TRAPPING OF RED PALM WEEVIL

Rhynchophorus ferrugineus F (Oliv.)

IN COCONUT GARDENS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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COLLEGE OF HORTICULTURE

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DECLARATION

I hereby declare that the thesis entitled **'Trapping of red palm weevil *Rhynchophorus ferrugineus* F (Oliv.) in coconut gardens'** 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 to me of any degree, diploma, fellowship, associateship or other similar title of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled **'Trapping of red palm weevil *Rhynchophorus ferrugineus* F (Oliv.) in coconut gardens'** is a record of research work done independently by **Mr.B. Ramesha** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the Advisory Committee of **Mr.B.Ramesha,** a candidate for the degree of **Master of Science in Agriculture** with major in **Agricultural Entomology,** agree that the thesis entitled **'Trapping of red palm weevil *Rhynchophorus ferrugineus* F (Oliv.) in coconut gardens'** may be submitted by Mr.B.Ramesha in partial fulfilment of the requirement for the degree.

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B. RAMESHA

To my beloved parents

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INTRODUCTION

The red palm weevil *Rhynchophorus ferrugineus* F. (Oliv) (Coleoptera curculionidae), is a serious pest of coconut, date and oil palms. It infests ornamental and other palms as well. Information on this pest was first published in 1891 in the Indian museum notes (Anonymous 1891). Lefroy (1906), described the insect as a major pest of coconut and other palms throughout India.

Red palm weevil is distributed within 35° North and 15° South latitudes. On the southern hemisphere it is reported from Papua New Guinea, Indonesia and Tanganica. In the Northern hemisphere the pest is present in Philippines, Thailand, Burma, India, Pakistan and the Arabian countries like Iraq, Saudi Arabia, UAE etc. (Ramachandran, 1993). Cox (1993) reported the establishment of the weevil in Egypt indicating the advance of the pest to north Africa.

The adult *R. ferrugineus* is a large sized ferrugineous brown weevil measuring on an average 35 mm in length and 12 mm in breadth. The prothorax will have black dots of varying size and shape. The male is distinguished from the female by a tuft of hairs on the dorsal side of the snout.

In coconut and date palm it has been estimated that five to seven per cent of the palms are damaged by weevil attack (Falerio *et al.*, 1998). Timely detection of the pest can save the crop. However, due to its concealed nature, early detection is difficult. This makes the problem of palm weevil management intricate (Falerio *et al.*, 1998).

As the infestation is difficult to be detected and the remedial measure difficult to be adopted in a curative manner, it is advisable to develop techniques for early monitoring of weevil population as well as to deter the weevils from coconut

by getting them attracted to alternate food sources and trapped. Use of aggregation pheromones combined with suitable food attractants would be much useful in this.

Pheromones are secretions of the exocrine glands used for intraspecific communication between individuals of a single species, triggering specific reaction in the receiving individuals, leading to alarm sexual attraction, aggregation, tracking or sexual determination at maturity (Karlson and Butenandt, 1959).

At present the most widely used pheromone lure in palm weevil management is FERROLURE manufactured and supplied by Chem Tica Naturals, Costa Rica. Two formulations i.e., Ferrolure (F) and Ferrolure+ (F+) are available. About 700 mg of the chemical is loaded in polyethylene sachets. When set in the traps the chemical from the sachet gets released into the surroundings, attracts the weevil towards the trap and the food attractants in the bucket orient the attracted weevils into the trap (Falerio *et al.*, 1998).

This pheromone has to be evaluated along with suitable trapping techniques and food attractants, under the conditions existing in Kerala. In this context the following experiment was conducted with the specific objectives as

1. Survey of the red palm weevil infestation in Thrissur district.
2. Design of a suitable trapping device for testing the efficiency of the pheromone.
3. Determination of the efficiency of the pheromone in combination with various food attractants.
4. Determination of the supplementary attraction of pheromone traps with UV light traps.
5. Determination of efficiency of relative heights of the pheromone exposure in the coconut garden.
6. Behavioural response of red palm weevils while perceiving the pheromone.

REVIEW OF LITERATURE

2.1 General description

Weevils in the genus *Rhynchophorus* are world wide pests of palm especially coconut (Wattanapongsiri, 1966). The Asiatic palm weevil *R. ferrugineus* (Oliver), is a serious pest throughout South and South east Asia where they are important pests of coconut, oil palm and date palm (Kalshoven, 1950 and Wattanapongsiri, 1966). *R. palmarum* is a major pest in the neotropical region by vectoring the Red ring disease (Griffith, 1987). The weevil *R. palmarum* (L.), is the primary vector of the red ring nematode *Radinaphalenchus* (= *Bursaphelenchus*) *cocophilus* Baujard (Cobb, 1922; Tidman, 1951; Martyn, 1953; Hagley, 1963; Griffith, 1967, 1968). In Florida *R. cruentatus* is a major pest of sabal palm, the state tree, and a popular ornamental. In Africa *R. phoenicis* causes losses in oil palm and coconut plantations while in south east Asia *R. ferrugineus* and *R. vulneratus* are significant pests. An isolated species, *R. bilineatus*, is a major pest of coconut palms used as shade trees in cocoa in Papua New Guinea (Ochlschlager *et al.*, 1993).

These large (2-3 cm long and ~1 cm wide) weevils initiate damage through deposition of small bunches of eggs (~5 each) in exposed palm tissue produced by wind or during harvesting and pruning. Adults of *Rhynchophorus* are attracted to wounded palms and fermenting sap (Kalshoven, 1950; Lever, 1969; Sadakathulla, 1991).

2.1.1 Damages, estimation and loss

The insect *R. ferrugineus* is a serious pest of coconuts in Kerala and causes about seven per cent loss to the coconut industry (Rajan and Nair, 1997). This is a devastating pest of coconut in Tamil Nadu also. The insects 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). Ganapathy *et al.* (1992) reported that the extent of damage by *R. ferrugineus* ranged six to 34 per cent in Coimbatore, Tamil Nadu, India.

2.2 Distribution

The red palm weevil *R. ferrugineus* is distributed all over the world but in most severe forms in India and South East Asia (Anonymous, 1992). Cox (1993) reported that *R. ferrugineus* was a major pest on date palms in Egypt and gave the first record of the curculionid from Africa. Shantappa *et al.* (1979) reported that *R. ferrugineus* is more severe in coastal areas of Kerala and Karnataka than in mid and High ranges.

2.3 Biology

Wilson (1962) reared *R. ferrugineus* in the laboratory and observed that the eggs were laid singly and larvae hatched in two to four days at 80°F and pupated at 24 to 62 days. The larvae moults nine to 12 times and when full fed, spun fibrous cocoons. Prepupal period lasted for four to 18 days and pupal stage for seven to 17 days. Neonate adult remained within the cocoon for two to 14 days. Oviposition began two to 14 days after the day of mating. Adult female laid on an average 105 eggs each and adult life span is 127.5 days for males and 93.3 for females.

Weissling *et al.* (1993) worked out the humidity preference of *R. cruentatus* adults. Total body water averaged 47±8 per cent by mass and cumulative loss increased with time at all humidities tested (0, 33, 63 and 100%

RH) at 30°C. Death occurred more rapidly at low than at high humidities at which time weevils had lost 50 per cent of their body water.

2.4 Nature of attack

The entire damage for the coconut palm is caused by the larvae wherein they feed on the inner tissues of crown and upper portion of trunk. The external symptoms produced by the pest include the presence of small holes on the stem, oozing out of brown liquid, extrusion of chewed up material (fibres) and longitudinal splitting of leaf bases. In severe cases the crown of the palm topples. Palms in the age group of five to 20 years are more susceptible to this pest attack (Vidyasagar and Kesavabhat, 1991). Often the palm weevil infestations of coconut and oil palms are not detected until the fronds wilt and the crown collapses suddenly (Kalshoven, 1950; Sivapragasam *et al.*, 1990).

Other than coconut the weevil coming under the genera *Rhynchophorus* also causes damage in oil palms. In date palms, often the only visible sign of attack is the oozing of palm sap from the trunk and infestations are only discovered once trees are blown over (Kalshovan, 1950). In the Tropical Americas 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; Chinchilla *et al.*, 1990). 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) and with fluctuations in the proportion of the weevil population that was infected with nematodes (Chinchilla *et al.*, 1990; Morales and Chinchilla, 1990). Symptoms do not become evident until two to three months after infection and nematicidal treatments have proven ineffective in oil palm (Chinchilla, 1988).

2.5 Management of red palm weevil

If the infestations of *R. ferrugineus* is seen in the initial stage only the palm can be saved. Any treatments with insecticides in the later stages of attack cannot save the palm (Rajamanickam *et al.*, 1995). Hence an integrated approach involving different methods like physical, biological, cultural, chemical and semio chemical aspects were resorted to.

In the case of red palm weevil, prevention of pest entry is a major step to be adopted in the IPM package. This is possible by avoiding injuries on the palm and by treating the wounds, if any with coaltar and carbaryl. Prophylactic crown treatment with insecticide sand mixture (25 g of Sevidol8G in 200 g of fine sand) in May, September and December and curative treatment with 0.1 per cent endosulfan/dichlorvos or one per cent carbaryl were effective in the management of the pest (Nair *et al.*, 1997). Trapping of the floating population of the weevil using coconut logs treated with fermenting toddy is also recommended (Nair *et al.*, 1998). Maintenance of field sanitation by removal and burning of dead palms helps a lot in reducing fresh incidence of weevil attack. Adoption of the above methods under an IPM package has yielded encouraging results in the farmers garden (Abraham *et al.*, 1989).

2.5.1 Physical control

According to Abraham (1971), when the green leaves of coconut palms are cut off in India for domestic use, there is a danger of attack through the cut petioles by the weevil. As the remaining portions of the petioles dry, they become unsuitable for the development of larvae. It is said that if leaves were cut at or beyond the region where leaflets emerge at the base, larval hatching from eggs laid

at the cut ends of petioles would not be able to make their way into the trunk before the petiole stump dried up.

2.5.2 Biological control

In nature the number of natural enemies for the *R. ferrugineus* is very less. But certain natural enemies were reported by different authors. A tachinid parasite *Parabillaea rhynchophorae* is seen to be parasiting at different degrees (Blanchard, 1937).

Abraham *et al.* (1973) reported a forficulid *Chelisoches morist* F. (Dermaptera) as a predator of eggs and larvae of red palm weevil under laboratory conditions.. The daily consumption by nymphs and adults, respectively averaged 5.3 and 8.5 weevil eggs and 4.2 and 6.7 larvae.

Prior and Arura (1985) found that *Metarhizium anisopliae* infects the red palm weevil in different degrees.

Peter (1989) conducted a survey for the natural enemies of red palm weevil in Tamil Nadu and the survey revealed the presence of three species of mites of which *Hypoaspis* sp. was the most abundant.

A potent cytoplasmic polyhedrosis virus was found out for the red palm weevil (Gopinadhan *et al.*, 1990). It infects all life stages and infection of the late larval stage results in malformed adults and a drastic suppression of the host population.

Banerjee and Dangar (1995) identified *Pseudomonas aeruginosa* as a facultative pathogen of *R. ferrugineus*.

2.5.3 Cultural control

As a prophylactic measure Copeland (1931) and Ayyar (1940) suggested that all scars, wounds and exposure of soft part of palm should be avoided. Copeland (1931) and Ayyar (1940) also prescribed the removal of grubs and dressing the wounds with tar, lime etc. In cases of severe infestation the affected palms should be cut and burnt to prevent the spread to healthy palms (Vestal, 1956). Cutting the trunk for making foot holds for climbing the palm or any other activity which provide sites for egg laying by weevils should be avoided (Child, 1974).

According to Mazumder (1995) the hybrid Tall x Dwarf was most susceptible to red palm weevil followed by MDY (Malayan Dwarf Yellow) x WCT (West Cost Tall). He also reported that the varieties West Cost Tall, Straight Settlement Green, Chavakkad Orange Dwarf x Tall, Andaman Ordinary, Cochin China and Assam Tall were resistant to red palm weevil.

2.5.4 Chemical control

Out of several insecticides tried, Pyrecon E one per cent when injected into infested trees gave the best results (Nirula *et al.*; 1953). As a prophylactic measure, the leaf axils of young palms may be filled with sand and BHC five per cent or chlordane dust in equal proportions. An adult mortality of 92 per cent at 0.5 and 100 per cent at 10 per cent concentration of endrin was reported by Mathen and Kurian (1962). By injecting the infested trees with Carbaryl 1.0 per cent nearly 93 per cent palms were cured (Mathen and Kurian, 1973). Subsequently Rao *et al.* (1973) achieved good success by placing aluminium phosphide tablets inside the damaged portion. Among several insecticides tested Trichlorphon 0.2 per cent gave best results with 92 per cent recovery of infested palms (Abraham *et al.*, 1975).

Muthuraman (1984) suggested the injection of Monocrotophos at 10 ml/tree or monocrotophos + dichlorvos (5 + 5 ml) and he obtained 100 per cent control over the red palm weevil.

The insecticides Carbosulfan and pirimiphos-ethyl when used for the control of *R. ferrugineus*, gave 98 per cent control of the pest (El-Ezaby, 1997).

2.5.5 Weevil Traps

Various designs of weevil traps with different attractants were tried in different coconut growing countries. A trap for the collection of *R. palmarum* was developed by Maharaj (1965) in Trinidad which was based on fermented toddy as its attractant. When this method consisting of traps with split fresh coconut petioles was tested in one estate in Sri Lanka, 302 red palm weevils (*R. ferrugineus*) were recovered from 10 traps in 141 days (Ekanayake, 1970). The trapping method was modified with the addition of sugarcane and yeast to the split petioles. By mixing the traps with BHC 50 WP (2 g/trap) the trapped weevils could also be killed (Anonymous, 1988).

