MASS TRAPPING OF THE SWEET POTATO WEEVIL, *Cylas formicarius formicarius* Fabr (COLEOPTERA: CURCULIONIDAE) MALES USING SEX PHEROMONE

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **Mass trapping of the Sweet Potato Weevil, Cylas formicarius formicarius Fabr (Coleoptera Curculionidae) males using sex pherorone** is a bonafide record of 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 associateship and other similar title of any other University or Society

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To my parents

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Introduction

INTRODUCTION

Sweet potato (Ipomea batatas (L) Lam) is one of the world s highest yielding crops and is grown over a wide range of agroclimatic conditions It is an important crop to exploit in a world of rising population and fixed area for food product ion It exceeds almost all food crops in productivity per unit time and ranks seventh in terms of production in the world (Anon, 1982 b) Apart from being the staple food for the poor the tubers are also used as animal feed and to a limited extent as raw material for industrial starch production Sweet potato is nutritionally important not only for its high calorific value but also for its rich vitamin and mineral contents

Asia accounts for more than 80 per cent of the world s annual production of 102 m tonnes with the Indian share being 1 5 m tonnes Among the States, Kerala enjoys seventh and sixth positions respectively in terms of tuber yield and area The productivity of the crop in India is reported to be 7 5 ton ha^{1} which is about half of the world productivity while Kerala produces 6 6 ton ha^{-1} on an average (Anon 1985)

One of the main reasons for the low productivity is the pest attack In India at least 20 species of insects and 17 species of mites are reported to cause varying degrees of economic loss both in the field and in store wherever the crop is grown Among the pests, the havoc caused by the weevil Cylas formicarius

formicarius F is the most important one and is chiefly responsible for reduction in yield Several species of sweet potato weevils have been recognised as the most destructive pests of the plant all over the world

The high damage potential of this pest invited attention of the plant protection technologists from very early times and several control measures had been recommended against the pest It was with the advent of synthetic insecticides chemical control was given more emphasis The application of chlorinated hydrocarbons to the soil remained as an accepted technology for a long time for fighting the pest The realisation of the deleterious effects of the long persistence of these chemicals in the soil ecosystem led to banning of these chemicals in many tropical countries Further, the ever escalating and prohibitive cost of pesticides and the high application costs for the repeated sprays recommended curtailed the scope of adoption of this crop protection technology in the developing countries High input pest control in particularly irrelevant for a less remunerative crop grown in marginal lands

It is realised that there is an urgent need to evolve a pest management programme of *C formicarius* which is ecofriendly and yet be able to curtail the losses due to the pest Currently a reliable monitoring system for the SPW is lacking Because of its concealed mode of life history the pest is difficult to detect and manage There is a considerable interest world over to develop a pheromone trap monitoring system and management programme for _C formicarius_ Coffelt _et al_ (1978) were the first to bioassay a female produced sex pheromone of _C formicarius elegantulus_ that attracted only males Heath _et al_ (1986) isolated characterised and synthesised the sex pheromone of _C formicarius elegantulus_ which was found to attract males of _C formicarius formicarius_ by Talekar (1983) The pheromone was synthesised by scientists of the Regional Research Laboratories of the CSIR at Trivandrum in 1989

The present study was conducted by using the RRL synthesised pheromone with the following objectives

1 To study the effectiveness of three doses of indigenous pheromone in mass trapping the males of sweet potato weevil in the field

2 To assess the impact of mass trapping of the male weevils on the population build up of the pest in the field

3 To design and fabricate low cost traps using locally available materials and to ascertain their influence on the effectiveness of pheromone and

4 To assess the effectiveness of the pheromone in terms of range of attraction to the male weevils

Review of Literature

REVIEW OF LITERATURE

The literature available on the distribution nature and extent of damage to sweet potato and biology of _C formicarius_ and also the use of sex pheromone for monitoring and management of the weevil are briefly reviewed in this chapter

2 1 Distribution

The sweet potato weevil was first recorded in India as _Brenthus formicarius_ F in 1798 (Pierce 1940) It was renamed as _Cylas formicarius_ F by Schoenherr in 1883 (Kissinger 1968) According to Sutherland (1986) only _C formicarius elegantulus_ was found in the western hemisphere

The occurrence of the weevil was reported from more than fifty countries (Anon 1970) and it was found from West Africa to East Africa and in South Africa Eastern Australia Bangladesh Madagascar Mauritius The Seychelles India Srilanka China Papua New Guinea The Solomon Islands Hawaii Samoa Fiji The Caroline Gillbert and Mariana Islands Mexico South East Asia and Venezuela (Hill 1975) Brazil and Central America (Onwuene 1978) Sorensen (1984) observed that the pest occurred in all the sweet potato growing areas in the five continents of the world

In India, the weevil was reported from sweet potato growing tracts of Maharashtra (Trehan and Bagal 1949) Tamil

Nadu (Subramanian 1959) Karnataka (Jayaramaiah 1975) Uttar Pradesh Bihar West Bengal and Orissa (Anon 1983) and North Eastern Complex of India (Barwal 1985)

2 2 Nature of damage

Sweet potato weevil attacks vines and tubers in the field and in storage resulting in quantitative and qualitative losses

