco, P., Pena. J. de. La., Martin, M.M., Cabello, T. and de. La. Pena, J. 1998. Efficiency of chemical control of new palm pest *Rhynchophorus ferrugineus* (Oliv.) (Coleoptera: Curculionidae). *Boletin. de. Sanidad. Vegetal, Plagas* (Spanish). 24:301-306

*Beek Van, T.A. and de Groot, A.C. 1986. Terpenoid antifeedants Part I. An overview of terpenoid antifeedants of natural origin. *Recucilades Travaux Chimiques-des-Bas* (Spanish). 105 : 573-527

Blair, G. 1970a. Studies on red ring diseases of the coconut palm. *Oleagineux* (French) 25: 19-22

Blair, G. 1970b. Studies on red ring diseases of the coconut palm. *Oleagineux* (French) 25: 79-83

Brand, E. 1917. Coconut red weevil, Some facts and fallacies. *Trop. Agric.* 49: 22-24

Buxton, P.A. 1920. Insect pests of dates and date palm in Mesopotamia and elsewhere. *Bull. ent. Res.* 11: 287-303

*Cendana, S.M. 1963. The roles played by rhinoceros beetle and red palm weevil in the death of coconut trees in relation to the control of coconut beetles. *Proceedings of the Symposium on Cadang- Cadang Coconut, September3-5, 1962* (edr. Cendana, S.M), Philippino Book House, Manila, pp. 68-70

Chakravarthy, D.P., Gosh, O.C. and Dhura, S.P. 1970. Repellent properties of thionemone (Neem seed extract) on the red pumpkin beetle (*Aulacophora foveicollis* Lucas). *Chem. Abstr.* 72: 42-82

Chandrikamohan. and Nair, C.P.R. 1996. *Studies on the effect of natural plant products and synthetic insect growth regulators on key pests of the coconut palm.* Annual Report 1995-1996, Central Plantation Crops Research Institute, Kasaragod, P. 102

Chandrikamohan. and Nair, C.P.R. 2000. Effect of *Clerodendrum infortunatum* on grubs of coconut rhinoceros beetle *Oryctes rhinoceros* L. *Recent Advances in Plantation Crops Research* (eds. Muraleedharan, N. and Rajkumar, R). Proceedings of PLACROSYM XII, Dec. 16-18, 1998. Allied publishers limited, Chennai, pp. 97-102

Chandrikamohan., Nair, C.P.R. and Rajan, P. 2001. Scope of botanical pesticides in the management of *Oryctes Rhinoceros* L. and *Rhynchophorus ferrugineus* Oliv. affecting coconut palm. *Entomon (Spl. Issue)* 26: 47-51

Chinchilla, C.M. 1988. *The red ring little leaf syndrome in oil palm and coconut*. Technical Bulletin No. 1. Agricultural Services Department, San Jose, Costa Rica, p.1000

Cobb, N.A. 1922. A note on coconut nematode of Panama. *J. Parasitol.* 9: 44-45

Cooper, R., Solomon, P.H., Kubo, I.; Nakanishi, K., Shoolery, J.N. and Occolunitz, J.L. 1980. Myrcoside, an African army worm antifeedant – seperation by droplet counter current chromatography. *J. Am. chem. Soc.* 102: 7953

Copeland, E.B. 1931. *The coconut*. Macmillan and Co. Ltd, London, p. 363

Corbett, G.H. 1932. *Insects of coconut in Malaya*. Technical Bulletin No.10. Malayan States Federated Department of Agriculture Services, P.106

Cox, M.I. 1993. *Red palm weevil, Rhynchophorus ferrugineus in Egypt*. Plant protection Bulletin No.41, Food and Agricultural Organization, Rome, p.31

CPCRI. 1998. *Annual Report*, Central Plantation Crops Research Institute, Kasaragod, p.123

Davich, T.B. 1969. *Control of cotton boll weevil Anthonomus grandis F. using sterile insect technique*. Technical Bulletin No. 13, International Atomic Energy Agency, Vienna, p. 224

Deshmukh, S.D. and Borle, M.N. 1975. Studies on the insecticidal properties of indigenous plant products. *Indian J. Ent.* 37: 11-18

Dharmasena, C.M.D., Blaney, W.M and Simmonds, M.S.J. 2001. Effect of storage on the efficacy of powdered leaves of *Annona squamosa* for the control of *Callosobruchus maculates* F. on cowpeas (*Vigna unghiculata* L). *Phytoparasitica*. 29: 191-196