Maharaj (1973) described a simple aluminimum trap baited with coconut tissue which has greased walls to prevent the escape of weevils by crawling and aperatures barred with wire to prevent escape by flying. This type of trap captured more than twice the number of weevils compared to coconut log traps.

Morin *et al.* (1986) observed that adult *Rhynchophorus* spp. were attracted for feeding and reproduction to the odour of fermentation emanating from wounds in healthy or from degenerated palms. He also reported that construction of traps along the edge of a plantation from cut pieces of palms which should be tender would attract palm weevils and these can be collected and destroyed.

Among different traps used the trap door and tanktraps containing baits of sugarcane and sugarcane + molasses were more efficient in trapping adult *R. palmarum* (Moura *et al.*, 1990).

Posada and Aaron (1991) used *Panela* (unrefined brown sugar) and molasses and observed that there was no significant differences between these two baits. Greatest capture rates were obtained when the bait was changed every 21 to 30 days.

A conventional light trap set up in coconut gardens in Tamil Nadu, did not attract the *R. ferrugineus* but they attracted beneficial *Apis cerana indica* and some parasitoids of Lepidoptera (Sadakathulla and Ramachandran, 1992).

According to Weissling *et al.* (1992) freshly felled *Sabal palmetto* was attractive to adults of *R. cruentatus* for about 35 days.

Attraction to plants by adult *R. palmarum* was due to the chemical pentone, hexanol and isopentanol. Pineapple contains ethanol and ethyl acetate to which weevils get more attracted than the pentone, hexanol and isopentanol (Jaffe *et al.*, 1993). They also reported that it was due to the production of aggregation pheromone when perceiving ethyl acetate that the weevils were attracted. It was suggested that a complex mixture of chemicals like ethanol, ethyl acetate, pentane, hexanol, isoamyl acetate and or isopentanol serve as a short range orientation cue to fresh wounds on the plant and Rhynchophorol can be considered to be a synergist having an anemotactic action at a distance.

According to Moura *et al.* (1995) baits made up of sugarcane sticks located in brick tanks were efficient in trapping the weevils.

In another experiment conducted by Rajamanickam *et al.* (1995), it was observed that among different natural phago stimulants tested sugarcane, molasses and toddy attracted the curculionids in large numbers.

Nadarajan *et al.* (1996) reported that coconut stem + toddy and coconut crown alone were equally effective in trapping adult weevils.

2.5.6 Irradiation and weevil control

Attempts have been made to develop control measures against red palm weevils *R. ferrugineus* making use of sterile insect technique with radio isotopes. Treatment of male weevils one to two days old at a dose of 1.5 K rad resulted in 90 per cent sterility with no adverse effect on survival (Rahalkar *et al.*, 1975).

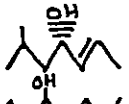
Treatment at higher doses increased sterility but reduced survival. A portion of the sperm present in males at exposure was less sensitive to treatment and contributed to higher viability of eggs laid by females during the initial stages of oviposition (Rahalkar *et al.*, 1973; Rahalkar *et al.*, 1975; Kloft *et al.*, 1986). However the results on the application of this technique in the field and its success are not available from any country.

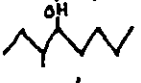
According to Ramachandran (1991), the use of increasing radiation doses decreased, the production of viable eggs. As the early detection of the damage in palms is difficult, some attempts have been made to develop simple electronic device for detecting infestations (Anonymous, 1990).

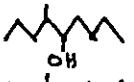
2.6 Pheromones and weevil behaviour

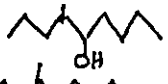
The Chemical Ecology Research Group at Simon Fraser University and INRA Laboratory in Magny-les-Hameaux, France (Rochat *et al.*, 1991a, 1991b) identified male produced aggregation pheromones for six economically important species of palm weevils in the genus *Rhynchophorus*.

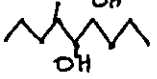
Male produced aggregation pheromones of *Rhynchophorus* weevils

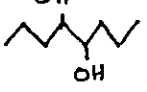
R. palmarum  (Oehlschlager *et al.*, 1992)

R. phoenicis  (Gries *et al.*, 1993; Perez *et al.*, 1994a)

R. ferrugeneus  (Hallet *et al.*,1993a, 1993b; Perez *et al.*,1994c)

R. vulneratus  (Hallet *et al.*,1993a, 1993b; Perez *et al.*, 1994c)

R. bilineatus  (Oehlschlager *et al.*, 1993; Perez *et al.*, 1994c)

R. cruentatus  (Perez *et al.*, 1994b)

Moura *et al.* (1989) studied the olfactory behaviour of red palm weevil *R. palmarum* and noted that the traps baited with stems only caught 27 insects, while those baited with stem plus five females, five males or five pairs of insects caught 27, 68 and 44 insects respectively. From this experiment it was concluded that males have some amount of semio chemics to attract females.

Male produced aggregation pheromone of *R. palmarum* was first reported by Rochat *et al.* (1991a).

Rochat *et al.* (1991b) found out male produced aggregation pheromone of *R. palmarum* which was identified from supelpak-2 and gas chromatography. The major male produced volatile was identified as (2E)-6-methyl-2-hepten-4 ol using coupled gas chromatography and mass spectrometry. They proposed the trivial name

Rhynchophorol for this new molecule which is the essential component of *R. palmarum* aggregation pheromone.

Nagnan *et al.* (1992) suggested that there is a similarity between the volatiles emanating from the oil palm sap and semio chemical released from *R. palmarum*.

Pheromone baited traps caught six to 30 times more individuals than unbaited traps (Chinchilla and Oehischlager, 1993).

According to Jaffe *et al.* (1993), males of *R. palmarum* produced aggregation pheromone when perceiving ethyl acetate produced in the plant. Rhynchophorol, 2(E) 6-methyl-2-hepten-4-ol, the active component of the aggregation pheromone, attracted weevils in the Olfactometer and in the field, only if plant tissue, ethyl acetate or the above odour mix were present. It was proposed that a complex mix of ethanol, ethyl acetate, pentane, hexanal, isoamyl acetate and/or isopentanol served as a short range orientation cue to fresh wounds on the plant and that additional host odour have still to be discovered. Rhynchophorol can be considered to be a synergist, having an anemotactic action at a distance.

Weissling *et al.* (1993) observed that *R. cruentatus* produce an aggregation pheromone that is highly attractive to conspecific adults of both sexes when combined with host-palm volatiles.

Gibblin-Davis *et al.* (1994) isolated different semio chemicals from *Sabal palmetto, Saccharum officinarum* and Syncarp tissue from pineapple which was equally attractive as that of Cruentol (5-methyl-4-octanol) which is an aggregation pheromone of *R. cruentatus*.

Gunawardena and Kern (1994) observed that *R. ferrugineus* showed a short range attraction to coconut sap, whose volatile constituents consist mainly of short chain alcohols.

The electroantennogram (EAG) responses of male and female *R. ferrugineus* to terpenes were determined by Gunawardena (1994). He observed that linalool and terpineol were more attractive than other terpenes.

Oehlschlager *et al.* (1995a) worked out the spatial distribution of adult *R. palmarum* and suggested that indices of aggregation showed that the adult population will aggregate initially and later become increasingly at random. 4 Methyl-5 nonanol (ferrugineol) is a male produced aggregation pheromone of *R. bilineatus* (Oehlschlager *et al.*, 1995b) and also *R. ferrugineus* (Gunawardena and Bandarage, 1995; Oehlschlager, 1995). The ferrugineol can be used for monitoring, mass trapping and immigrant study (Gibblin-Davis *et al.*, 1996).

2.6.1 Pheromone bioefficacy and persistence

According to Gunawardena and Bandarage (1995) ferrugineol remained attractive to weevils for at least 60 days. The weevil response to the bait was observed only between 1800-2000 and 0600-0800 hours. Generally, 3 mg per day of synthetic pheromone plus insecticide treated tissue constituted highly attractive trap baits (Gibblin-Davis *et al.*, 1996).

In a comparative experiment, ferrugineol attracted more weevils than the coconut bark steam distillate (Gunawardena and Bandarage, 1995). The trapping of adult red palm weevils were more in insecticide + pheromone contained traps than insecticide alone (Morin *et al.*, 1997; Moura *et al.*, 1997).

2.6.2 Pheromone response height and its efficacy

El-Garhy (1996) observed that when pheromone traps were tied in between one to three meter above ground, weevils were trapped in good numbers even though there was no significant difference between one to three meter.

2.6.3 Pheromone efficacy in relation to weather and climate

El-Garhy (1996) reported that many more adult palm weevils were captured during the warmer summer months than during the cooler winter months. The threshold for *R. ferrugineus* was found to be in the range of 12-14°C.

2.6.4 Physiology of pheromone

Histological and chemical analyses of different corporal segments of *R. palmarum* showed the presence of two symmetrical glands (modified salivary glands) in the prothorax of males which was absent in females. These glands were known to produce aggregation pheromone. The rostrum and rectum of males also produce this pheromone. The secretion starts approximately 10 minutes after the insect detects ethyl acetate and continues for several hours. The more concentrated form of pheromone is secreted through the rostrum (Sanchez *et al.*, 1996).

MATERIALS AND METHODS

3.1 Survey of red palm weevil infestations in Thrissur district

A survey was conducted in the Thrissur district to judge the extent of damage inflicted by the red palm weevil of coconut and its infestation levels in different geographical locations of the district. Three regions of Thrissur district representing coastal belt, mid lands and high lands (upland) were surveyed to find out the level of infestation.

Survey was conducted in Chavakkad area representing the coastal belts, Peruvallur area representing the midlands and Peechi area representing the upland regions of the district. In each area coconut groves were classified into three age groups based on the age of the palms as (1) Five to ten years (2) 11-30 years and (3) above 30 years.

3.1.1 Mode of survey

In each area ten sites were selected at 1 km distance each from the starting point and covered a total distance of 10 km in each representative area. In each site 30 palms consisting of 10 palms under each age group was observed. Direct observations as well as by interview with the owners of palm were made to verify the damage by the red palm weevil. A total of 300 palms were surveyed in each area. Likewise the survey was conducted in the other two regions also observing a total palm number of 900 in three regions.

3.2 Selection of site

For setting up of pheromone traps along with food attractants, three sites namely coconut groves of Instructional Farm, Vellanikkara, Coconut plantations, College of Horticulture, Vellanikkara and Banana Research Station, Kannara were

selected with palms of the young age group preferably between 10 to 15 years to get maximum red palm weevil attack.

3.2.1 Layout

The experiment was laid out in a randomised complete block design with three replications (blocks) and seven treatments. The traps under each treatment were set on palms at a distance of 22.5 m (three palm distance) and the palms were selected at random.

3.2.2 Treatments

T_1 - Pheromone along with pineapple waste

T_2 - Pineapple waste alone

T_3 - Pheromone along with cut coconut fronds

T_4 - Cut coconut fronds alone

T_5 - Pheromone along with fermenting toddy

T_6 - Fermenting toddy alone

T_7 - Pheromone alone - control

3.3 Design of a suitable trapping device for testing the efficiency of the pheromone

Plastic buckets of 20 l capacity with its lid and of uniform size, shape and colour were utilised for designing the bucket trap. Buckets were provided with rectangular window hole (of size 2 cm x 2.5 cm) to facilitate entry of palm weevils inside the traps. The hole was closed with mylar sheets of 3 cm width and 5 cm length pasted from inside on one side so as to allow one way entry of weevils into the bucket trap and to prevent its escape. Mylar pieces pasted as one way shutters was provided with punch holes to allow the volatile pheromone compound to

Plate I. Ferrolure bucket trap

Plate II. Ferrolure bucket trap under field exposure

Plate III. Pineapple waste within the bucket trap

Plate IV. Coconut frond pieces within the bucket trap

permeate out and attract weevils into the bucket traps. Once the weevil entered inside, the mylar shutter prevented its exit. The pheromone sachet was secured inside the bucket using a twine passed through the lid. Buckets were roughened and tied with coir ropes on the outside to give maximum grip to the alighted weevils to crawl inside the bucket through the entry window (Plate 1).

Bucket traps were tied on the selected palms at 1.5 m above ground level (Plate 2) using coir rope to get the maximum trapping efficiency, as described by Falerio *et al.*, 1998.

3.4 Determination of the efficiency of pheromone traps and the relative efficiency of various food attractants

The male produced aggregation pheromone 4-methyl-5-nonanol commercially available as ferrolure from Chem Tica Naturals, Costa Rica were tried for experimentation. It is available in polythene sachets in a slow release formulation which releases @ 3 mg of active principle per day at a temperature of 35°C, reported to be effective for three months (Hallet *et al.*, 1993a).

3.4.1 Determination of the efficacy and persistance of the food attractants

From the preliminary observations on the performance of the various food attractants tried pineapple waste as well as fermenting toddy was giving better results. In order to evaluate the persistance of the freshness, the pheromone with the food substance kept in the bucket trap were monitered by recording the daily catches of both the sexes of weevils.

Plate III. Pineapple waste within the bucket trap

Plate IV. Coconut frond pieces within the bucket trap

Plate V. Toddy with floats

3.4.2 Weevil attractant treatments

1. Pheromone with pineapple waste

Commercially available pheromone sachet was secured by hanging it from the lid inside the bucket at window level. Waste from ripened pineapple weighing 1.5 kg was cut into pieces and placed inside the bucket traps. Pineapple was changed once in every four days to maintain the attractiveness of the food substance.

2. Pineapple alone

Ripened pineapple waste weighing 1.5 kg was cut into pieces and were placed inside the bucket trap (Plate 3).