2 2 1 Quantitative losses

Adults of C formicarius feed on the leaves tender buds stems root and tubers while larvae feed on vines and tubers only (Rajamma 1983) The infestation generally starts in the crown region and spreads upwards or downwards In a severely infested field the attacked vines possess much less foliage and are thickened about the collar (Subramanian 1959) The grubs bore into the plant parts and feed by making irregular tunnels which get filled with excreta (Reinhard 1923) As a results of feeding by the grubs the collar region of the vine shows malformation and hypertrophy of tissues and in severe cases the vigour and growth of the plant are affected At times the plant breaks off at the collar region (Edmond 1971 Pillai et al 1987)

2 2 2 Qualitative losses

Sweet potato weevil infestation causes characteristic terpenoid odour in tubers which render them bitter in taste and unpalatable (Akazawa *et al* 1960 Uritani *et al* 1975) The attacked tuber will show a number of holes on the surface and on opening it will be found badly riddled and numerous grubs pupae and just formed adults will be noticed inside the tunnels The infested tubers emit a disgusting odour (Subramanian 1954) Sato *et al* (1977) found that larvae feeding in sweet potato roots induced the formation of a terpene phytoalexin which caused the bitter taste The chemical was later identified as ipomea marone (Sato *et al* 1981) Terpene phytoalexin was seen produced by the feeding of adult weevils also (Sato *et al* 1982)

2 2 3 Secondary infections

Utsu (1940) found that the weevil incidence in tubers favoured the infection by a fungus *Ceratocystis fimbriata* (Eill and Halst) which aggravated the damage and the fungus was found to be transmitted by the weevil

2 3 Extent and Intensity of damage

The extent of damage reported from different sweet potato growing countries showed wide variations The extent of tuber damage was estimated as 48 per cent in Formosa (Fukuda 1933) 10 to 20 per cent in Ha waii (Sherman and Tamashiro 1954) 38 per cent in Puerto Rico (Walcott and Perey 1955) 50 per cent in the Solomon Islands (Anon 1982) 10 to 50 per cent in the Philippines (Esguerra 1982) 53 per cent in Taiwan (Anon 1984) and 2 to 42 per cent in Nigeria (Anon 1986b) Mullen (1984) found significant tuber yield loss due to the weevil incidence and that the reduction extended upto 69 per cent Sutherland (1986b) observed that the infestation of vines by the weevil reduced the vigour of the plant and tuber yield

However Cockerham et al (1954) Hahn and Leuschner (1981) and Talekar (1982) observed that the incidence of C formicarius did not cause any significant reduction in total yield

In India the extent of tuber damage was reported to range from 17 to 70 per cent at Coimbatore (Subramanian 1959 and Subramanian et al 1977) 16-40 per cent at Bangalore (Jayaramaiah 1975) 41 per cent in Bihar 53 per cent in Orissa 6 7 per cent in West Bangal and 8 8 per cent in UP (Anon 1983) The mean percentage of damaged tubers at harvest ranged from 54 to 78 7 32 to 58 3 and 40 to 67 8 respectively in the 3 seasons in Kerala (Rajamma 1983) Pillai et al (1987) reported that the yield loss ranged from 4 to 82 per cent at Trivandrum

2 4 Biology of C formicarius

The biology of the pest has been reviewed by Mullen (1981) Rajamma (1983) Sutherland (1986a) and Pillai et al (1987)

2 4 1 Egg

Adult female lays cream coloured eggs (0 71 x 0 40 mm) singly in vines or tubers A cavity 1 4 mm deep and 0 4 mm wide is excavated by the female (Jayaramaiah 1975) Tubers are preferred oviposition sites (Strong 1938 Subramanian 1959) After oviposition the egg cavity is sealed with a grey faecal plug that preserves moisture protects the egg from predacious mites and also disguises the location of the oviposition site (Sherman and Tamashiro 1954) The egg stage averaged 7 7 days (Cabrera et al 1990) The number of eggs laid varied from one to nine per day and a single female could lay 24 340 eggs in its life span (Mullen 1981 Rajamma 1983 Sutherland 1986 and Pillai et al 1987)

2 4 2 Larva

Several workers have noted five larval instars (Gonzales 1925 Subramanian 1959 and Jayaramaiah 1975) However four instars have also been reported (Fukuda 1933) None provided statistical evidence to support their claims Sherman and Tamasiro (1954) after detailed measurements of 964 larval head capsules demonstrated three larval instars and concluded that frequent handling of larvae would interfere with feeding and increase the number of instars

The larva is apodus and creamy white in colour with moderately curved body (Subramanian 1959) It feeds and develops within the vines and tubers of sweet potato (Sutherland 1986a) The larval duration ranged 16-58 days (Rajamma 1983) depending on temperature According to Cabrera *et al* 1990 the duration was 28 days

2 4 3 Pupa

Pupation occurs in a small chamber prepared by the final instar larva Some workers have recorded a pre pupal stage (Reinhard 1923 Sherman and Tamashiro 1954 Subramanian 1959) The pupa is white and measures 1 5 mm The oupal stage ranged from 4 to 15 days (Rajamma 1983) and averaged 7 2 days (Cabrera *et al* 1990)