Dwivedi, S.C and Amitakumari. 2000. Investigations of five plants for ovicidal effect against the pulse beetle, *Callosobruchus chinensis* L. *Pestology*. 24: 19-22

El Ghar, G.E.S.A. and El Sheikh, A.E. 1987. Effectiveness of some plant extracts as surface protectants of cowpea seeds against the pulse beetle (*Callosobruchus chinensis* F.). *Phytoparasitica*. 15: 109-113

Fletcher, T.B. 1914. *Some South Indian Insects*. Government Press, Madras, p.202

Fried, M. 1971. Determination of sterile insect competitiveness. *J. Econ. Ent*. 64: 869

Ganapathy, T., Rajamanickam, K., Raveendran, T.S., Lourduraj, A.C. and Kennedy, F.J.S. 1992. Status of coconut cultivation in Pollachi tract. II Prevalence of pests and diseases. *Indian Cocon. J.* 23: 4-6

Gattefosse, M.J. 1949. *A novel insecticide in agriculture from (Thevetia neriifolia Juss.)*. Bulletin No.4. Society of Science and Nature, Morocco, p.22

George, T.G. 1977. A study of the knowledge and attitude of farmers towards selected pest control measures for coconut. *Agric. research J. of Kerala*. 15: 133-136

Ghosh, C.C. 1911. Life history of Indian insects. 3. The rhinoceros beetle (*Oryctes rhinoceros*) and the red palm weevil *Rhynchophorus ferrugineus*. *Mem. Dep. Agric. Indian Ent. Ser*. 2: 193-204

Goonewardena, H.F. and Velu, M.S. 1958. The red palm weevil *Rhynchophorus ferrugineus* Oliv. in Ceylon. 1. Introduction, distribution and life history. *Ceylon Cocon. J.* 9: 20

Green, E.E. 1906. *Rhynchophorus ferrugineus* (Oliv). *Trop. Agriculturist*. 27: 18-22

Griffith, R. 1967. Progress on the Entomological aspects of red ring disease of coconuts. *J. agric. Soc. Trin. Tob*. 67:209-218

Griffith, R. 1968. The mechanism of transmission of the red ring nematode. *J. agric. Soc. Trin. Tob*. 68: 437-457

Griffith, R. 1987. Red ring diseases of coconut palm. *Pl. Dis*. 71: 193-196

Hagley, E.A.C. 1963. The role of palm weevil *Rhynchophorus palmarum* as a vector of red ring disease of coconuts. I. Results of the preliminary investigations. *J. Econ. Ent*. 56: 375-380

Harwalkar, M.R. and Rahalkar, G.W. 1973. Sperm utilization in the female red cotton bug. *J. Econ. Ent.* 66: 805-806

Henry, G.M. 1911. The coconut red weevil, *Rhynchophorus ferrugineus*. *Trop. Agric. Peradeniya.* 48: 218-219

Horber, E. 1963. *Control and eradication of the cockchafer (Melolonthus vulgaris F) by sterile insect technique.* Technical Bulletin No.74. International Atomic Energy Agency ,Vienna, p.331

Hudson, J. C. 1933. *The red weevil of coconut. Leaflet No.* 22, Department of Agriculture, Ceylon, p.2

Indoo Mc, N.B. 1945. *Plants of possible insecticidal value, a review of literature upto 1941.* USDA Bureau of Entomology and Plant quarantine, E 661, Washington DC, p.286

Islam, B.N. 1993. Evaluation of indigenous pest control agents from Meliaceae and Annonaceae – An approach to pest management strategy in Bangladesh. World Neem Conference, Feb 24 – 28, 1993. Bangalore, India. Abstract: 12

Jacobson, M. 1958. *Insecticides from plants, a review of literature 1942-1953.* USDA Hand book, Washington DC. P.121

Jacobson, M., Stokes, J.B., Warthen, J.D., Reffern, K.E. Reed, D.K. and Webb. R.E. 1983. Neem research in the United States Department of Agriculture-an update. *Neem Newsletter*, 1983. pp. 44-48

Janardhanan, R.S., Chitra, K.C., Kameswara Rao, P. and Subramanyam Reddy, K. 1992. Antifeedant and insecticidal properties of certain plant extracts against brinjal spotted leaf beetle, *Henosepilachna vigintioctopunctata* F. *J. Insect Sci.* 5: 163-164

Kardinam, A. and Wikardi, E.A. 1997. The prospect of botanical insecticides on stored food insects management. *BIOTROP special publication,* pp. 59: 199-208

Karmarkar, M.S. and Bhole, S.R. 2000. Efficiency and persistent toxicity of some neem products against adults of *Epilachna dodecastigma* Weidemann. *Pl. protection Bull. (Faridabad).* 52: 22-25