3. Pheromone along with cut coconut fronds

Fresh coconut fronds were cut into pieces of size 15 cm x 4 cm and were kept in the bucket along with the pheromone sachet secured below the lid and coconut fronds were replenished at every two days interval.

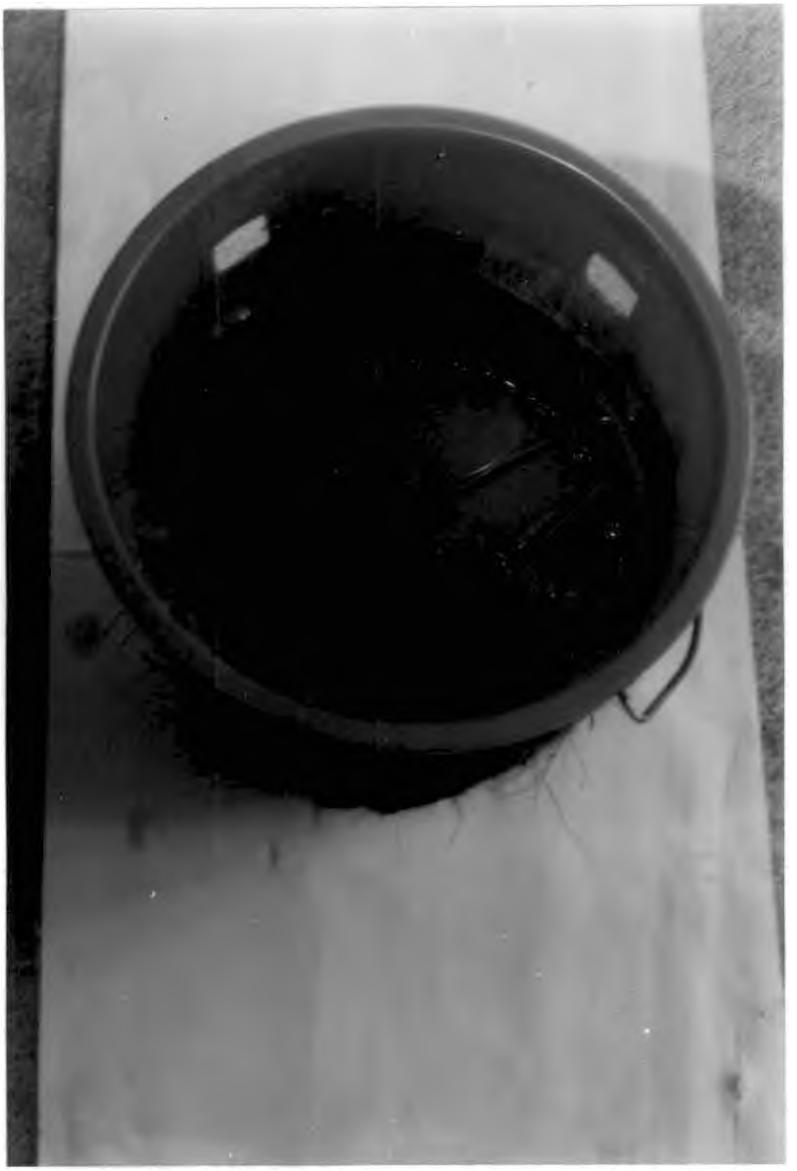
4. Coconut fronds alone

Fresh coconut fronds were cut into pieces of size 15 cm x 4 cm and were kept in the bucket. In each case coconut fronds were changed once in every two days (Plate 4).

5. Pheromone with fermenting toddy

Pheromone sachet was secured inside the bucket trap as usual. One day old fermented toddy @ two litres per trap was poured in the bucket trap and it was replenished once in every three days to maintain the attractiveness.

Plate V. Toddy with floats



6. Fermenting toddy alone

One day old fermented toddy was kept in the bucket trap @ two litres and exposed (Plate 5).

7. Pheromone alone

Here a bucket trap containing pheromone sachet alone was exposed.

3.4.2 Observations

Weevils trapped in each bucket trap were collected between eight to 11 am every day. The weevils trapped from all the treatment bucket traps were collected separately from all the three sites and brought to the laboratory for further observations. (1) The weevils were separated based on their sex to determine the sex ratio and the trap efficiency (Fig.1). (2) Sexes were separated based on male and female distinguishing characters. The male was identified by a robust snout with a tuft of hairs on their beak and females with a long smooth and slender snout without hairs on the snout. (3) Female weevils were separated and kept for egglaying to determine their fecundity and gravidity. Female weevils were confined in separate containers and allowed for oviposition. Cotton pads wetted with pineapple juice was given for the weevils to lay eggs and deposited eggs were counted at 10 am every morning.

3.5 Determination of the supplementary attraction of the pheromone traps with UV light traps

An experiment was conducted at the coconut plantation of the College of Horticulture, Vellanikkara. In this experiment, an ultraviolet lamp was installed at a height of four meter on a coconut palm and provided with an iron sheet roofing as a

Plate VI. Ferrolure bucket trap with UV light source

Plate VII. Ferrolure bucket trap at 5 m height and at 1 m height

R. ferrugineus

Male weevil

Female weevil

Fig : 1

Plate VI. Ferrolure bucket trap with UV light source

Plate VII. Ferrolure bucket trap at 5 m height and at 1 m height

rainguard (Plate.6). Bucket trap with pheromone and attractant pineapple were exposed on the coconut palm at a height of 1.5 m. Observations on the number of weevils caught daily were made as described earlier.

3.5.1 Determination of efficiency of relative heights of the pheromone exposure in the coconut garden

This experiment was conducted to test the efficiency of pheromone traps exposed at different heights. For keeping the traps at different heights two bamboo poles measuring six meter length were marked with black paint at meter intervals. By a pully and rope arrangement the pheromone bucket trap could be hoisted at the desired heights on the metered marks on the bamboo pole (Plate.7).

On one set the bucket trap was in the ascending order while on the second it was in the descending order. The traps were kept at heights of one, two, three, four and five meter and the setting was changed every week. Observations were taken in the morning between eight to 11 am on the number of trapped weevils.

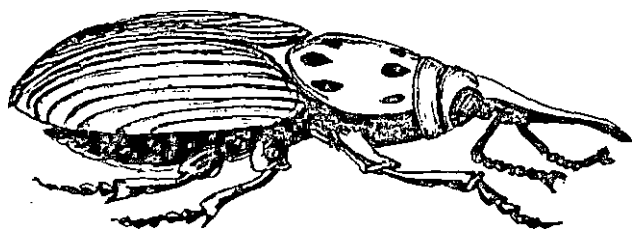
3.5.2 Behavioural response of red palm weevils to pheromones under captivity

An experiment was conducted to study the behavioural response of weevils as evinced by the antennal response. The study was undertaken within the corridor of the building acting as a wind tunnel measuring 65 m long which was then marked at each five meter intervals. A powerful pedestal fan (5000 rpm) was installed at one end of the corridor to give sufficient air current to take the volatile pheromonal odour to the other end of the corridor. One male and one female weevil were confined together in petridishes covered with wire gauge and the confined weevils were placed at distances of 5m upto 65m in the corridor and were exposed to the air currents with the permeated pheromone. The pheromone sachet was hung at 1.5m above the floor level and a pedestal fan was kept 0.5 m behind the

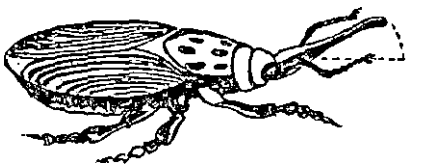
pheromone source. The antennal vibration, and orientation and the movement of the weevil were monitered when placed at these distances marked on the floor of the corridor. The observation was repeated ten times with the confined weevils. The weevils were released from the confinement at the effective distance and their movement and time taken to reach the pheromone source are measured (Fig.2).

Antennal response of *R. ferrugineus* to Ferrolure

Normal Weevil



Raised Snout



Snout Swinging

Antennae Swinging

Fig : 2

RESULTS

4.1 Survey of the red palm weevil in Thrissur district

The survey conducted in Thrissur district and results presented in Table 1 revealed that the average infestation level was six per cent irrespective of the land regions and age groups of the palms.

The observations on the red palm weevil infestation (RPW) and the age group of palms showed an increasing trend of infestation level with the age of the palms. The younger palms of five to 10 years recorded the lowest percentage of 3.33 per cent as against the highest level of 9.67 per cent in older palms of 30 years and above. A moderate infestation level of five per cent was observed in palms at the age group of 11-30 years.

4.1.1 Determination of the relative efficiency of pheromone traps and various food attractants

The attraction of the adult RPW to pineapple and fermenting toddy along with pheromone is presented in Table 2. It revealed that maximum attraction was recorded in pheromone with pineapple waste with a maximum catch of 56 weevils in 12 days. In pheromone with fermenting toddy contained maximum weevils caught were only 22 for the same period. This showed that pineapple as a food attractant was 2.5 times more efficient than toddy along with pheromone. Maximum attraction for the pineapple containing pheromone trap was on the fourth day and from then onwards the attraction to the trap started decreasing and reached zero on 10th day. Maximum number of males were also caught from the same trap with a total male count of 33, while the total females trapped was 23 only.

Table 1. Percentage kill of coconut palms* due to *R. ferrugineus* infestation

Age group of the palms	Coastal land (Chavakkad)	Midland (Poovathur)	Upland (Peechi)	% mean
5 to 10 years	3	4	3	3.33
11 to 30 years	5	7	3	5.00
Above 30 years	8	12	9	9.67
% mean	5.33	7.66	5	6

* 1) Number of palms per location = 300
2) Number of palms under each age group per location = 100
3) Total palms observed by random sampling = 900

Table 2. Performance of food attractants with Ferrolure against *R. ferrugineus*

Days	Pineapple-pheromone trap			Toddy-pheromone trap		
	Male catch	Female catch	Total catch	Male catch	Female catch	Total catch
0	0	0	0	0	0	0
1	3	1	4	1	4	5
2	4	3	7	3	0	3
3	6	4	10	4	6	10
4	8	10	18	0	1	1
5	6	1	7	0	1	1
6	4	0	4	1	1	2
7	0	2	2	0	0	0
8	1	2	3	0	0	0
9	1	0	1	0	0	0
10	0	0	0	0	0	0
11	0	0	0	0	0	0
12	0	0	0	0	0	0
Total	33	23	56	9	13	22

In toddy-pheromone trap, maximum catch was recorded on the third day with a total count of 10 weevils. From fourth day onwards attraction started decreasing and it reached zero on the seventh day and same trend continued upto 12th day with no weevils caught. The experiment was then discontinued. Total males caught in pineapple-pheromone trap was more with a total number of 33 weevils where as in the toddy-pheromone trap it was nine only. Females trapped in the pineapple-pheromone trap was 23 and that of toddy-pheromone trap was 13 weevils.

4.1.2 Total catch of weevils for three months period

Total catch of RPW for three months period was analysed and presented in Table 3a. Treatment 1 (Pineapple-pheromone) showed a significant difference in the mean weevil catch of 119.5 as compared to treatment 5 (Toddy-pheromone) with a catch of 50 weevils only. Treatment 4 (CFR) gave least weevil catch with a mean weevil catch of 6.00 only.

4.2 Influence of sex factor on the trap efficiency

4.2.1 Total male catch for 3 months period

Total mean male catch for three months period is analysed and depicted in Table 3b.

T_1 (Pineapple-pheromone) caught significantly higher males as compared to other treatments, with a mean male weevil catch of 72.33. The T_5 (Toddy-pheromone) and T_7 (pheromone alone) showed no significant difference. T_4 (CFR) was having the lowest catch of weevils with a mean of 4.67 weevils.

Table 3. Total catch of male and female *R. ferrugineus* in Ferrolure traps with and without food attractants

	3a		3b		3c			
Treatment	Mean total catch for 3 months period	Performance ranking	Mean total male catch for 3 months period	Performance ranking	Mean total female catch for 3 months period	Performance ranking	Male: Female ratio	Female: Male ratio
T_1	119.50(10.91)	1	72.33(8.49)	1	46.66(6.84)	1	1.55	0.64
T_2	12.33(3.58)	5	8.00(2.88)	5	4.33(2.14)	5	1.80	0.54
T_3	20.00(4.48)	7	10.33(3.19)	7	9.66(3.18)	7	1.06	0.93
T_4	6.00(2.45)	3	4.67(2.17)	3	1.33(1.27)	3	3.50	0.28
T_5	50.00(7.10)	2	25.00(5.04)	2	25.00(5.04)	2	1.00	1.00
T_6	11.00(3.27)	6	6.33(2.56)	6	4.33(1.95)	6	1.40	0.68
T_7	25.67(5.02)	4	13.33(3.64)	4	12.33(3.52)	4	1.08	0.92
CD	1.5226		1.4522		1.1796			

Figures in paranthesis indicate transformed ($\sqrt{x+0.5}$) mean value

T_1 - Pineapple-pheromone trap
T_2 - Pineapple waste alone
T_3 - Coconut fronds- pheromone
T_4 - Coconut fronds alone
T_5 - Toddy-pheromone trap
T_6 - Toddy alone
T_7 - Pheromone alone-control

4.2.2 Total female catch for three months period

The analysed data of total female catch for three months period was presented in Table 3c. Here again T_1 (Pineapple-pheromone) recorded the highest catch of females with mean catch of 46.66 weevils as compared to T_4 (CFR) with 1.33 mean weevil catch. T_5 (Toddy-pheromone) recorded equal number of male and female red palm weevils with a mean count of 25.00 each. Pineapple-pheromone (T_1) showed more attraction for male red palm weevils with a mean catch of 72.33 weevils and lower attraction for females with a mean count of 46.66 weevils.