2 4 4 Adult

After emerging from the pupal case, the teneral adult remains within the pupal chamber or larval tunnel for six to nine days It emerges from the vine after attaining full duration and does not develop normal cuticular hardness until after it has started feeding (Reinhard 1923) The adults have a bluish black head with reddish brown thorax the elytra are of the same colour as the head and the body The beetles feign death when disturbed (Jayaramaiah 1975)

2 4 4 1 Sexual dimorohism

Adults may be conveniently sexed by the shaoe of the distal antennal segment which is filiform in males and clavate like in females (Nair 1975 Sutherland 1986a)

2 4 4 2 Adult longivity and duration of life cycle

The total life cycle from egg to adult ranged from 23 to 52 days (Rajamma 1983) The life cycle occupying 23 2 to 24 7 days in February May 26 2 to 26 5 days in June to September and 27 0 to 29 1 in October to January Adult longivity ranged from 96 to 113 days with food and about a week without food (Mullen 1984 Sutherland 1986a and Pillai et al 1987) The optimum temperature for development is between 27 and 30°C where the complete life cycle takes approximately 33 days The mean longivity for adults at 27°C and a relative humidity of 60 per cent is 93 5 days (Mullen 1981)

2 4 4 3 Oviposition

Breeding took place throughout the year Oviposition took place both during day and night (Dhingra, 1990) Sex ratio was 1 1 (Mullen 1984 Sutherland 1986a Pillai et al 1987) The observed pre-oviposition and oviposition periods were in general 4 to 9 and 63 to 120 days respectively

2.5 Incidence of *C formicarius* at different growth stages of sweet potato in field

2 5 1 Vine

Remoroza (1978) based on the weevil population studies in the Philippines, observed that six week old plants were more suitable for the weevil development and multiplication than younger or older plants while Sanchez (1981) and Sanchez *et al* (1984) observed that 8 to 11 week old plants were preferred for the development Weevils were more abundant in vines between June and August (Jansson *et al* 1990)

2 5 2 Tuber

Hua (1970) observed higher population of the weevil in tuber from 50 days after planting in Malaysia From Kerala, higher incidence was reported at 70 to 80 DAP (Rabindranath 1979) Eusebio (1983) noted that though the weevil was present in the field as early as 30 DAP it was noticed in the roots only from 44 DAP The weevils were more abundant in below ground plant tissues during September and October (Jansson *et al* 1990)

Sherman and Tamashiro (1954) showed that damage increased sharply between 24 to 30 weeks Sutherland (1986b) demonstrated that at low levels the relationship between damage and time was positive and linear between 20 to 26 weeks in a work done in Papua New Guinea

2 6 Use of pheromone

Eventhough the population of the weevil can be managed by using several methods the citation of literature is restricted to aspects related to the use of sex pheromone only

Sex pheromone use in pest management was studied with special reference to slow release formulation insect behaviour monitoring by trapping mass trapping and communication disruption (Tamaki 1980) It is also a useful tool of population suppression (Roelofs 1980) The pheromone trapping kept the population below damaging levels longer than did the standard adhesive wing raps baited with males and in addition it did not injure predators and parasites (Lloyd et al 1972)

Beetles were able to respond and fly to pheromone sources shortly after emergence without prior feeding or prolonged flight activity (Lindeloew and Western 1986) The recaptures were recorded at distances upto 1800 m Pheromone traps were used for detecting the presence of insects at very low densities and widely used for monitoring endemic species and they are only rarely deployed for exotic pest detection (Schewalbe and Mastro 1988)

2 6 1 Monitoring C formicarius populations using sex pheromones

In 1986 USDA scientists demonstrated the existence of female sex pheromones in C formicarius elegantulus and synthesised the chemical (Heath _et al_ 1986) This compound (Z) 3-dodecen 1-ol (E)-2-butenoate has shown remarkable potency in attracting males of _C_ _formicarius_ _elegantulus_ (Proshold _et al_ 1986) According to Talekar (1989) tests conducted at AVRDC Taiwan revealed that 10 microgram dose of this pheromone attracted large number of _C_ _formicarius_ _formicarius_ males continuously for over seven months He also suggested that besides monitoring of the onset of weevil infestation this chemical could be used for mass trapping of males

Jansson _et al_ (1990) conducted studies to determine the potential of the synthetic sex pheromone for monitoring population of the sweet potato weevil _C_ _formicarius_ _elegantulus_ Trap counts consistently increased with an increase in pheromone dosage Slope values from the regression of $\log_{10}$ counts on $\log_{10}$ dosage and arcsine-transformed percentage of weevils caught per dosage on $\log_{10}$ dosage did not differ among most trials despite large difference in weevil densities and time of the year Jansson (1990) developed a pheromone trap monitoring and management programme which indicated that synthetic sex pheromone of _C_ _formicarius_ _elegantulus_ has long-term potential for monitoring and managing this weeil in both large scale commercial production system and small scale subsistence farming systems throughout the world Manson _et al_ (1990) also studied the effects of sex pheromone (99 9 per cent purity) dosages on the movement of males of _C_ *formicarius elegantulus* in fallow fields Using mark release rcapture techniques insects were collected from sweet potato fields Trap counts from various distances downwind of the release point were compared for dosage of 0 01 - 10 0 μg and found that percentage of males recaptured decreased in dosage at each corres ponding distances He found that slopes of percentage recapture release distances for the two higher dosages (10 to 1 0 μg) differed from those of the 2 lower dosages (0 1 to 0 01 μg) but did not differ from each other Jansson *et al* (1990) found that a dosage of 10 μg of pheromone formulated on methylene chloride extracted rubber septa is adequate for monitoring the weevil *C formicarius elegantulus*