KAU, 1993. *Annual report.* Kerala Agricultural University, Directorate of Research, Vellanikkara, Thrissur, Kerala, India, p.31

Kirthisinghe, J.K.F. 1966. Pest control in coconut cultivation. *Ceylon Cocon.* 4: 34-38

Knipling, E.F. 1955. Sterile Insect Technique, a way to eradicate cattle screw worm (*Cchliomya hominivorax* L). *J. Econ. Ent.* 48: 459

Kolkar, H.M., Mendki, P.S., Sadan, S.V.G.S., Jha, S.R., Upasoni, S.M. and Maheswari, V.L. 2002. Antimicrobial and pesticidal activity of partially purified flavanoids of *Annona squamosa. Pest Mgmt. Sci.* 58: 33-37

Kraus, W., Cramer, R. and Saivitzki, G. 1980. New tetranotri-terpenoids from seeds of *Azadirachta indica* (Neem tree). *Phytochemistry.* 19: 117-120

Kunjanpillai, N. 1919. Coconut: The wealth of Travancore. *Agric. J. India* 15: 608-628

Kurian, C. and Mathen. 1971. Red palm weevil- Hidden enemy of coconut palm. *Indian Fmg.* 21: 29-31

La Chance, L. E. 1967. Genetics of Insect Vectors of Diseases. *Insect Vectors* (eds. Wright, J. W. and Pal, R.). Elsevier, Amsterdam, pp.617-650

Ladd, T.L. Jr. 1980. Neem seed extracts as feeding deterrents for the Japanese beetle (*Popillia Japonica* F.). *Proceedings of First International Neem Conference, Rottachegrern, June 16-18, 1980* (eds. Schmutterer, H, Ascher, K.R.S and Rembold, H). GTZ, Eschborn, pp 149-156

Lefroy, H.M. 1906. *The more important insects injurious to Indian Agriculture.* Government Press. Calcutta, p.301

Lever, R.J.A.W. 1969. *Pests of coconut palm.* Plant Production and Protection Series No. 18, Food and Agricultural Organisation, Rome, p. 190

Lily, B. 1995. Effects of extracts of *Clerodendrum infortunatum* L. on the Epilachna beetle, *Henosepilachna vigintioctopunctata* F. with relation to safety to its natural enemies. M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.103

Mackenna, J. 1919. *Report on the Progress of Agriculture in India for 1916-1917.* Government Press, Calcutta, p.84

Maheswaran, P. and Ganesalingam, V. K. 1988. Effect of volatile substances from *Azadirachta indica* seeds on the reproductive biology of *Tribolium castaneum* (Coleoptera: Tenebrionidae). *Vignanam J. Sci.* 3: 20-26

Martyn, E.B. 1953. Red ring disease of coconut in Trinidad and Tobago. *Trop. Agric.* (Trinidad) 30 : 43-53

Mazumdar, N. 1995. Reaction of coconut cultivars and hybrids to the incidence of different pests and diseases. *Hort. J.* 8: 147-149

Menon, K.P.V. and Pandalai, K.M. 1958. *The Coconut Palm – a monograph.* Indian Central Coconut Committee, Ernakulam, p.384

Misra, H.P. 2000. Effectiveness of indigenous plant products against the pulse beetle, *Callosobruchus chinensis* F. on stored black gram. *Indian J. Ent.* 62: 218-220

Murthy, N.B.K and Amonkar, S.V. 1974. Effect of a natural insecticide from garlic (*Allium sativum* L.) and its synthetic from (Diallyl-disulphide) on plant pathogenic fungi. *Indian J. of Exp. Biol.* 12: 208-209

Nagayama, L. and Nagasawa, S. 1966. Radio active chemicals in sterilizing the red palm weevil, *Rhynchophorus ferrugineus* (Oliv). *Japan J. Appl. Ent. Zool.* 10: 192

Nair, M.R.G.K. 1978. *A Monograph on Crop Pest of Kerala and its Control.* Kerala Agricultural University, Thrissur, p. 189

Naqvi, S.N.H., Rahila Tabassum., Azmi, M.A., Imtiaz Ahmad. and Yasmeen Hidaya. 1998. Activity of chlorinesterase in a lady bird beetle, *Coccinella* spp. after treatment of neem extract (RB-b) and Bakayan berries (BB). *J. Exp. Biol.* 1: 91-94

Nirula, K.K. 1956. Investigations on the pests of coconut palm, Part IV. *Rhynchophorus ferrugineus. Indian Cocon. J.* 9: 229-247