4.3 Influence of weather elements on trap efficiency and the population dynamics of *R. ferrugineus*

The weather data for the experimental period from 26-2-98 to 20-5-98 is presented in Table 4. The data revealed that maximum temperature during the three months period was the highest on fourth and sixth week with 37.5°C on both days. Remaining weeks did not have much variation in the maximum temperature. Minimum temperature recorded showed that the highest was on eighth week (26.8°C) and lowest was on fifth week (22.9°C).

Relative humidity (RH) showed no much variation except on 12th week when the morning humidity was highest (93%). The lowest RH was on third and sixth week, with 83 per cent RH on both these weeks. The evening humidity was highest on 12th week (72%) and lowest was on fourth week (44%).

There was a slight fluctuation in the wind speed. During 12th week lowest wind speed was observed (2.1 km/h) while the highest wind speed was on third week (4.1 km/h).

Table 4. Weather data during the experimental period (26-2-98 to 20-5-98)

Weeks	Temperature °C		RH (%)		Wind speed (km/h)	Sunshine (hrs)	Rain (mm)	Lunar phase
	Max.	Min.	Morning	Evening				
1	35.3	24.3	89	50	2.8	9.6	-	No moon
2	35.9	23.6	89	49	3.5	10.3	-	Half moon
3	35.5	23.8	83	46	4.1	10.3	-	Full moon
4	37.5	23.7	84	44	3.6	10.5	-	Half moon
5	36.2	22.9	88	50	2.8	9.0	11.0	No moon
6	37.5	25.1	83	40	3.6	9.6	-	Half moon
7	36.4	26.1	86	52	2.8	9.1	-	Full moon
8	36.6	26.8	85	53	3.1	8.5	4.2	Half moon
9	35.9	24.6	89	54	3.0	8.7	57.2	No moon
10	35.2	25.5	89	61	2.7	8.5	4.8	Half moon
11	35.5	25.3	89	59	2.3	6.5	80.4	Full moon
12	32.4	24.1	93	72	2.1	4.6	107.8	Half moon

Highest sunshine recorded was during second and third week (10.3 hrs each) and lowest was during 12th week (4.6 hrs).

There was no rainfall from first week to fourth week but during fifth week a total of 11 mm rain was recorded. During sixth and seventh week there was no rain and on eighth week a total rainfall 4.2 mm was observed and during ninth week there was an increase in rainfall i.e., 57.2 mm. But it fell down drastically and reached 4.8 mm during 10th week. However, during subsequent weeks rainfall data revealed that there was increase in the rainfall and attained 107.8 mm during 12th week.

During first, fifth and ninth week it was no moon day and third, seventh and 11th week showed full moon condition.

There was no discernible influence of temperature on the total weevil count. However, the T_1 (Pineapple-pheromone) on fourth week recorded a total mean weevil catch of 21.00 but on sixth week it was 8.00 only. In T_5 (Toddy-pheromone) during fourth week the mean weevil count was 4.00 and during sixth week it was only 0.67 weevils.

The total weevil count was not influenced by RH, wind speed and sunshine hours. However, when the total rain was 57.2 mm (ninth week), a good weevil catch was recorded in T_1 (Pineapple-pheromone) with 17.67 mean weevils and 8.67 weevils in T_5 (Toddy-pheromone).

4.3.1 Total weevil catch for three months period at weekly intervals

In the first week, toddy-pheromone showed significant difference among the treatments and there was no significant difference between the other treatments (Table.5). Toddy-pheromone was found superior with mean weevil catch of 8.67 weevils. This was an increase of 1.13 more weevils during the first week period.

Table 5. Weekly catches of *R. ferrugineus* in Ferrolure traps with and without food attractants

Treatment	Mean weekly catch of *R. ferrugineus*											
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	12th week
T_1	7.67 (2.67)	5.67 (2.44)	12.67 (3.55)	21.00 (4.59)	11.33 (3.42)	8.00 (2.56)	5.00 (2.34)	7.67 (2.81)	17.67 (4.25)	11.67 (2.17)	9.33 (3.10)	1.33 (1.18)
T_2	2.67 (1.64)	0.67 (0.99)	0.67 (0.99)	2.00 (1.47)	0.00 (0.70)	1.00 (1.09)	0.67 (0.99)	2.33 (1.64)	1.33 (1.26)	0.33 (0.88)	0.00 (0.70)	0.67 (0.99)
T_3	2.00 (1.52)	5.67 (2.23)	1.33 (1.26)	1.00 (1.17)	2.67 (1.55)	0.33 (0.88)	0.33 (0.88)	1.67 (1.35)	2.33 (1.65)	1.00 (1.09)	1.33 (1.26)	0.33 (0.88)
T_4	0.33 (0.88)	0.33 (0.88)	0.00 (0.70)	1.33 (1.26)	0.33 (0.88)	1.33 (1.29)	0.00 (0.70)	1.33 (1.29)	0.00 (0.70)	1.00 (1.09)	0.00 (0.70)	0.00 (0.70)
T_5	8.67 (3.02)	6.00 (2.53)	2.00 (1.55)	4.00 (2.02)	4.00 (2.09)	0.67 (1.05)	0.33 (0.88)	9.33 (3.02)	8.67 (3.02)	2.67 (1.87)	3.33 (1.95)	0.33 (0.88)
T_6	1.00 (1.17)	2.00 (1.32)	0.00 (0.70)	0.00 (0.70)	1.67 (1.35)	0.33 (0.88)	0.00 (0.70)	1.67 (1.35)	2.33 (1.49)	0.67 (1.00)	1.33 (1.26)	0.00 (0.70)
T_7	1.67 (1.25)	1.00 (1.17)	3.67 (1.96)	2.67 (1.77)	1.00 (1.17)	0.67 (0.99)	0.67 (0.99)	2.33 (1.65)	8.33 (2.88)	3.00 (1.82)	0.67 (0.99)	0.00 (0.70)
CD	1.1763	1.3014	1.0062	1.0383	1.0518	1.4708	0.5958	0.9536	1.0684	0.3503	0.7434	0.7108

Figures in paranthesis indicate transformed $\sqrt{x+0.5}$ mean

T_1 - Pineapple-pheromone trap; T_2- Pineapple waste alone; T_3- Coconut fronds-pheromone trap; T_4- Coconut fronds alone; T_5 - Toddy-pheromone trap; T_6- Toddy alone; T_7- Pheromone alone-control

Total weevil count for the second week of installation showed that there was no significant difference between the treatments toddy-pheromone, pineapple-pheromone, CFR-pheromone and toddy alone with the toddy-pheromone showing the mean weevil catch of 6.0, pineapple pheromone with 5.67, CFR-pheromone with 5.67 and toddy with 2.0. Pineapple pheromone and CFR-pheromone showed an equal number of mean catch of weevils. Pheromone alone, pineapple and CFR showed least significant difference with the treatments toddy-pheromone, pineapple-pheromone, CFR-pheromone and toddy.

Total catch of weevils in the second week for the pineapple-pheromone decreased with a mean total catch of 5.67 weevils which is low as compared to first week which got a mean weevil catch of 7.67. Pineapple alone showed a decrease in the total weevil count for the second week with a mean weevil count of 0.67. There was an increased trend for the CFR-pheromone for the second week with a mean weevil catch of 5.67 which is greater than the first week mean weevil count of 2.0 weevils/trap. Coconut fronds in the second week showed no difference in the total weevil count wherein it showed 0.33 weevils in first and second week each. Toddy pheromone in the second week showed decrease in the total weevil catch (6.00 weevils) than the previous weeks catch (mean of 8.67 weevils). when toddy alone was offered, increase in the mean weevil count was seen with a total count of two weevils which is greater than the first week period which recorded one weevil. Pheromone alone, when used, there was no increase in the mean count in the second week.

In the third week Pineapple-pheromone differed significantly with the other treatments with a mean catch of weevils 12.67. Pheromone alone, Toddy-pheromone, CFR-pheromone and Pineapple alone were least significantly different. No weevils were caught in CFR and toddy.

During fourth week Pineapple-pheromone was significantly better than Toddy-pheromone and other treatments. The maximum weevil catch of 21.00 was recorded from Pineapple-pheromone. The Toddy-pheromone with a catch of four weevils was also significantly better when compared to other treatments. This trend continued for the fifth week also wherein Pineapple-pheromone recorded the highest weevil catch of 11.33 and Pineapple alone with no catch while Toddy-pheromone retained the efficacy with a weekly mean catch of four weevils.

The total weevil count for the sixth week showed that there was no difference between the treatments pineapple-pheromone and CFR. Pineapple-pheromone remained superior over the rest of the treatments with the mean weevil catch of 8.00 weevils and T_4 (CFR) with a mean catch of 1.33. CFR-pheromone and toddy alone showed least attraction with the total weevil catch of 0.33 each.

In the seventh week also T_1 (Pineapple-pheromone) recorded the maximum catch of five numbers and in pineapple alone it was only 0.67 and the T_6 (toddy alone) showed no catch.

During eighth week pineapple-pheromone and toddy-pheromone showed no significant difference and toddy-pheromone got the total mean of 9.33 weevils while pineapple-pheromone got a total mean of 7.67 weevils. During ninth week maximum catch of weevils were recorded in pineapple-pheromone trap which gave a total catch of 17.67; there was no catch in CFR. Pineapple-pheromone trap was significantly superior to all other treatments. Toddy-pheromone trap and pheromone alone showed no significant difference where as pineapple-pheromone, toddy-pheromone and pheromone alone were significantly different to other treatments.

The catch during tenth week showed that pineapple-pheromone trap was significantly better (11.67) than pheromone alone, toddy-pheromone,

CFR-pheromone, CFR, toddy alone and pineapple alone. Pheromone alone and toddy-pheromone showed no significant difference with the total catch in pheromone alone as 3.00 and toddy-pheromone and CFR-pheromone showed no significant difference among them, with the total weevil catch of 2.67 and 1.0 respectively.

In the 11th week the total weevil catch in pineapple-pheromone decreased to 9.33 from 11.67 during 10th week. But during 11th week, T_1 (Pineapple-pheromone) was significantly superior to all other treatments and toddy-pheromone, CFR-pheromone, toddy alone, pheromone alone, pineapple alone and CFR showed different degrees of attractions.

During 12th week (last week) the maximum catch of 1.33 weevils was obtained in pineapple-pheromone and during this week also all the treatments showed very less attraction.

4.3.2 Total male catch for three months period at weekly intervals

The weekly male weevil catch in different traps for 12 weeks period are depicted in Table 7.

During the first week, pineapple-pheromone and toddy-pheromone recorded the maximum weekly catch of male red palm weevils with 4.00 and 3.33 catches/trap respectively. All other treatments had significantly lower catches. No catch was recorded in CFR.

During the second week, after the first replenishment of the food material, maximum catch was obtained in CFR-pheromone. All other treatments recorded a relatively lower catch.

Table 6. Fortnightly catches of *R. ferrugineus* in Ferrolure traps with and without food attractants as influenced by the lunar phases

Pineapple-pheromone trap				Toddy-pheromone trap				Pheromone alone			
No moon		Full moon		No moon		Full moon		No moon		Full moon	
Weeks	Weekly mean weevils	Weeks	Weekly mean weevils	Weeks	Weekly mean weevils	Weeks	Weekly mean weevils	Weeks	Weekly mean weevils	Weeks	Weekly mean weevils
1st	7.67 (2.67)	3rd	12.67 (3.55)	1st	8.67 (3.02)	3rd	2.00 (1.55)	1st	1.67 (1.25)	3rd	3.67 (1.96)
5th	11.33 (3.42)	7th	5.00 (2.34)	5th	4.00 (2.09)	7th	0.33 (0.88)	5th	1.00 (1.17)	7th	0.67 (0.99)
9th	17.67 (4.25)	11th	9.33 (3.10)	9th	8.67 (3.02)	11th	3.33 (1.95)	9th	8.33 (2.88)	11th	0.67 (0.99)

Figures in paranthesis indicate transformed $\sqrt{x+0.5}$ mean

Table 7. Weekly catches of *R. ferrugineus* males in Ferrolure traps with and without food attractants

Treatments	Mean weekly catch of *R. ferrugineus*											
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	12th week
T_1	4.00 (2.04)	1.67 (1.35)	10.00 (3.14)	10.33 (3.19)	0.67 (2.41)	7.00 (2.41)	3.67 (2.03)	5.00 (2.32)	10.67 (3.32)	6.33 (2.45)	6.00 (2.45)	1.00 (1.09)
T_2	1.00 (1.17)	0.67 (0.99)	0.00 (0.70)	1.33 (1.29)	0.00 (0.70)	1.00 (1.09)	0.67 (0.99)	1.67 (1.35)	1.33 (1.26)	0.33 (0.88)	0.00 (0.70)	0.00 (0.70)
T_3	1.33 (1.34)	3.33 (1.79)	0.33 (0.88)	0.67 (1.05)	2.00 (1.47)	0.33 (0.88)	0.33 (0.88)	0.33 (0.88)	1.00 (1.17)	0.33 (0.88)	0.33 (0.88)	0.00 (0.70)
T_4	0.00 (0.70)	0.33 (0.88)	0.00 (0.70)	0.67 (1.05)	0.33 (0.88)	1.33 (1.34)	0.00 (0.70)	1.00 (1.17)	0.00 (0.70)	1.00 (1.09)	0.00 (0.70)	0.00 (0.70)
T_5	3.33 (1.93)	2.00 (1.47)	0.67 (1.05)	2.00 (1.52)	2.33 (1.56)	0.33 (0.88)	0.00 (0.70)	4.33 (2.16)	5.00 (2.33)	2.00 (1.42)	2.67 (1.76)	0.33 (0.88)
T_6	0.67 (1.05)	0.67 (0.99)	0.00 (0.70)	0.00 (0.70)	1.33 (1.34)	0.33 (0.88)	0.00 (0.70)	1.33 (1.26)	1.33 (1.26)	0.66 (0.99)	0.00 (0.70)	0.00 (0.70)
T_7	0.33 (0.88)	0.00 (0.70)	0.67 (1.05)	1.00 (1.17)	0.67 (1.05)	0.00 (0.70)	0.00 (0.70)	1.33 (1.26)	6.00 (2.48)	3.00 (1.78)	0.33 (0.88)	0.00 (0.70)
CD	0.6679	0.9579	0.7742	0.8396	1.3408	1.3411	0.4288	0.8466	0.8858	1.2666	0.6910	0.4627

Figures in paranthesis indicate transformed $\sqrt{x+0.5}$ mean

T_1 - Pineapple-pheromone trap; T_2- Pineapple waste alone; T_3- Coconut fronds-pheromone trap; T_4- Coconut fronds alone;

T_5 - Toddy-pheromone trap; T_6- Toddy alone; T_7- Pheromone alone-control

During third week, only pineapple-pheromone showed a good catch with a mean number of 10 red palm weevils while all other treatments recorded very poor catches of less than 1.00 weevil (mean) for the entire week.