2 6 2 Control of spw using sex pheromone

Talekar and Lee (1989) showed a trap baited with 0 1 μg sex pheromone attracted significantly more males of the weevil in Taiwan than a trap baited with 5 virgin females A linear dosage response was observed between pheromone concentration of 0 001 to 1 mg/trap and the number of weevils captured in 4 weeks The dosage gave more than 80 per cent control of the weevils

2 6 3 Role of age of the septa in monitoring the population of spw

Hardee *et al* (1972) found that a wick type formulation of grandlure containing glycerol water polyethylene glycol and methanol was over 80 per cent comparative as an attractant for 7 days with caged live males Slow release formulation of grandlure was effective for 8 weeks than the standard formulation changed weekly (Johnson _et al_ 1976) Jansson _et al_ (1990) determined that septa aged outdoor were as attractive as fresh septa (refrig erated septa) for 7 weeks (49 days) Trap counts decreased with an increase in septum age However aged septa were almost as attractive as fresh septa for atleast 30 days When pheromone is formulated on methylene-chloride extracted rubber septa septa can be used continuously for atleast 30 days or longer without a substancial decrease in attractiveness Manson _et al_ (1990) found lure ages ranging from fresh to 64 days old He also showed that intercepts of fresh and 24 days old septa differed at 16 h while those of fresh and 34 days old septa differed at 40 h Most males were caught within first 16 h period Talekar and Lee(1989) found a 10 µg sample was uniformly active for atleast one month in field

2 7 Factors affecting bioefficacy of pheromone

2 7 1 Formulation of sex pheromone

Different formulations were tested to prolong the effective ness of the attractant in traps A physical barrier preparation consisting of a cigarette filter impregnated with grandlure in a solution of polythene glycol 1000 glycerol water and methanol and contained in an open use drum glass vial and a commercial occurs from dusk to 6 h after darkness (Proshold 1983) The mating stimulant is present on the surface of female (Tilles et al 1988)

Burkholder (1973) observed that in Black carpet beetle the high concentration of pheromone induced confusion or habituation in males in treated ones where the average percentage was 28 3 against 86 6 in untreated ones However Brady and Daley (1975) found in Cadra cautella (Wlk) sex pheromone along with a compound Cis-9 tetra adecenyl acetate reduced mating and acted as mating inhibitor

2 7 3 Distance of attraction

Talekar and Lee (1989) reported a highly significant negative correlation between the distance from the pheromone source (upto 100 m) and the number of male sweet potato weevil recapt red A sample containing one mg sex pheromone could capture more than 94 7 per cent of marked males from 10 m and 11 4 per cent from 100 m in 24 hrs Hwang et al (1989) determined the percentage of males recaptured at varying distances from funnel PET traps baited with one mg synthetic sex pheromone was greater at 5 m (69 1 per cent) At 10 20 and 40 m these figures were 10 7 1 5 and 0 4 per cent respectively Thus the capture of male weevils decreased with releasing marked males at increasing distances from the pheromone source When males of Ayeria (synanthedon) pictipes (G R) was released at distances

100 200, 400 and 800 m down wind of pheromonee traps the recovery was 67 per cent at 100 m and decreased gradually to 40 per cent at 800 m (Karandinos 1974) However according to Mitchell and Hardee (1974) the long range movement of weevils was primarily with the wind The adults were probably unable to detect an attractant further than 500 600 ft and move at random with the wind until they come within the distance of attraction of the source

2 7 4 Height of release of pheromone

Pheromone baited sticky traps captured maximum adults when they were suspended at or just below the height of the surrounding under brush (Shore and Mclean 1984) When traps baited with 100 ng, more than 90 per cent of the males came in contact with the trap were caught When the opening to the trap was approximately at the same height as the canopy of the sweet potato plants traps baited with 100 ng captured more males than when the opening was either below or several centimeters above the canopy (Proshold _et al_ 1986) However Talekar (1983) estimated that maximum capturing occurred when the traps were placed at 10 to 20 cm above the plant canopy

2 7 5 Behaviour

C formicarius is said to be most active during early evening with flight restricted to the hours of darkness (Jayaramaiah

1975) The same author also recorded adults attracted to light the greatest numbers arriving between 18 00 and 19 00 hrs and the majority being males Weevils have also been seen at lights in Papua New Guinea (Sutherland, 1986a) Adults weevils were thigmotactic and tend to show aggregated distribution in bulked tubers (Barlow and Rolston 1981) Indications are that foliage populations of adults are also contagious (Southwood 1978) and clumped or aggregated populations have been recorded in the field (Sutherland 1986a) Adults are most active just after sunset and again just before sunrise Traps placed at evening captured maximum males (Proshold _et al_ 1986)