Nirula, K.K., Antony, J. and Menon, K.P.V. 1953. The red palm weevil and its control. *Proceedings of 40th Session of Indian Science Congress, December 13-16, 1952*, Thiruvananthapuram, pp. 147-148

Noordink, J. Ph. W. 1971. *Sterile insect technique on onion fly (Hyemya antique)* Publication No. 265, International Atomic Energy Agency, Vienna, p. 328

Oehlschlager, A.C. 1993. *Rhynchophorus ferrugineus* as a pest of date palm in the Middle East. *Current and future strategies for management of weevil*

populations (edr *Al Ain*). Expert consultation on date palm pest problems and their control in the near East, 22-26 April, 1992. Food and Agricultural Organisation regional office for near East, Cairo, Egypt, pp.1-29

Oshawa, K., Kato, S., Honda, H. and Yamamoto, I. 1990. Pesticidal active substances in tropical plants – insecticidal substances from the seeds of Annonaceae. *J. agric. Sci.* 34: 253-258

Pacumbaba, E.P. 1972. Biology of *Rhynchophorus schah* (Oliv.). Proceedings of third Annual Conference of Crop Science Society, March 21-27, 1971, Manila, Philippines, pp. 73-75

Paul, W.R.C. 1929. The control of red palm weevil (*Rhynchophorus ferrugineus* F.) in coconut palms. *Trop. Agric.* 73: 131-135

Proverbs, M.D. and Newton, J.R. 1969. Some effects of Gamma radiation on the reproductive potential of the codling moth, *Carpocapsa pomonella* L. *Entomon.* 94: 1162

Rahalkar, G.W., Harwalkar, M.R., Rananavare, H.D., Shantaram, K and Gopal Ayengar, A.R. 1973. Laboratory studies on radiation sterilization of red palm weevil (*Rhynchophorus ferrugineus* Oliv.) males. *J. Plant. Crops* 1:141-146

Rahalkar, G.W., Shantaram, K., Harwalkar, M.R. and Rananavare, H.D. 1982. *Mating competitiveness and effective life of the radiation sterilized male red palm weevil, Rhynchophorus ferrugineus Oliv.* Reprint from Sterile Insect Technique and Radiation in Insect Control, International Atomic Energy Agency, Vienna, pp. 105-106

*Rajamanickam, K., Kennedy, J.S. and Christopher, A. 1995. Certain components of integrated management for red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Curculionidae: Coleoptera) on coconut. Mededelingen-Faculteit Landbouwkundige en Toegepaste Biologische Wetenschappen, *Universiteit Gent* (German) 60: 803-805

Rajamma, P. 1986. Effect of some organic materials on the control of sweet potato weevil (*Cylas formicarius* F.). *J. Root. Crops* 8: 64-65

Rajan, P. and Nair, C.P.R. 1997. Red palm weevil- the tissue borer of coconut palm. *Indian Cocon. J.* 27: 2-3

Rananaware, H.D., Shantaram, K., Harwalkar, M.R. and Rahalkar, G.W. 1975. Method of laboratory rearing of red palm weevil. *J. plantation Crops* 3: 65-67

Rao, S.J., Chitra, K.C., Rao, P.K. and Reddy, K.S. 1992. Properties of certain plant extracts against brinjal spotted leaf beetle *Henosepilachna vigintioctopunctata* F. *J. Insect Sci.* 5: 163-164

Rao, S.M. and Chitra, K.C. 1990. Antifeedant properties of certain plant extracts against second stage larvae of *Henosepilachna vigintioctopunctata* F. *Indian J. Ent.* 52: 681-685

Reddy Venkatarami, P., Chitra, K.C. and Kameswara Rao, P. 1990. Field evaluation of certain plant extracts for the control of brinjal spotted leaf beetle, *Henosepilachna vigintioctopunctata* F. *J. Insect Sci.* 3: 194-195

Reed, D.K., Freedman, B. and Ladd, T.L. Jr. 1982. Insecticidal and antifeedant activity of neriifolin against codling moth, striped cucumber beetle and Japanese beetle. *J. Econ. Ent.* 75: 1093-1097

Rembold, H., Sharma, G.K. and Czoppelt, Ch. 1981. Growth regulating activity of Azadirachtin in two holometabolous insects. *Proceedings of First International Neem Conference, Rottachegrern, June 16-18, 1980* (eds. Schmutterer, H, Ascher, K.R.S and Rembold, H). GTZ, Eschborn, pp. 121-128

Salgado, M.L.M. 1952. Note on the breeding of red weevil in crown of palms recently felled. *Ceylon Cocon. J.* 3: 12-13