In subsequent weeks, from fourth to twelfth, pineapple-pheromone showed consistently more catch ranging from 3.00 to 10.67 weevils per week except for fifth week with a catch of only 0.67 weevils.

4.3.3 Total female catch for three months period at weekly intervals

Total females caught in traps at weekly intervals was analysed and presented in Table 8.

During first week, toddy-pheromone recorded maximum mean weevil catch of 5.33 which was more as compared to others. Pineapple-pheromone gave a total of 3.67 and the least count was observed in CFR and Toddy alone which recorded 0.33 weevils each.

During second week onwards, pineapple-pheromone recorded the highest catch ranging from 1.00 to 10.67 upto seventh week. During eighth week maximum catch was recorded in toddy-pheromone with mean catch of 5.00 weevils. But this decreased during ninth week and pineapple-pheromone recorded maximum weevil catch of 7.00 and toddy-pheromone traps caught only 3.67 weevils. The trend continued upto 12th week and during 12th week, total weevil catch recorded was very low with 0.67 weevils in pineapple and 0.33 weevils each in pineapple-pheromone and CFR-pheromone traps.

Table 8. Weekly catches of *R. ferrugineus* females in Ferrolure traps with and without food attractants

Treatments	Mean weekly catch of *R. ferrugineus*											
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	12th week
T_1	3.67 (1.85)	4.00 (2.11)	2.67 (1.77)	10.67 (3.24)	4.67 (2.24)	1.00 (1.17)	1.33 (1.29)	2.67 (1.71)	7.00 (2.73)	5.33 (2.38)	3.33 (1.95)	0.33 (0.88)
T_2	1.67 (1.39)	0.00 (0.70)	0.67 (0.99)	0.67 (0.99)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.67 (0.99)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.67 (0.99)
T_3	0.67 (0.99)	2.33 (1.56)	1.00 (1.09)	0.33 (0.88)	0.67 (0.99)	0.00 (0.70)	0.00 (0.70)	1.33 (1.17)	1.33 (1.16)	0.67 (1.05)	1.00 (1.17)	0.33 (0.88)
T_4	0.33 (0.88)	0.00 (0.70)	0.00 (0.70)	0.67 (0.99)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.33 (0.88)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)
T_5	5.33 (2.40)	4.00 (2.11)	1.33 (1.34)	2.00 (1.48)	1.67 (1.38)	0.33 (0.88)	0.33 (0.88)	5.00 (2.09)	3.67 (2.03)	0.67 (1.05)	0.67 (1.05)	0.00 (0.70)
T_6	0.33 (0.88)	1.33 (1.17)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.33 (0.88)	1.00 (1.09)	0.00 (0.70)	1.33 (1.26)	0.00 (0.70)
T_7	1.33 (1.18)	1.00 (1.17)	3.00 (1.78)	1.67 (1.44)	0.33 (0.88)	0.67 (0.99)	0.67 (0.99)	1.00 (1.22)	2.33 (1.54)	0.00 (0.70)	0.33 (0.88)	0.00 (0.70)
CD	0.9399	0.8853	0.7769	1.0416	0.6465	0.5183	0.5343	1.1066	0.6804	0.4493	0.5801	0.4373

Figures in paranthesis indicate transformed $\sqrt{x+0.5}$ mean

T_1 - Pineapple-pheromone trap; T_2- Pineapple waste alone; T_3- Coconut fronds-pheromone trap; T_4- Coconut fronds alone;

T_5 - Toddy-pheromone trap; T_6- Toddy alone; T_7- Pheromone alone-control

4.4 Gravidity of females caught in traps

A perusal of the egg count as given in Table 9, revealed that pineapple-pheromone attracted more gravid females (with 304.33 eggs) followed by toddy-pheromone with 141.00 eggs laid under captivity. The food attractants viz., pineapple alone, coconut fronds and toddy alone when exposed alone without pheromone gave lower rates of egg deposition (i.e., 23, 10.67 and 16.33 respectively). At the same time pheromone alone gave an egg count of 56.67, which is considerably better in attracting the gravid female than the food substances exposed alone.

4.4.1 Cumulative count of the total weevils caught in traps at weekly intervals for 12 weeks

The cumulative count of the total weevils on each treatment at weekly intervals were analysed and depicted in Table 10. The table revealed that a total number of 119.00 weevils were recorded in pineapple-pheromone trap which is very high when compared to other treatments like toddy-pheromone which recorded 50.00 weevils over the 12 week period. The least catch was recorded in CFR which had a total mean of 6.00 weevils only.

4.5 Determination of the supplementary attraction of pheromone traps with UV light source

A perusal of the Table 11 revealed that when pineapple-pheromone was given, a total number of 20 weevils were trapped for the five weeks period and total males trapped was seven and females were 13. This showed that females are more attracted to ovipositing substratum.

Table 9. Efficiency of Ferrolure along with food attractants on fecundity of *R. ferrugineus* for the experimental period

Treatment	Mean	Performance ranking
T_1	304.33 (17.36)	1
T_2	23.00 (4.56)	5
T_3	64.00 (7.91)	3
T_4	10.67 (2.86)	7
T_5	141.00 (11.83)	2
T_6	16.33 (3.81)	6
T_7	56.67 (7.48)	4
CD	3.13	

Figures in paranthesis indicate transformed $\sqrt{x+0.5}$ mean value

T_1 - Pineapple-pheromone trap

T_2 - Pineapple waste alone trap

T_3 - Coconut fronds-pheromone trap

T_4 - Coconut fronds alone

T_5 - Toddy-pheromone trap

T_6 - Toddy alone

T_7 - Pheromone alone-control

Table 10. Weekly cumulative catches of *R. ferrugineus* in Ferrolure traps with and without food attractants

Treatments	Mean weekly catch of *R. ferrugineus*											
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	11th week	12th week
T_1	7.68 (2.67)	13.33 (3.60)	26.00 (5.08)	47.00 (6.88)	58.33 (7.88)	66.33 (8.14)	71.33 (8.44)	79.00 (8.90)	96.67 (9.83)	108.33 (10.42)	117.67 (10.86)	119.00 (10.91)
T_2	2.67 (1.64)	3.33 (1.93)	4.00 (2.06)	6.00 (2.50)	6.00 (2.50)	7.00 (2.72)	7.67 (2.85)	10.00 (3.22)	11.33 (3.44)	11.67 (3.49)	11.67 (3.49)	12.33 (3.58)
T_3	2.00 (1.52)	7.67 (2.82)	9.00 (3.01)	10.00 (3.21)	12.67 (3.55)	13.00 (3.59)	13.33 (3.63)	15.00 (3.90)	17.33 (4.18)	18.33 (4.29)	19.67 (4.44)	20.00 (4.48)
T_4	0.33 (0.88)	0.67 (1.05)	0.67 (1.05)	1.99 (1.46)	2.67 (1.57)	3.67 (1.87)	3.67 (1.87)	5.00 (2.29)	5.00 (2.29)	6.00 (2.46)	6.00 (2.46)	6.00 (2.46)
T_5	8.67 (3.02)	14.67 (3.89)	16.67 (4.14)	20.67 (4.59)	24.67 (5.01)	25.33 (5.07)	25.67 (5.07)	35.00 (5.96)	43.67 (6.64)	46.33 (6.85)	49.67 (7.08)	50.00 (7.10)
T_6	1.00 (1.17)	3.00 (1.79)	3.00 (1.79)	3.00 (1.79)	4.67 (1.86)	5.00 (2.29)	5.00 (2.29)	6.67 (2.57)	9.00 (2.89)	9.67 (3.07)	11.00 (3.26)	11.00 (3.26)
T_7	1.67 (1.25)	2.67 (1.56)	6.33 (2.42)	9.00 (2.96)	10.00 (3.18)	10.67 (3.19)	11.33 (3.38)	13.67 (3.70)	22.00 (4.66)	25.00 (4.94)	25.67 (5.02)	25.67 (5.02)
CD	1.1763	1.3304	1.3778	1.0913	2.1659	1.8221	2.2091	1.2041	1.6523	1.8474	1.8021	1.5226

Figures in paranthesis indicate transformed $\sqrt{x+0.5}$ mean

T_1 - Pineapple-pheromone trap; T_2- Pineapple waste alone; T_3- Coconut fronds-pheromone trap; T_4- Coconut fronds alone; T_5 - Toddy-pheromone trap; T_6- Toddy alone; T_7- Pheromone alone-control

Table 11. Influence of UV light on weevil catch in the pineapple ferrolure trap

Pineapple-pheromone trap				Pineapple-pheromone UV light trap			
Weeks	Male *R. ferrugineus*	Female *R. ferrugineus*	Total weevils	Weeks	Male *R. ferrugineus*	Female *R. ferrugineus*	Total weevils
1st	1	1	2	1st	0	0	0
2nd	6	1	7	2nd	1	1	2
3rd	0	6	6	3rd	6	6	12
4th	0	1	1	4th	8	6	14
5th	0	4	4	5th	21	8	29
Total	7	13	20	Total	36	21	57

When UV was supplemented as an additional source of attraction to increase the efficiency of pheromone-pineapple, there was an additive effect. A total number of 57 weevils were trapped for the five weeks period which is 2.85 times greater than the pheromone-pineapple alone. A total number of 36 males and 21 females were trapped which is greater than the corresponding treatments without UV, which recorded seven males and 13 females for five weeks period.

4.5.1 Determination of efficiency of relative heights of the pheromone exposure in the coconut garden

The results of the experiment presented in Table 12, showed that the maximum number of mean weekly catch was observed when the pheromone traps were exposed at one and two meter heights. The traps exposed at three, four and five meter recorded lower catches ranging from 3.5 to four weevils which were not significantly different among them at different heights. The catches obtained at lower heights viz. one and two meter heights with weekly catch ranging from 10-13 weevils were significantly higher than the catches at further heights above three meter.

There was a similar response with respect to both the male and female weevils also with higher counts at lower heights as compared to the response at higher heights. The maximum male count of 4.5 and maximum female count of 8.5 were recorded from the trap exposed at one meter height followed by four males and six females recorded at two meter height.

4.5.2 Behavioural/antennal response of red palm weevils under direct response of the pheromone

It was observed from the experimentation that both the male and female weevils responded to the pheromonal signals after 20 minutes of exposure under observation after switching on the pedestal fan in the corridor test. After 30

Table 12. Effect of different exposure heights on *R. ferrugineus* catches in the pineapple - ferolure trap (no./week/trap)

Weeks/meter	Male *R. ferrugineus* weekly total	Female *R. ferrugineus* weekly total	Total weevil catch
1	9 (4.5)	17 (8.5)	26 (13)
2	8 (4)	12 (6)	20 (10)
3	3 (1.5)	4 (2)	7 (3.5)
4	5 (2.5)	2 (1)	7 (3.5)
5	4 (2)	4 (2)	8 (4)

Figures in paranthesis indicate mean value

Behavioural response of Ferrolure to *R. ferrugineus* under corridor test

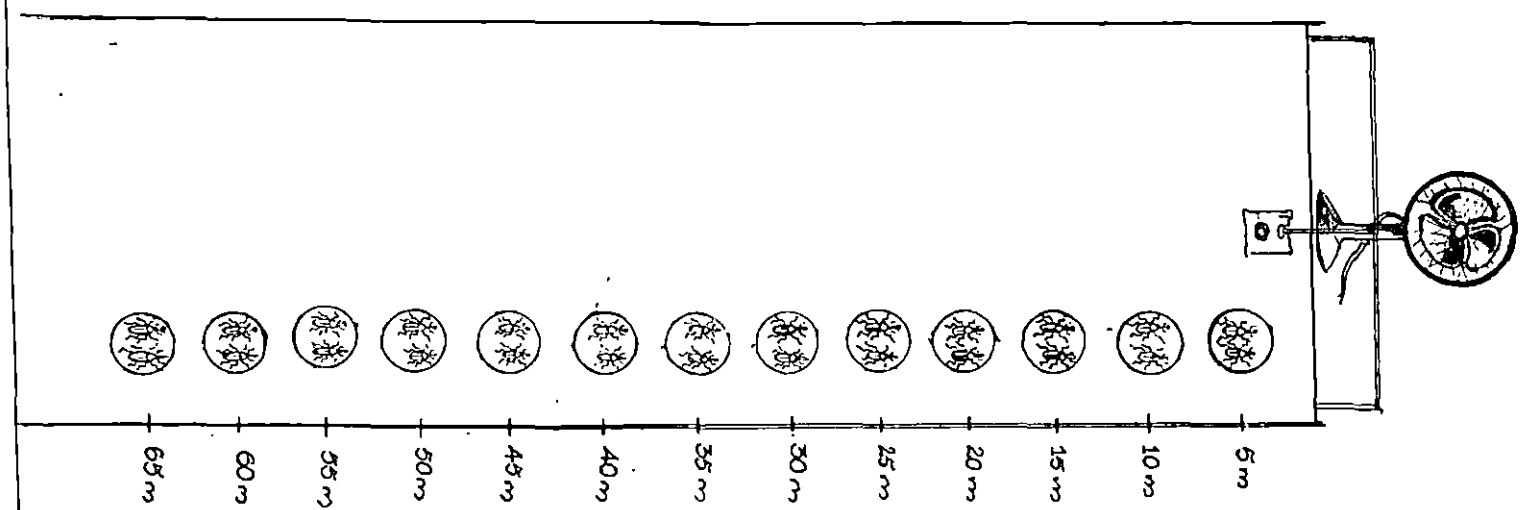


Fig: 3.

minutes, the weevils kept at distances of five meter and 10 m were showing alert movements within the petriplate while the weevils kept at 15, 20, 25, 30, 35, 40, 45, 50, 55, 60 and 65 m marks were showing random movement only(Fig. 3).