2 7 6 Effect of photoperiod

The effect on sex pheromone releasing or calling behaviour of diel photoperiod of varying length of light cycle phase shifts and of continuous illumination were investigated in _Trogoderma glabrum_ (Hbst) In light regimes with photophases of 8 to 20 h calling maxima tended to be close to photophase mid points Day length had little effect on the calling period when light cycles of L D 16 8 were advanced or delayed by 4 h the time of day at which calling peaks were observed shifted within 2 to 4 cycles so that constant phase relationship with photoperiod was maintained Daily calling peaks were evident in groups of beetles exposed to between one to 5 days of continuous illumination but mean calling time occurred earlier in day on light exposures were lengthened Circadian rhythm of calling behaviour exists in females of *T glabrum* and that the rhythm can be entrained to 24 h periodicity by photoperiod (Hammack and Burkholder 1976)

2 8 Traps for capturing adults

A trap for surveying or monitoring males of *C formicarius elegantulus* using virgin female or the synthetic sex pheromone as bait was described by Proshold *et al* (1986) Rubber septa were baited with 10 ng 100 ng 1 µg or 10 µg of pheromone Traps baited with 100 ng or 10 µg caught more males than ones baited with 1 or 3 female which in turn caught more males than did light traps Pheromone baited traps caught males throughout day and night where as light trap and those baited with females caught males only during night

Water trough trap with an opening near the top in all directions was more effective easy to use and relatively less expensive than other traps (Talekar and Lee 1989)

Aluminium funnel trap (Proshold *et al* 1986) or a plastic funnel trap (Jansson *et al* 1989) were most effective at catching sweet potato weevil males The uni trap (Universal moth trap) was almost as effective as the plastic funnel trap in catching weevils Both the funnel trap and the uni trap caught significantly more weevil males than Screen cone boll weevil trap When studies were made at high weevil density differences among the traps were striking The trap efficiencies of the funnel trap (80 to 90 per cent) and uni trap (75 per cent) were significantly higher than the Screen cone boll weevil trap (49 per cent) Also the percentage of weevil males that escaped from traps overnight was significantly higher in uni trap (2 per cent) and plastic funnel trap (1 per cent escaped)

Hwang _et al_ (1989) designed three trap models in Taiwan for catching _C formicarius elegantulus_ Single funnel double funnel and netting funnel PET bottle traps baited with 1 mg synthetic sex pheromone were more effective at catching adult males

Materials and Methods

MATERIALS AND METHODS

3 1 **Raising of the sweet potato crop**

Field experiment was conducted at the College of Horticult ure Vellanikkara during May September 1991

3 1 1 Variety

The sweet potato cultivar Kanhangad local with a duration of 105 to 110 days was used in the experiment

3 1 2 Land preparation

Lang was cleared of weeds followed by surface scrapping ploughing and clearing of weeds was followed by raising ridges and furrows of size 25 30 cm height and 80 cm apart

3 1 3 Selection of planting materials

Vine cuttings of size 25 cm were used for planting at a spacing of 20 cm on the ridges

3 1 4 Cultural operations

The crop was raised by following the package of practices recommendations (Kerala Agricultural University 1989) Irrigation was given on need basis

3 2 **Culturing of sweet potato weevil *C formicarius***

Fresh tubers of variety Kanhangad local were placed in glass troughs of size 30 cm diameter The weevil culture obtained from CTCRI Sreekaryam was used for building up of population of test insect in the laboratory

3 2 1 Culturing of the weevil

The pairs of weevils were released into the troughs containing about one kilogram of tubers The troughs were then covered with wet muslin cloth The cloth was moistened period ically inorder to maintain proper humidity during the dry periods

The weevils were removed after 24 hours and the tubers were used for observations on the life stages of the weevil

3 2 2 Mass culturing of the weevil for use in field experiment

The tubers were retained in the troughs after egg laying till the emergence of adults These adults were sexed and the males were used for making and release in studies with recapture of marked males

3.3 Assessment of the efficacy of synthetic sex pheromone against the males of *C formicarius* in the field

A field experiment was conducted at the College of Horticulture Vellanikkara in order to assess the relative efficacy of different doses of synthetic sex pheromone for mass trapping of male weevils The efficacy of different low cost traps designed and fabricated out of locally available materials was also assessed simultaneously

3 3 1 Layout

The experiment was laid out in a Randomised Block Design with three replications The treatments consisted of combination of three doses of pheromone viz 1000 500 and 250 µg with three trap designs viz tin trap mudpot trap and polythene bag trap as given hereunder The experimental plot was in an East west orientation and it was divided into six blocks In two blocks nine plots were taken Each plot had a length of 8 m width 10m

Types of traps		Dosages		
		1000 ug	500 ug	250 ug
		D_1	D_2	D_3
Tin trap	T_1	T_1D_1	T_1D_2	T_1D_3
Mudpot trap	T_2	T_2D_1	T_2D_2	T_2D_3
Polythene bag trap	T_3	T_3D_1	T_3D_2	T_3D_3

A control plot was maintained 200 m away from the main plot All practices carried out in the treatment plot was also followed in the control plot

3 3 2 The pheromone

The female sex pheromone (2) 3 dodecon 1-01(E) 2 butenoate (Talekar and Lee 1989), synthesised at the Regional Research Laboratories CSIR Trivandrum was used in the studies Rubber septa impregnated with different doses of the pheromone were obtained