Santhoshbabu, P.B., Madhusudhana Rao, J., Joy, B. and Sumathykutty, M. A. 1996. Evaluation of some plant products as feeding deterrents against adult *Longitarsus nigripennis* Mots. (Coleoptera: Chrysomelidae). *Entomon.* 21: 291-294

Saradamma, K. 1989. Biological activity of different plant extracts with particular reference to their insecticidal, hormonal and antifeeding actions. Ph.D. thesis, Kerala Agricultural University, Thrissur

Schuiling, M. and Van Dinther, J.M.B. 1981. Redring disease in the Parlcatuba oil palm estate, Para, Brazil. *Z. agric. Ent.* 91: 154-169

Shantappa, P.B., Viswanath, B.A. and Sullamath, V.V. 1979. *Rhynchophorus ferrugineus* from the inland planations of Karnataka. *Curr. Res.* 8: 32

Siddigi, S.A. 1981. Efficacy and persistence of powdered neem seeds for treatment of stored wheat against *Trogoderma granarium Proceedings of First International Neem Conference, Rottachegrern, June 16-18, 1980* (eds. Schmutterer, H, Ascher, K.R.S and Rembold, H). GTZ, Eschborn, pp.251-257

Singh, B.P. and Singh, S. 1985. Evaluation of dried neem (*Azadirachta indica* Juss.) seed kernel against (*Trogoderma granaium* Everts.). *Curr. Sci.* 54: 950-951

Sivapragasam,A., Arikiah,A. and Renjith, C. A. 1990. The red stripe weevil, *Rhynchophorus schach* Oliv. (Coleoptera: Curculionidae), an increasing menace to coconut palms palms in Hilir Perak. *Planter*: 113-123

Speilman, Sr, A., Leahy, M.G. and Skaff, V. 1967. Seminal loss in repeatedly mated female *Aedes aegypti. Biol. Bull.* 132:404-412

Stebbing, E.P. 1903. *Departmental notes on insects that affect forestry*. Govt. Press, Calcutta. P.79

Steiner, L.F., Mitchell, W.C. and Baumhover, A. H. 1962. Sterilization for the management of Fruit fly, *Daccus dorsalis* F. *Int. J. appl. Radiat.* 13: 427-434

Takenouchi, Y. 1965. Chromosome survey in thirty four species of bisexual and parthenogenic weevils in Canada. *Can. J. Genet. Cytol.* 7: 663-687

Thampan, P.K. 1993. *Hand book on coconut palm*. Third edition, Oxford and IBH publishing Co. Pvt. Ltd. P. 207-209

Ticheler, J. 1971. A new mass rearing technique for onion fly (*Hyemya antiqueF.*) Publications No. 265, International Atomic Energy Agency, Vienna, p.67

Tidman, D.A. 1951. Agricultural and horticultural problems of Brazil. *Wld. Crops* 3: 341-344

Vestal, E.F. 1956. Control of coconut beetles and weevils in Thailand. *FAO Plant Prot. Bull.* 5: 37-44

Viado, G.B.S. and Bigornia, A.E. 1949. A biological study of the Asiatic palm weevil *Rhynchophorus ferrugineus* Oliv. (Curculionidae: Coleoptera). *Philipp. Agric.* 33: 1-27

Vidyasagar, P.S.P.V. and Kesavabhat, S. 1991. Pest management in coconut gardens. *J. Plantation Crops.* 19:163-182

Vidyasagar, P.S.P.V., Ali, A, Al Saihati., Omer E. Al Mohanna., Ali. I. Subbei. and Abdul Mohsin, A.M. 2000. Management of red palm weevil *Rhynchophorus ferrugineus* Oliv. a serious pest of date palm in Al Qatif, Kingdom of Saudi Arabia. *J. Plantation Crops.* 28:35-43

Von Bosstel, R.C. 1960. Population control by release of irradiated males. *Science.* 131. P. 878-880

Wattanapongsiri, A. 1966. *A revision of the genera Rhynchophorus and dynamics (Coleoptera: Curculionidae).* Technical Bulletin No. 1, Department of Agricultural Science, Bangkok, p.328