The weevils showing the alertness at five meter and 10 m marks were closely watched and it was found that the weevils moved at random initially and then orientated their position with the head and snout pointing to the pheromonal source rubbing the snout on the side of the petriplate. Later they raised their snout and the antennae started vibrating with swinging movements to left and right.

When sensitised weevils from the petriplates were released free and allowed to crawl on the corridoor floor, it was observed that the males moved at double the pace than the pace of female. They crawled towards the pheromone source and took to flight when they were at one meter distance from the pheromone source.

DISCUSSION

5.1 Survey of the red palm weevil in Thrissur district

Result on the survey was presented in chapter 4.1 and Table 1. It revealed that upland and coastal land recorded five per cent and 5.3 per cent infestations respectively and midland recorded highest damage of 7.6 per cent. From the survey it was determined that the average RPW infestation level was six per cent irrespective of the land regions and age of the palms. Lowest incidence and the highest incidence were found to be three per cent and 12 per cent in Thrissur district with a mean count of six per cent. The percentage of infestation was in agreement with the earlier reports of Ganapathy *et al.* (1992) who reported that the extent of damage by *R. ferrugineus* ranged from six to 34 per cent in Coimbatore, Tamil Nadu, India.

The percentage of attack was more in mid lands which is not in agreement with the reports by Shantappa *et al.* (1979) who found that *R. ferrugineus* is more severe in coastal areas of Kerala and Karnataka than in mid land and high ranges.

There is a progressive trend of RPW infestation along with the age of the palms. This trend is against reports that the weevil infestation was higher in palms belonging to the age groups of seven to 10 years (Nair, 1978). It may be that the infestation in older palms were not being properly detected and effective remedial measures taken in Kerala because of the peculiar shortage of skilled climbers and increased cost of labour which prevent the farmers from adopting timely measures as in earlier times. At the same time younger palms which recorded the lowest infestation rate of 3.33 per cent irrespective of the land regions showed that the damage on these palms were properly detected and taken care of. The damage on

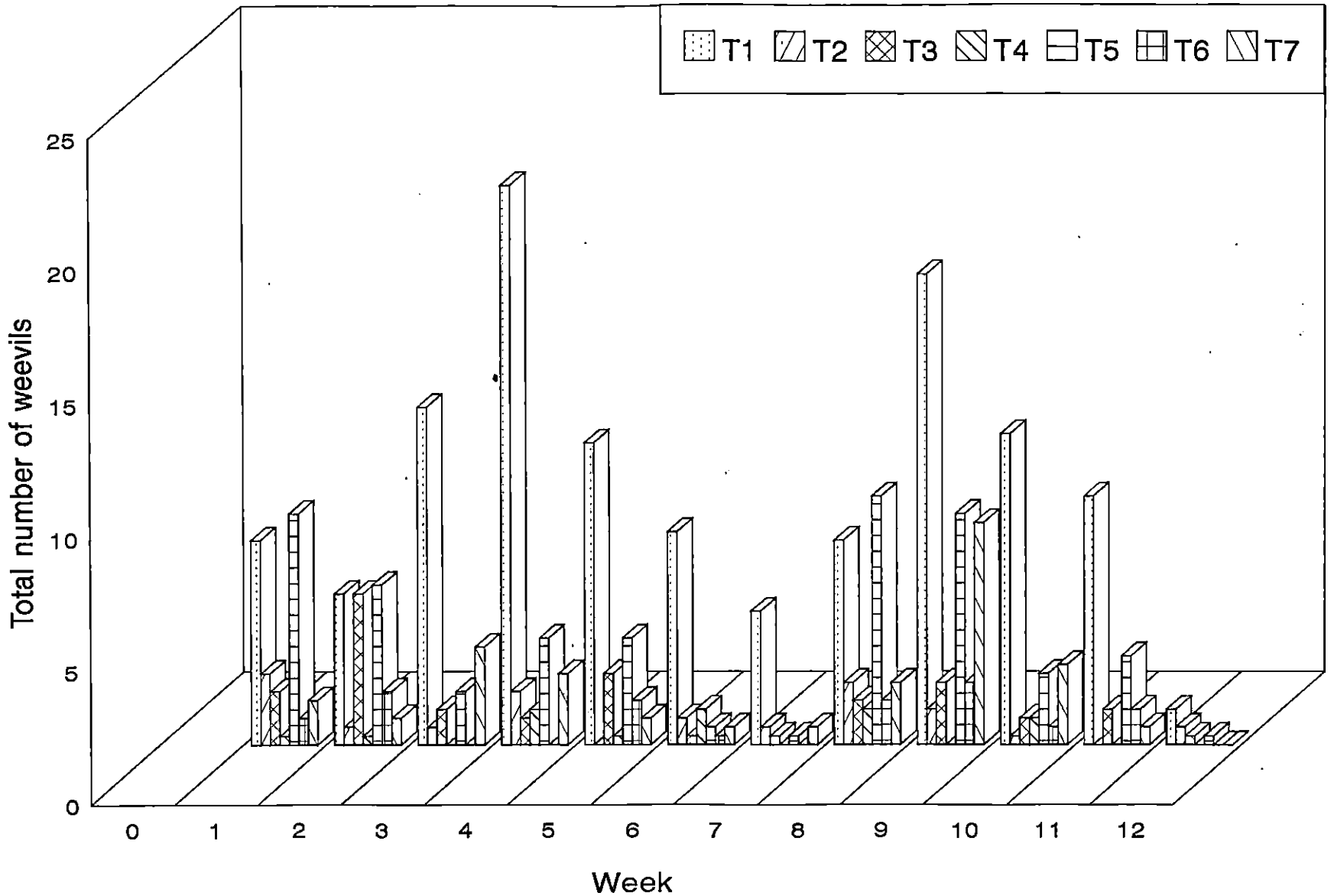


Fig.4. Total weevil catch for three months period at weekly intervals in pineapple-ferrolure traps

the younger groups of palms are almost at the same level in all the regions. Among all the age groups of the palms, maximum damage was recorded in the mid land region as this region is mainly consisting of paddy, banana and other field crops which consume the maximum labour and hence the poor attention on the plant protection side of the palms leading to higher incidence of RPW damage.

5.1.1 Determination of the relative efficiency of pheromone traps and various food attractants

The result presented in chapter 4.1.1 and Fig.4 revealed that pheromone along with the pineapple fruit was found to be more efficient than any other food or ovipositional source. The maximum weevil catch was recorded on fourth day of pineapple-pheromone exposure, which showed that putrification of pineapple is inversely proportional to the total number of weevils caught. The reduction of weevil catch is due to the rotting of pineapple. This showed that the food attractant pineapple have to be changed on fourth day. In the case of toddy maximum catch was observed on third day and there after showed decrease in the total weevils trapped which indicated that the maximum fermented odour was for upto third day and there after it ceases. Pineapple as a food attractant trapped 2.5 more weevils as compared to toddy. It also revealed that more males were caught in pineapple trap than the toddy trap which indicated that after perceiving a suitable food attractant males will release aggregation pheromones and for this odour more male and females will be trapped. This is also reported by Sanchez *et al.* (1996) that the secretion of aggregation pheromone starts approximately 10 minutes after the insect detects ethyl acetate and secretion continues for several hours.

Pineapple is more attractive since it contains ethyl acetate and ethyl propionate in the syncarp. Food attractant pineapple has only four days of active attraction after which the attraction is lost, either because it dehydrated or in many

cases got decayed giving out foul odour, which might have repelled the weevils by the presence of noxious gases. The more number of males attracted to traps showed that the pineapple along with the pheromone is more a male aggregation type than the females. This trend was reported by many workers (Hallet *et al.*, 1993a, b, Moura *et al.*, 1997, Oehlschlager *et al.*, 1992, 1993, Perez *et al.*, 1994a, b, Falerio *et al.*, 1998) as a typical male aggregation pheromone.

On comparison it was found that pineapple was more attractive to the weevils than that of toddy both in terms of number of weevils attracted as well as period of efficacy by one day. However, it was found that females were more attracted to toddy than males which might be due to the preference of female weevils to a substrate which satisfy the requirements of food and oviposition as cued by natural substances like toddy indicating the presence of the substrate coconut based material as a natural base. This might be the reason that the coconut stumps and coconut wood locked traps gave better attraction when soaked with fermenting toddy which served both as food and oviposition attractant. Therefore it can be inferred that both pineapple and toddy mud could be used as an effective attractant eventhough pineapple performs better with longer efficacy.

5.1.2 Influence of sex factor on trap efficiency

5.1.3 Total male and female catch for three month period

Total male and female catch for three months period is presented in chapter 4.2.1 and 4.2.2 of results, respectively. From this result it can be inferred that pineapple with pheromone attracted more male weevils as compared to pheromone with toddy. It shows that the ethyl acetate content in the pineapple is more attractive to males. Whereas it is less attractive to females than males. But toddy has got the same attraction power to both male and females.

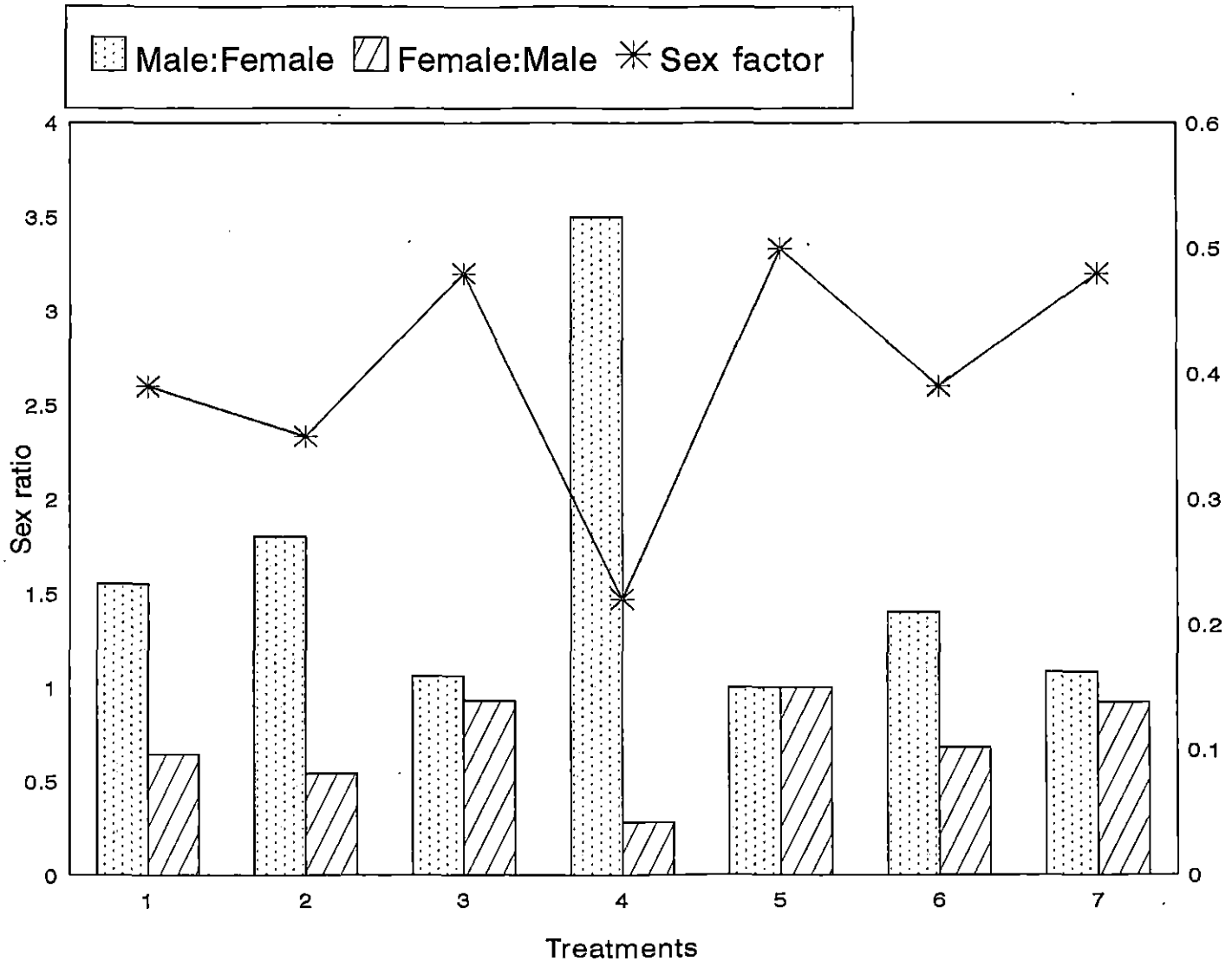


Fig.5. Influence of Ferrolure on the sex ratio of *R. ferrugineus*

In all the treatments except toddy, more males are trapped with higher male:female ratio or rather low female:male ratio (Fig.5). The male:female ratio is almost 1:1 in the case of fermenting toddy with pheromone trap which corroborates with earlier observation of more attraction of female to an attractant viz., the fermenting toddy which brings out the cues of both a food source and an ovipositional site. The general trend as indicated the male:female ratio of more than one in all the treatments shows that the pheromone is more a male aggregation pheromone and secreted by the males as reported by Hallet *et al.* (1993).