Plate 1 Tin Trap in position in field

Plate 2. Mudpot Trap in position in field

Plate 3. Polythene bag Trap in position in field

in ready to-use condition sealed in a aluminium foil packings

3 3 3 Design and fabrication of traps

The basic design of the trap consisted of a receptacle containing soap solution for the collection of weevils which were attracted by the pheromone, a roof over the receptacle from which the pheromone septum was hung such that it was just above the water level and supports for the roof Incorporating these features three traps were designed and fabricated using locally available and cheap materials and were tested under field conditions

3 3 3 1 Tin trap

A 15 litre capacity empty oil tin or a biscuit tin of the same capacity was selected for fabricating this trap (Plate 1) The side walls of the tin were cut and removed from the four sides such that the bottom 10 cm wall was left intact This served as the receptacle for soap solution The top portion of the tin served as the roof from which the pheromone cap was hung by a galvanized iron wire

3 3 3 2 Mud pot trap

An ordinary wide mouthed baked mud pot of 30 cm diameter was selected to serve as the receptacle for holding the soap solution (Plate 2) The pot was placed on the ground and around which wooden stakes were provided which served as supports for a thermocole roof The pheromone cap was hung from the centre of the roof by a thin galvanized iron wire

3 3 3 3 Polythene bag trap

In this design, a polythene bag of size 25 x 16 cm and gauge 350 was used as the receptacle to hold the soap solution (Plate 3) Three sticks were struck into the soil around the bag which served as supports for a small rectangular piece of thermocole sheet which served as roof for the trap The pheromone septum was hung from the centre of the roof by using a thin galvanized iron wire

3 3 4 Placement of traps

The traps fabricated as described above were placed in the respective plots such that the pheromone cap was hung just above the soap solution contained in the receptacles Each trap was placed on a heap of soil such that the height of the pheromone cap coincide with the top of the plant canopy The soil around the trap was arranged in such a way that gradual slope was obtained for easy crawling of male weevils after alighting on the ground near the trap Each trap was located on eastern end of the ridge since the general direction of wind was from east to west The traps were shifted to the adjacent ridges of the same plot after every 24 hours

3 3 5 Ensuring adequate population of <u>C formicarius</u> in experimental plot

The adult weevils were released in plots 25 insects per ridge on 30 DAP The egg laid tubers are placed on alternate ridges at the rate of 3 per ridge The population build up from this served as a source of inoculum for the plants raised in the experimental plots and control plot subsequently

3 4 Observations

The number of adults collected in each trap was counted and recorded during morning i e 06 00 and evening at 18 00 hrs The number of adult caught in each trap was collected using a sieve recorded and destroyed The data was collected in the morning and evening to assess the maximum capturing efficiency during day and night The data was analysed statistically Effect of moonphase on capturing of adult males also studied

3 4 1 Assessment of damage to vines

There were approximately 40 plants in a ridge Samples were collected from the ridges where the traps were placed by destructive sampling Two plants were collected from each ridge randomly every week The number of weevils (male and female) on the foliage and life stages in the vines the weight of vine in eacn plot were recorded The observations were taken till harvest The same procedure was followed in the control plot also

3 4 2 Assessment of damage to tubers

The sampling of tubers was similar to the sampling of vines The life stages egg larva pupa and adult are recorded

3 4 3 Statistical analysis

The experiment was laid out as a Randomised Block Design with treatments as a factorial set up

The analysis was carried out in the following parameters

1) To analyse the weevil catch	Morning catch
2) To analyse the weevil catch	Evening catch
3) To analyse the weevil catch	Morning + Evening catch
4) To analyse the catch of weevils once in 15 days	Morning catch
5) To analyse the catch of weevils once in 15 days	Evening catch
6) To analyse the catch of weevils once in 15 days	Morning + Evening catch
7) To analyse weekly totals of life stages	Egg
8) To analyse weekly totals of life stages	Larva
9) To analyse weekly totals of life stages	Pupa
10) To analyse weekly totals of life stages	Adult males
11) To analyse weekly totals of life stages	Adults (male + female)
12) To analyse weekly totals of life stages	Adult females

The yield of tubers roots and vines are analysed using ANOVA in RBD

13) Vine yield at different intervals vs traps

14) Vine yield at different intervals vs dosage

15) Tuber yield at harvest

16) Vine yield at harvest

17) Root yield at harvest

The cost benefit ratio of the tubers was also calculated for different dosage and different traps It is calculated from the cost of trap cost of installation and yield of tubers

3 5 Assessment of range of attraction of pheromone to the marked adults of *C formicarius*

To find out the range of attraction of the pheromone the weevils were marked with enamel paints of different colours Five colours were selected for marking viz white blue yellow red and orange The adult males were collected and marked with paint on their posterior portion of the elytra using a blunt needle without affecting their locomotion It has taken 3 5 minutes for drying of the paint Fo rty adult males were makred with each colour

3 5 1 Distance of release of marked male weevils

A tin trap was set-up in the field orienting the wind direction The marked adults were released in various directions at various distances Marked males were released all sides of the trap to determine the range Five distances were selected viz 25 50 100 200 and 400 meters The range of attraction of the 3 doses were tested