---

*Original not seen

APPENDICES

APPENDIX – I

PROFORMA

RED PALM WEEVIL INCIDENCE IN THIRUVANANTHAPURAM DISTRICT OF KERALA

1. Name of Taluk :
   Krishi Bhavan :
2. Name and address of farmer :
   Educational status :
3. Details of land
   Total area owned :
   Area under coconut :
   Pure or mixed plantation :
   Total number of palms :
   Other crops cultivated :
4. Nature of land : Upland Plain Low
   Area :
   Soil type :
   Total number of trees :
   No. of trees infested and destroyed :
   No. of trees infested :
   Approx. age of infested tree :
5. Cultivation practices :
   (Last five years)
   Intercultivation : Yearly/Biyearly/Not done
   Organic fertilizers (per tree) :
   Inorganic fertilizers (per tree) :
   Plant protection measures :
   (Present practices)
   Intercultivation : Yearly/Biyearly/Not done
   Organic fertilizers (per tree) :
   Inorganic fertilizers (per tree) :
   Plant protection measures :
6. Details of infestation already occurred
   When detected :
   How detected :
   Stage of insect inside :
   PP measures adopted :
   No. of trees saved :
   No. of trees destroyed :

7. Infestation and yield loss by other pests (put tick mark)
   : Mite
   : Rhinoceros beetle
   : Black headed caterpillar
   : Coreid bug

8. Have you received any information on the control aspect of these pest earlier : Yes / No
   If yes
   From whom
   What was the message :

9. Do you think that complete destruction of the different stages of insect in the infested trees is required to avoid further spread : Yes / No
   Reason :

10. Mention the control measures adopted :

11. Prophylactic application of chemicals practiced : Yes / No

12. Have you ever heard of Pheromone trap :
   If yes
   From where :
   Give details :

13. Have you ever heard of sterile male techniques : Yes / No
   If yes
   Details of their awareness :
   Their opinion :

14. Any other information on coconut and pest problem :

15. Destructive sampling

Variety of coconut	No. of palms	No. of larvae						No. of pupae	No. of adult
		I	II	III	IV	V	VI		

16. IPM measures undertaken :

17. Yield :

18. Others if any :

Signature

APPENDIX – II

Major findings of the survey of red palm weevil infestation in Thiruvananthapuram district

Details	Kadakkavur		Varkkala		Thiruvallam		Kalliyoor	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Educational status of farmers								
Only read and write	0	0	0	0	0	0	1	6.67
Lower primary	0	0	0	0	0	0	2	13.33
Upper primary	6	40	6	40	7	46.67	5	33.33
High school	5	33.33	4	26.67	5	33.33	6	40
Collegial education	4	26.67	5	33.33	3	20	1	6.67
Total	15	100.00	15	100.00	15	100.00	15	100.00
Plantation type								
Pure	8	53.33	12	80	6	40	9	60
mixed	7	46.67	3	20	9	60	6	40
Total	15	100.00	15	100.00	15	100.00	15	100.00
Other crops cultivated								
No other crops	8	53.33	12	80	2	13.33	9	60
Banana	1	6.67	0	0	10	66.67	2	13.33
Spices	6	40	3	20	3	20	4	26.67
Common perennial crops	0	0	0	0	0	0	0	0
Medicinal plants	0	0	0	0	0	0	0	0
Tapioca	0	0	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00
Nature of land								
Low land	7	46.67	7	46.67	7	46.67	10	66.67
Plain land	6	40	5	33.33	6	40	4	26.67
Upland	2	13.33	3	20	2	13.33	1	6.67
Total	15	100.00	15	100.00	15	100.00	15	100.00

APPENDIX – II Continued

Details	Kadakkavur		Varkkala		Thiruvallam		Kalliyoor	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Approximate age of the infested tree								
Up to 7 years	12	80	12	80	12	80	12	80
7-14 years	3	20	3	20	3	20	3	20
>14 years	0	0	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00
Intercultivation								
Not done	1	6.67	3	20	0	0	1	6.67
Bi yearly	0	0	0	0	0	0	0	0
Yearly	14	93.33	12	80	15	100	14	93.33
Total	15	100.00	15	100.00	15	100.00	15	100.00
Application of manures								
Organic	6	40	8	53.33	4	26.67	5	33.33
Inorganic	0	0	0	0	0	0	0	0
Organic + Inorganic	7	46.67	3	20	8	53.33	3	20
No manures	2	13.33	4	26.67	2	13.33	7	46.67
Total	15	100.00	15	100.00	15	100.00	15	100.00
Time of first detection of the pest								
Years back and still continuing	15	100	15	100	15	100	15	100
Recently	0	0	0	0	0	0	0	0
This year	0	0	0	0	0	0	0	0
Not infested	0	0	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00