5.2 Influence of weather elements on trap efficiency and population dynamics of red palm weevil

The weather data for the experimentation period is presented in Fig.6.

During the period under observation (26-2-98 to 20-5-98) there was not much marked fluctuation in the weather elements viz., the maximum temperature, minimum temperature and RH. However, wind speed, sunshine hours and precipitation were showing a little variation but were not found to be influential in affecting the weevil catch in traps towards the end of the experimental observation period. However, low sunshine hours due to overcast skies followed by the precipitation, which coincided with ninth, tenth and 11th weeks resulted in steady catches of the weevil positively because of the retention of the freshness of the food attractant due to low drying of food material. The experiment could not be conducted further in the rainy season because of the expiry of the pheromonal efficiency. Efficacy and attractive power of the pheromones decreases along with the increasing expiry period but however efficacy is still maintained by the weather conditions with decrease in sunshine hours but with increasing precipitation from eighth week onwards. The speed of volatilization of pheromone with low temperature and high humidity might have maintained the trapping efficiency.

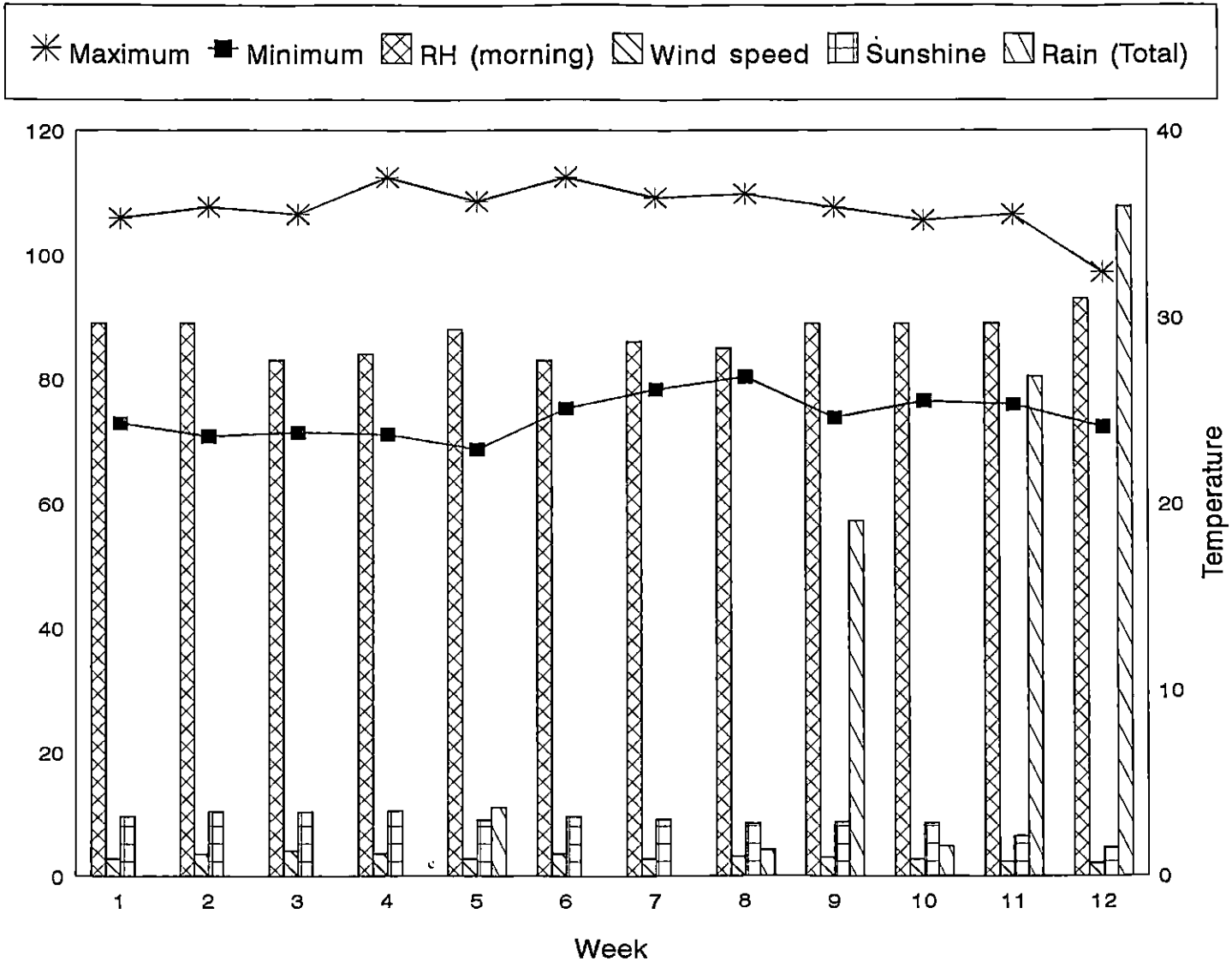


Fig.6. Weather data for the experimental period (26-2-98 to 20-5-98)

5.2.1 Influence of lunar phases

As in the light trap catches it was found that there was an influence upon the weevil catches in the pheromone traps by the lunar phase. The presence of the lunar light during night was found to reduce the number of catches in the traps especially with pheromone alone, pineapple-pheromone and toddy-pheromone. This phenomenon might be due to distracted orientation in the presence of nocturnal light. The darkness during the no moon days gave appropriate orientation to the pheromonal signals resulting in more catches.

5.3 Total male catch for three months period at weekly intervals

From the results which is presented in chapter 4.3.2 and graphically in Fig.7; it is clear that pineapple-pheromone attracted more male weevils. The second best treatment was found to be toddy-pheromone which recorded better efficiency of the weevil with 4.33 and five mean weevils per week respectively. This was because toddy mud lost its attractiveness on successive days due to fermentation. It was only when fresh toddy was added that attractiveness for males increased. Increased count of yeast in such toddy make the fermentation of the fresh toddy much faster, facilitating increased attraction.

When compared to pineapple and toddy, coconut frond was not showing any consistent attraction of the weevils. Therefore frond pieces are not found to be suitable as a food attractant for the weevil because of the faster dehydration and no changes due to fermentation.

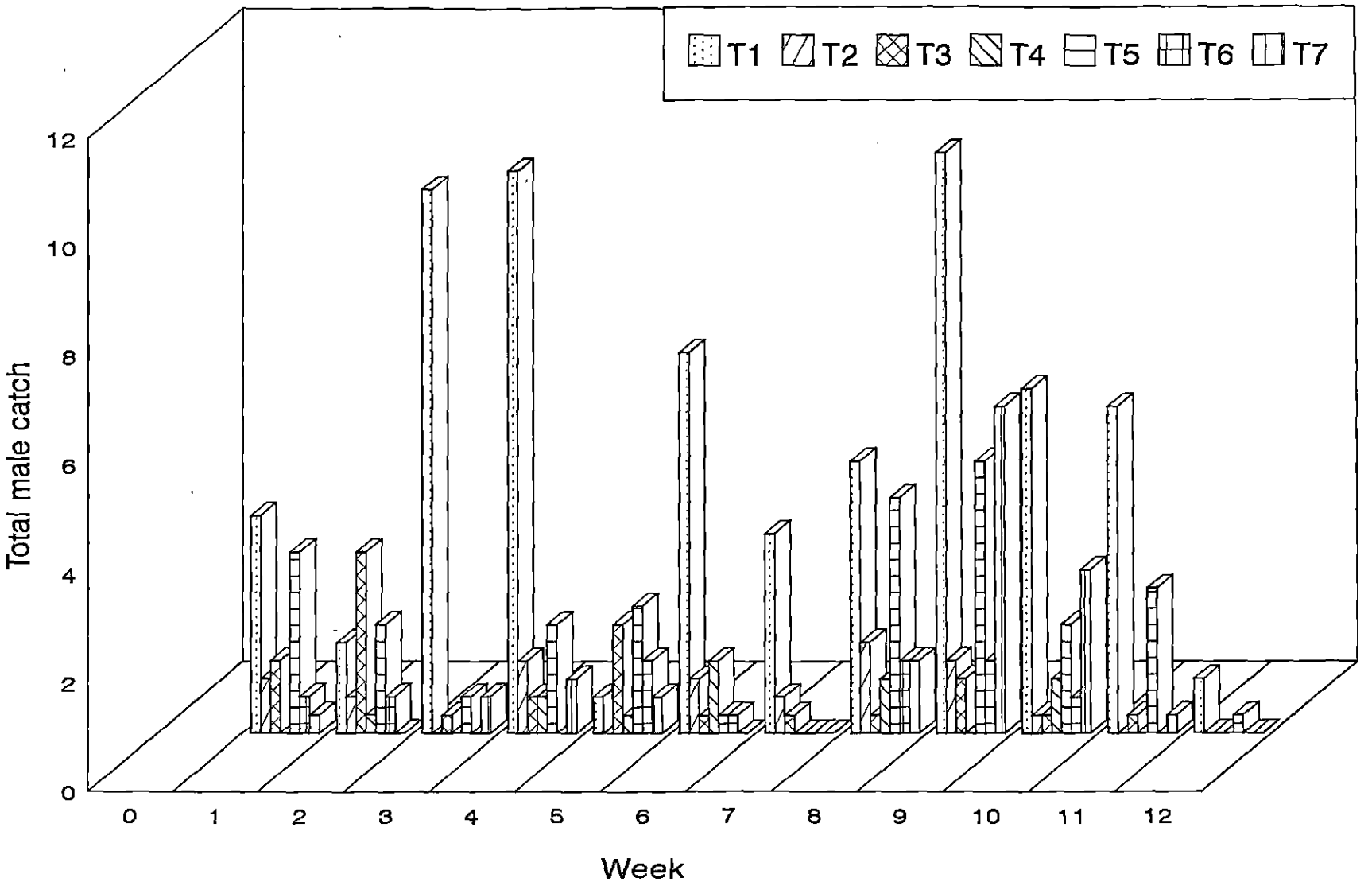


Fig.7. Total males caught in traps at weekly intervals to Ferrolure

5.3.1 Total female catch for three months period at weekly intervals

From the results depicted in chaper 4.3.3 and graphs represented in Fig.8 it was clear that males were more attracted towards the toddy-pheromone for the first two weeks whereas from third week onwards pineapple-pheromone was found to be the best.

Comparing the total male catch and total female catch for the three months period, it could be observed that the male weevils are attracted more towards a food source like pineapple while the female weevils prefer to go for a source which serve both as a food as well as a site for oviposition cued by an attractant like toddy.

5.4 Gravidity of females caught in traps

The result revealed that the pheromone + food substance is more capable of attracting gravid females than the food attractant alone. Between the food substances, pineapple in both cases of exposure gave higher count of gravid females. Pheromone alone is more efficient than the food attractants alone in order to attract sexually mature females about to mate and oviposit.

5.4.1 Cumulative count of the total weevils caught in traps at weekly intervals

Cumulative count of the total weevils caught in traps at weekly intervals is graphically presented in Fig.9. Comparison of the treatments with pheromones along with the attractants showed that for the first two weeks there was no significant attraction among all the treatments. Therefore it could be inferred that the response to the pheromone and attractants was expressed from third week of exposure only and from third week onwards there is a steady increase in the catch in