The observations were taken by collecting the adult from the trap one day after release and on two day after release The experiment was replicated twice in 5 days after first replication The number of adults having different colours were counted and recorded and analysed using Friedman s Two way analysis of variance by Ranks

Results

RESULTS

4 1 Assessment of the efficacy of synthetic pheromone against the male of *C formicarius* in the field

The efficacy of the pheromone was assessed by analysing the number of male weevils caught in different traps fitted with different doses of pheromone at weekly intervals

4 1 1 Morning catch

The number of males caught in each treatment during the night as recorded in the morning were analysed The results were presented in Table 1 and the ANOVA in Appendix I

The treatment effects were not significant at the end of first and second weeks after installation with respect to the number of weevils trapped At 3 weeks after placement the treat ment effects due to traps and doses were significant Maximum weevil catch of 68 11 was recorded in the T_1D_1 followed closely in T_1D_2 and T_2D_1 Tin (T_1) and Mudpot (T_2) traps were better than polythene bag trap (T_3) The treatment effects were not significant at 4 weeks after placement At 5 weeks the treatment effects due to traps doses and interaction were significant Maximum weevil catch of 87 93 was seen in T_1D_1 followed by 57 06 in T_1D_2 Lowest number was recorded in T_2D_3 At 6 weeks after placement the treatment and interaction effects were signifi cant T_1D_1 recorded the maximum number of weevils (85 30) while

Table 1 Mean morn ng catch of adult males of C formicar us n different treatments as analysed at weekly nte vals

Sl No	Weeks / Treatments	12th 18th July 1	19th 25th July 2	26th 1st July 3	2nd–8th August 4	9th 15th August 5	16th 22nd August 6	23rd 29th August 7	30th 5th Sept 8	6th 12th Sept 9	13th 19th Sept 10	20th 26 h Sept 1
1	T_1D_1	57 02 (7 617)	68 11 (8 313)	68 11 (8 313)	71 28 (8 502)	87 93 (9 430)	85 30 (9 290)	68 77 (8 353)	45 06 (6 787)	32 87 (5 820)	23 90 (4 990)	2 94 (4 790)
2	T_1D_2	46 29 (6 877)	59 68 (7 790)	46 71 (6 907)	64 45 (8 090)	57 06 (7 620)	50 22 (7 157)	33 02 (5 833)	25 73 (5 170)	22 52 (4 850)	7 66 (4 320)	17 81 (4 337)
3	T_1D_3	21 59 (4 753)	31 34 (5 687)	19 37 (4 513)	37 35 (6 193)	19 89 (4 570)	24 20 (5 020)	12 27 (3 643)	14 90 (3 987)	9 94 (3 307)	6 06 (4 130)	5 89 (4 110)
4	T_2D_1	30 06 (5 573)	41 159 (6 493)	46 24 (6 873)	42 43 (6 590)	47 72 (6 980)	50 88 (7 203)	52 33 (7 303)	8 71 (4 440)	17 21 (4 267)	15 87 (4 107)	4 11 (3 887)
5	T_2D_2	32 67 (5 803)	41 16 (7 090)	35 28 (6 023)	37 81 (6 230)	40 56 (6 447)	41 68 (6 533)	46 57 (6 897)	14 79 (3 973)	14 05 (3 880)	16 53 (4 187)	6 87 (4 227)
6	T_2D_3	35 36 (6 030)	49 23 (7 087)	19 61 (4 540)	37 60 (6 213)	19 64 (4 543)	18 36 (4 400)	8 47 (3 077)	13 49 (3 807)	13 90 (3 860)	12 76 (3 710)	14 31 (3 913)
7	T_3D_1	35 88 (6 073)	42 73 (6 613)	23 61 (4 960)	41 86 (6 547)	38 40 (6 277)	29 17 (5 493)	20 93 (4 683)	17 38 (4 287)	19 98 (4 580)	8 60 (4 427)	15 59 (4 073)
8	T_3D_2	30 06 (5 573)	46 20 (6 870)	20 46 (4 633)	30 92 (5 650)	21 40 (4 733)	22 20 (4 817)	15 22 (4 027)	10 83 (3 443)	10 18 (3 343)	13 75 (3 840)	13 29 (3 780)
9	T_3D_3	38 48 (6 283)	46 16 (6 867)	22 33 (4 830)	32 29 (5 770)	23 87 (4 987)	15 62 (4 077)	6 06 (2 657)	14 92 (3 990)	15 24 (4 030)	13 59 (3 820)	13 19 (3 767)
F test	Traps	NS	NS	**	NS	**	**	**	NS	NS	NS	NS
	Dosages	NS	NS	**	NS	**	**	**	**	**	NS	NS
	Interaction	NS	NS	*	NS	**	**	NS	NS	*	NS	NS
CD(0 05)	Traps			1 49		26	0 93	1 77				
	Dosages			49		1 26	0 93	1 77	25	1 07		
	Interaction			1 05		0 89	0 66			0 76		

(Figures given n parentheses are transformed ($\sqrt{x\ 1}$) values)

** Significant at 1% level

* Significant at 5% level

Table 2 Mean even ng catch of adult males of C form car us n d fferent treatments as analysed at weekly ntervals