APPENDIX – II Continued

Details	Kadakkavur		Varkkala		Thiruvallam		Kalliyoor	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Method adopted on *infestation detection*								
By visualising the symptoms	2	13.33	2	13.33	0	0	2	13.33
Collapsing of the tree	13	86.67	13	86.67	15	100	13	86.67
Not applicable	0	0	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00
***Stage of insect inside the* infested tree as noticed by the farmer**								
Grub	6	40	10	66.67	11	73.33	7	46.67
adult	0	0	0	0	0	0	0	0
Pupae	2	13.33	2	13.33	2	13.33	5	33.33
Grub + Pupae	6	40	3	20	2	13.33	2	13.33
All stages	1	6.67	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00
Presence of other pests								
Mite								
Not present	0	0	0	0	0	0	0	0
Present	15	100	15	100	15	100	15	100
Total	15	100.00	15	100.00	15	100.00	15	100.00
Rhinocerous beetle								
Not present	0	0	0	0	0	0	0	0
Present	15	100	15	100	15	100	15	100
Total	15	100.00	15	100.00	15	100.00	15	100.00

APPENDIX – II Continued

Details	Kadakkavur		Varkkala		Thiruvallam		Kalliyoor	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Coreid bug								
Not present	0	0	9	60	7	46.67	4	26.67
Present	15	100	6	40	8	53.33	11	73.33
Total	15	100.00	15	100.00	15	100.00	15	100.00
Black headed caterpillar								
Not present	10	66.67	10	66.67	13	86.67	12	80
Present	5	33.33	5	33.33	2	13.33	3	20
Total	15	100.00	15	100.00	15	100.00	15	100.00
Control measures adopted								
No measures adopted	11	73.33	6	40	13	86.67	11	73.33
Cultural	2	13.33	7	46.67	2	13.33	2	13.33
Mechanical	1	6.67	0	0	0	0	1	6.67
Chemical	1	6.67	2	13.33	0	0	1	6.67
Total	15	100.00	15	100.00	15	100.00	15	100.00
Knowledge about pheromone trap								
Not known	15	100	15	100	9	60	6	40
Known	0	0	0	0	6	40	9	60
Total	15	100.00	15	100.00	15	100.00	15	100.00
Knowledge about SIT								
Not known	15	100	15	100	15	100	15	100
Known	0	0	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00

APPENDIX – II Continued

Details	Kottukal		Vizhinjam		Vidhura		Karakulam	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Educational status of farmers								
Only read and write	3	20	0	0	0	0	0	0
Lower primary	3	20	8	53.33	4	26.67	3	20
Upper primary	2	13.33	1	6.67	5	33.33	3	20
High school	7	46.67	4	26.67	4	26.67	7	46.67
Collegial education	0	0	2	0	2	13.33	2	13.33
Total	15	100.00	15	100.00	15	100.00	15	100.00
Plantation type								
Pure	6	40	11	73.33	1	6.67	6	40
Mixed	9	60	4	26.67	14	93.33	9	60
Total	15	100.00	15	100.00	15	100.00	15	100.00
Other crops cultivated								
No other crops	6	40	11	73.33	1	6.67	6	40
Banana	6	40	3	20	8	53.33	5	33.33
Spices	0	0	0	0	2	13.33	2	13.33
Common perennial crops	1	6.67	0	0	0	0	0	0
Medicinal plants	0	0	0	0	0	0	0	0
Tapioca	2	13.33	1	6.67	4	26.67	2	13.33
Total	15	100.00	15	100.00	15	100.00	15	100.00
Nature of land								
Low land	7	46.67	4	26.67	5	33.33	8	53.33
Plain land	5	33.33	9	60	6	40	7	46.67
Upland	3	20	2	13.33	4	26.67	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00

APPENDIX – II Continued

Details	Kottukal		Vizhinjam		Vidhura		Karakulam	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Approximate age of the infested tree								
Up to 7 years	11	73.33	10	66.67	5	33.33	10	66.67
7-14 years	4	26.67	5	33.33	7	46.67	3	20
>14 years	0	0	0	0	3	20	2	13.33
Total	15	100.00	15	100.00	15	100.00	15	100.00
Intercultivation								
Not done	3	20	3	20	12	80	0	0
Bi yearly	0	0	0	0	1	6.67	0	0
Yearly	12	80	12	80	3	20	15	100
Total	15	100.00	15	100.00	15	100.00	15	100.00
Application of manures								
Organic	8	53.33	8	53.33	5	33.33	4	26.67
Inorganic	0	0	0	0	0	0	0	0
Organic + Inorganic	5	33.33	0	0	4	26.67	6	40
No manures	2	13.33	7	46.67	5	33.33	5	33.33
Total	15	100.00	15	100.00	15	100.00	15	100.00
Time of first detection of the pest								
Years back and still continuing	8	53.33	9	60	7	46.67	5	33.33
Recently	7	46.67	6	40	7	46.67	5	33.33
This year	0	0	0	0	1	6.67	5	33.33
Not infested	0	0	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00