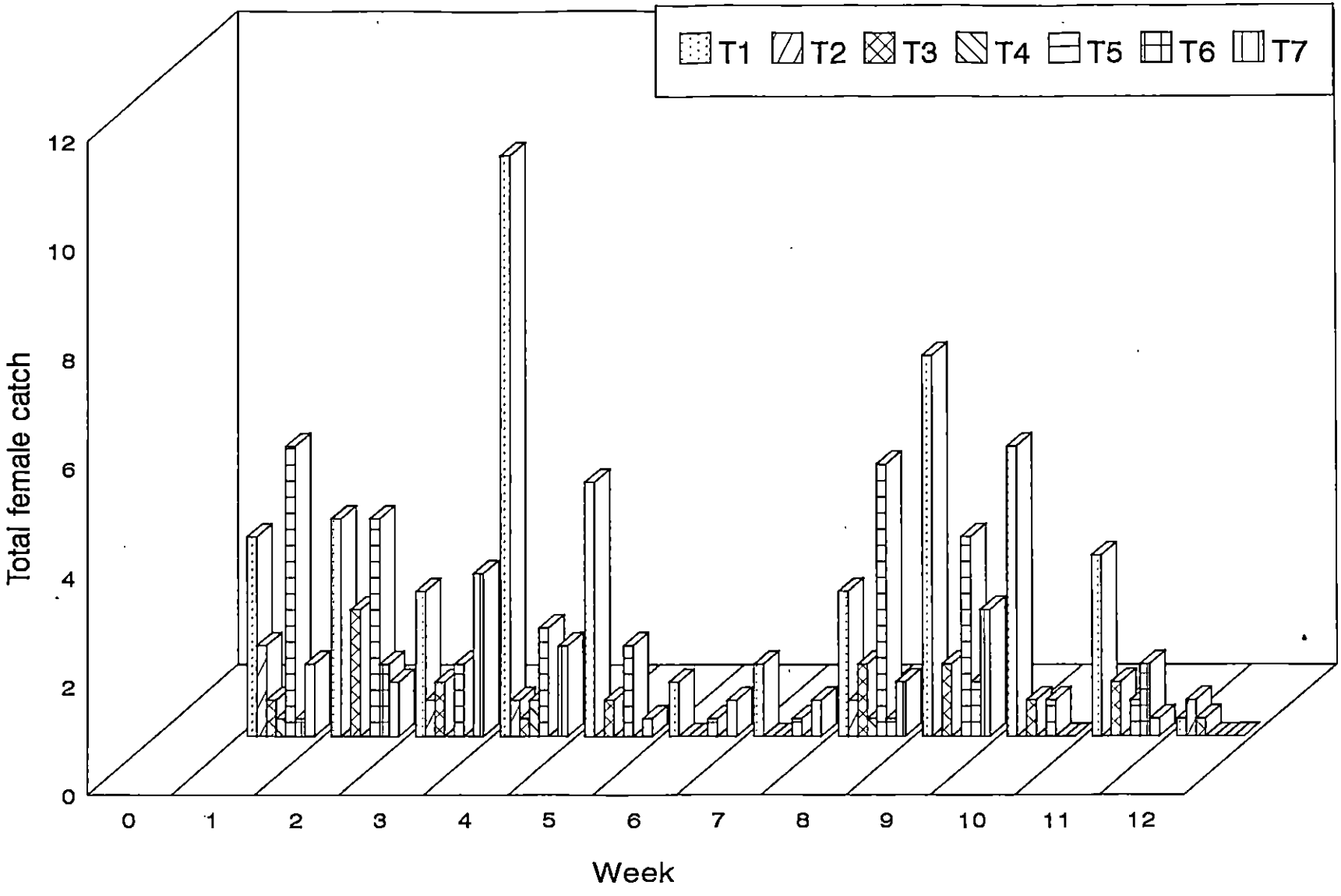


Fig.8. Total females caught in traps at weekly intervals to Ferrolure

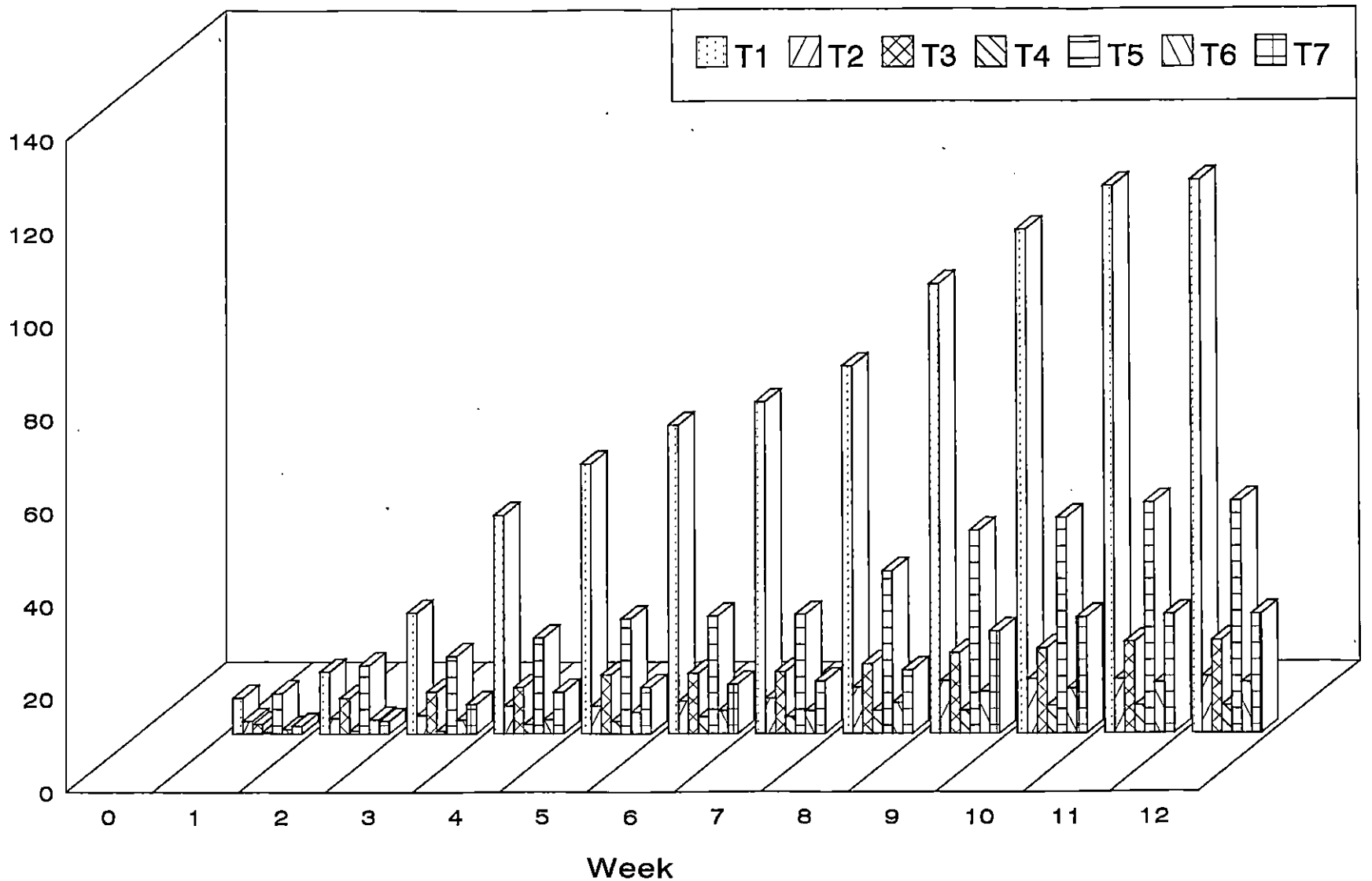


Fig.9. Cumulative count of the total weevils at weekly intervals to Ferrolure

all the pheromone traps. But the treatment pineapple-pheromone as a food attractant surpassed all others in giving higher catches and maintaining the trap efficiency upto 11th week and there after no catch was obtained so that pheromone was found to be performing its attractiveness upto 12 weeks. The same trend was shown by the second best attractant toddy-pheromone also but was only less than half efficient to that of pineapple-pheromone. Eventhough the catch efficiency was less than half to that of pineapple, here again the pheromone efficiency was retained upto 12 weeks. The persistence of the pheromone could also be observed without any attractants till 12th week but the efficiency of the weevil catch was very low. The total weevil catch in the traps with various food attractants showed that there is some attraction to the food sources but this was not of significance as compared to the catch obtained in traps fortified with pheromone.

5.5 Determination of the supplementary attraction of the pheromone traps with UV light traps

The result presented in chapter 4.5 revealed that there was added advantage when UV light is kept along with pineapple-pheromone trap. There was a marked increase in the total number of weevils caught and it is also seen that males were more attracted to UV than the females.

UV influenced the catch by 2.85 times than that of the trap without it. The results prove that UV has got an added advantage and therefore UV could be used to trap the weevils in higher infestation zones along with the pheromone and the preferred food attractant pineapple.

5.5.1 Determination of efficiency of relative heights of the pheromone exposure in the coconut garden

The results revealed the maximum response of the weevil catch at lower height viz., between one and two meter above the ground level which again proved that RPW adults are weak fliers with maximum flight range of one to two meter. El-Garhy (1996), also reported the same response of the flight range at one to three meter above the ground level. And therefore, the traps should be sett at an average height of 1.5 m above ground level to have maximum trapping efficiency. As it is an aggregation pheromone both males and females are attracted.

Summary

SUMMARY

The red palm weevil is the most fatal pest of coconut leading to the permanent debility or death of the palms. Most of the available methods are curative in nature wherein early and timely detection and adoption of measures can only save the palms. Detection at the later stages of the weevil attack cannot save the palms. Therefore, it has become imperative to develop alternative and cost effective trapping devices and techniques to monitor and bring down the population to prevent higher mortalities of the palms. Synthetic pheromone has been developed for attracting the red palm weevil (Hallet *et al.*, 1993a). Suitable pheromone dispensation techniques and trapping devices are yet to be evolved. At present the most widely used pheromone lure in palm weevil management is *Ferrolure* manufactured and supplied by Chem Tica Naturals, Costa Rica (Falerio *et al.*, 1998).

This pheromone is evaluated along with suitable trapping techniques and food attractants under the peculiar conditions existing in Kerala. In this context a study was conducted with the specific objectives such as

1. Survey of the red palm weevil infestation in Thrissur district,
2. Design of a suitable trapping device for testing the efficiency of the pheromone,
3. Determination of the efficiency of the pheromone in combination with various food attractants,
4. Determination of the supplementary attraction of pheromone traps with UV light traps,
5. Determination of efficiency of relative heights of the pheromone exposure in the coconut garden,
6. Behavioural response of red palm weevil to the pheromonal communication.

A preliminary survey conducted representing three geographical areas in the Thrissur district revealed that on an average six per cent of palms were destroyed in the district irrespective of the regional distribution, age of the palms and management practices. It was also found from the survey that the older palms above 30 years of age were having the maximum damage, probably because of the peculiar socio-economic problems of Kerala while the younger palms, even though they are susceptible to red palm weevil attack, were found to be better protected.

A suitable, reliable and cost effective bucket trap was developed and fabricated ensuring the maximum retention of the trapped weevils with one way entry. Pheromonal efficiency and trapping along with different food attractant was evaluated to find out that pineapple waste cheaply available throught in Kerala gave the maximum performance in the weevil catch.

The pheromone along with food attractant in the bucket trap when exposed at one to two meter height above the ground level in the coconut plantation gave the maximum weevil catch. This could be easily installed in the plantation with minimum cost and labour on the palm trunk itself.

The pheromone efficiency was found to be expressed from the third week after installation and was found to be retaining its efficacy for 10 weeks and thereafter efficacy stopped completely by the 12th week. The maximum efficiency of trapping was observed during nine weeks of exposure with pheromone and food attractant.

Experiments revealed that the food attractant once exposed should be changed once in four days to maintain the pheromonal efficiency.

Comparison of the various food attractants showed that toddy can also be substituted for pineapple waste but with lesser efficiency. Coconut frond pieces cannot be used as an effective attractant material as it is very poor in its attractiveness. The pheromone alone when exposed is not very attractive unless it is fortified provisioned with preferred food source.

Both male and female weevils are attracted to the pheromone trap with a preponderance male weevils proving that ferrolure is predominantly a male aggregation pheromone.

The attracted females were found to be gravid ones as evidenced by their oviposition under captivity. Thus, mated females with gravid eggs could be attracted to the pheromone and mass destroyed, proving the use of the traps in reducing the weevil attack.

The preliminary studies to improve the efficiency of pheromone trapping showed that in the presence of UV light source, 2.85 times more catch of weevils were obtained than that of the bucket trap with pheromone and food material alone. Hence the UV light has an additive effect to improve the weevil catch in the pheromone trap.

The direct olfactory response of the weevil to the pheromonal signals under the simulated wind tunnel test when observed by the behavioural response of antennal vibration, flexing of the snout and directional mobility of the weevils proved that the effective range of attraction is five meter and that too were evinced by the male weevils. The weevils were found to be responding to the pheromonal signals showing a random movement at a distance of 10 m away from the source. It was found that the pheromones took 20 minutes time to evince a positive taxis in the males where as it took 30 minutes for the females.

In conclusion the experimental observation proves the overall efficacy of the ferrolure with pineapple as a food attractant coupled with the bucket trapping device. Exposure at one to two meter above the ground level installed in the plantation gives good performance in trapping the male and female adult weevils for an effective period of nine to 10 weeks. A good number of weevils could be trapped which will probably reduce the damage of this weevil below the existing six per cent of damage. Food substance should be changed periodically at an interval of four days to retain the efficiency.

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TRAPPING OF RED PALM WEEVIL

Rhynchophorus ferrugineus F (Oliv.)

IN COCONUT GARDENS

By

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ABSTRACT OF A THESIS

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ABSTRACT

Experiments were undertaken in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 1997-1998 to evaluate the efficacy of the male aggregation pheromone *Ferrolure* (4-Methyl-5 nonanol) in mass trapping the redpalm weevil of coconut *Rhynchophorus ferrugineus* F (Oliv.) in the coconut plantations of Thrissur district.

A survey was conducted in Thrissur district in three regions representing three geographical zones viz., coconut plantations in coastal zones, midland regions and upland conditions with the respective red palm weevil damage incidence of 5.33 per cent, 7.66 per cent and five per cent with an average incidence of six per cent.

A convenient and suitable bucket trap was designed and fabricated for the mass trapping of the adult weevils from the field and for further laboratory experiments.

Out of the different food attractants tried pineapple waste and toddy gave increased trapping efficiency of the weevils with the pheromone sachet. The food attractants was necessarily to be renewed afresh once in three to four days interval so as to keep the trap effective. At this rate of change of the food attractant a single pheromone sachet was found to be actively performing to trap the weevils for a period of 10-12 weeks.

The *Ferrolure* tried was found to be predominently a male aggregation pheromone but with reasonable attraction to female weevils as well.

The best exposure height of the pheromone trap was at a height range of one to two meters from the ground level within the coconut plantations to offer maximum trapping efficiency.

An UV light source at night was found to supplement the weevil trapping along with the pheromone trap giving 2.85 times more catch.

In conclusion the experimental observation proves the overall efficacy of the ferrolure with pineapple as a food attractant coupled with the bucket trapping device. If the traps are installed at one to two meter above the ground level in the plantation, this gives good performance in trapping the male and female adult weevils for an effective period of nine to 10 weeks. A large number of weevils could be trapped which will probably reduce the damage of this weevil below the existing six per cent of damage. Food substance should be changed periodically at an interval of four days to retain the efficiency.