APPENDIX – II Continued

Details	Kottukal		Vizhinjam		Vidhura		Karakulam	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Method adopted on infestation detection								
By visualising the symptoms	4	26.67	2	13.33	3	20	2	13.33
Collapsing of the tree	11	73.33	13	86.67	12	80	13	86.67
Not applicable	0	0	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00
Stage of insect inside the infested tree as noticed by the farmer								
Grub	8	53.33	6	40	7	46.67	5	33.33
adult	3	20	4	26.67	4	26.67	5	33.33
Pupae	1	6.67	2	13.33	1	6.67	3	20
Grub + Pupae	2	13.33	2	13.33	2	13.33	1	6.67
All stages	1	6.67	1	6.67	1	6.67	1	6.67
Total	15	100.00	15	100.00	15	100.00	15	100.00
Presence of other pests								
Mite								
Not present	0	0	0	0	3	20	0	0
Present	15	100	15	100	12	80	15	100
Total	15	100.00	15	100.00	15	100.00	15	100.00
Rhinocerous beetle								
Not present	0	0	0	0	0	0	0	0
Present	15	100	15	100	15	100	15	100
Total	15	100.00	15	100.00	15	100.00	15	100.00

APPENDIX – II Continued

Details	Kottukal		Vizhinjam		Vidhura		Karakulam	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Coreid bug								
Not present	7	46.67	8	53.33	6	40	7	46.67
Present	8	53.33	7	46.67	9	60	8	53.33
Total	15	100.00	15	100.00	15	100.00	15	100.00
Black headed caterpillar								
Not present	11	73.33	11	73.33	12	80	11	73.33
Present	4	26.67	4	26.67	3	20	4	26.67
Total	15	100.00	15	100.00	15	100.00	15	100.00
Control measures adopted								
No measures adopted	8	53.33	13	86.67	7	46.67	9	60
Cultural	5	33.33	0	0	4	26.67	5	33.33
Mechanical	0	0	0	0	0	0	1	6.67
Chemical	2	13.33	2	13.33	4	26.67	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00
Knowledge about pheromone trap								
Not known	15	100	9	60	15	100	15	100
Known	0	0	6	40	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00
Knowledge about SIT								
Not known	15	100	15	100	15	100	15	100
Known	0	0	0	0	0	0	0	0
Total	15	100.00	15	100.00	15	100.00	15	100.00

EFFECT OF PLANT PRODUCTS AND STERILE INSECT TECHNIQUE IN THE MANAGEMENT OF RED PALM WEEVIL (*Rhynchophorus ferrugineus* Oliv.)

MAHESWARI, P.

Abstract of the
thesis submitted in partial fulfilment of the requirement
for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2003

Department of Agricultural Entomology
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695522

8. ABSTRACT

An experiment was conducted in the Department of Entomology, College of Agriculture, Vellayani to find the effectiveness of plant products and sterile insect technique to contain red palm weevil in coconut. As a part of the experiment, survey was conducted in the red palm weevil infested tracts of Thiruvananthapuram district between June 2001- February 2002 to find out the extent of damage caused by red palm weevil.

The data collected during the survey revealed that, the infestation of red palm weevil was highest in coastal area than that in inland areas. The percentage infestation was higher during June and less during February months. Also the infestation was higher in palms upto 7 years old.

The results on the study of the effect of plant products to contain red palm weevil showed that apple extract of *Anacardium occidentale* 10% was the best treatment which caused highest mortality of red palm weevil. Also leaf extract of *Thevetia neriifolia* , seed oil of *A. indica* and seed oil of *Samadera indica* had shown considerable repellency of red palm weevil under laboratory conditions.

In the case of sterile insect technique, gamma radiation at 1.5 Krad was found to be the best treatment as it caused considerable sterility as well as higher longevity of irradiated insects. The irradiated insects should be exposed to 6 virgin females for the duration of 12 days before releasing in the field to nullify the effect of initial fertility of unaffected sperms in the irradiated insects. The studies also revealed that there were repeated mating in red palm weevil and the sperms transferred during the recent mating only aids fertilization. To counteract the competition by wild males to mate with females, the irradiated males should be flooded in the field with a ratio of 10 irradiated male insects per normal male in the field.

In conclusion the experiment reveals the overall efficiency of plant products and sterile insect technique to manage red palm weevil in coconut.