Sl No	Treatments \ Weeks	2th 28th July 1	19th 25th July 2	26th 1st July 3	2nd 8th August 4	9th 15th August 5	16th 22nd August 6	23rd 29th August 7	30th 5th Sept 8	6th 12th Sept 9	3th 19th Sept 0	20th 26 h Sept 11
	T_1D	45 10 (6 790)	46 98 (6 927)	20 87 (4 677)	39 92 (6 397)	45 01 (6 783)	56 65 (7 593)	37 48 (6 203)	18 25 (4 387)	17 32 (4 280)	13 54 (3 813)	8 98 (4 47)
2	T_1D_2	33 33 (5 910)	30 06 (5 573)	19 98 (4 580)	35 12 (6 010)	22 07 (4 803)	52 73 (7 33)	38 56 (6 290)	16 67 (4 203)	8 26 (3 043)	10 54 (3 397)	11 32 (3 51)
3	T_1D_3	11 58 (3 547)	14 11 (3 887)	9 13 (3 183)	18 25 (4 387)	14 68 (3 960)	22 55 (4 853)	14 55 (3 943)	9 41 (3 227)	5 09 (2 467)	5 99 (2 643)	0 8 (3 343)
4	T_2D_1	14 55 (3 943)	19 25 (4 500)	16 22 (4 150)	25 45 (5 143)	31 95 (5 740)	52 33 (7 303)	40 26 (6 423)	11 25 (3 500)	8 65 (3 107)	7 14 (2 853)	8 90 (3 147)
5	T_2D_2	20 22 (4 607)	22 98 (4 897)	15 43 (4 053)	28 89 (5 467)	26 59 (5 253)	35 57 (6 047)	22 69 (4 867)	6 99 (2 827)	4 82 (2 413)	8 88 (3 143)	1 96 (3 600)
6	T_2D_3	20 84 (4 673)	28 95 (5 473)	8 16 (3 027)	20 44 (4 630)	10 51 (3 393)	12 32 (3 650)	8 28 (3 047)	4 52 (3 940)	6 91 (2 813)	6 90 (2 810)	1 27 (3 503)
7	T_3D_1	22 40 (4 837)	25 45 (5 143)	7 60 (2 933)	20 97 (4 687)	18 10 (4 370)	33 85 (5 903)	22 98 (4 897)	13 80 (3 847)	8 94 (3 153)	9 43 (3 230)	10 49 (3 390)
8	T_3D_2	13 54 (3 813)	17 49 (4 300)	5 64 (2 577)	16 53 (4 187)	17 86 (4 343)	15 89 (4 110)	12 94 (3 733)	10 81 (3 437)	6 84 (2 800)	6 22 (2 687)	7 29 (2 880)
9	T_3D_3	19 79 (4 560)	17 84 (4 340)	6 58 (2 753)	19 25 (4 500)	11 96 (3 600)	10 02 (3 320)	5 29 (2 507)	10 70 (3 420)	8 51 (3 083)	10 97 (3 460)	7 64 (2 940)
F test	Traps	NS	NS	NS	**	NS	**	**	NS	NS	NS	NS
	Dosages	NS	NS	NS	NS	**	**	**	NS	NS	NS	NS
	Interact on	*	*	NS	NS	NS	NS	NS	*	NS	NS	NS
CD(0 05)	Traps				1 13		1 47	57				
	Dosages					33	1 47	1 57				
	Interact on	1 37	1 2						0 67			

(Figures given n parentheses are transformed ($\sqrt{x\ 1}$) values)

** S gnificant at 1% level
* S gn ficant at 5% level

T_3D_3 caught 15 62 weevils At 7 weeks the treatment effects were significant the treatment T_1D_1 continued to give the highest weevil count (68 77) while the lowest (6 06) was seen in T_3D_3 The effects of doses alone were found significant at the end of 8 weeks when the weevil number in 1000 µg dose was 45 06 18 71 and 17 38 in tin mudpot trap and polythene bag respect ively The weevil catch was significantly lower in the other two doses The effects of designs were only significant at 9 weeks when the tin trap with a weevil count of 32 87 22 52 and 9 94 respectively at 1000 500 and 250 µg was significantly superior to the other trap designs The treatment effects due to traps doses and interaction were not significant at 10 and 11 weeks where the maximum weevil catch was 23 9 and 21 9 respectively

4 1 2 Evening catch

The results of analysis of the day catch of male weevils as recorded in the evening were presented in Table 2 and the ANOVA in Appendix II

The treatment effects due to traps and doses were not significant during the observations recorded at 1 2 and 3 weeks after the installation of traps At 4 weeks the effect due to doses alone was significant Maximum weevil catch was seen in 1000 µg dose The effect of dosages was alone significant at 5 weeks The tin trap was found to be significantly better than

Table 3 Mean morning and evening catch of adult males C <u>formicarius</u> in different treatments as analysed at weekly intervals

Sl No	Treatments \ Weeks	12th 18th July 1	19th 25th July 2	26th 1st July 3	2nd 8th August 4	9th 15th August 5	16th 22nd August 6	23th 29th August 7	30th 5th Sept 8	6th 12th Sept 9	13th 19th Sept 10	20 h 26th Sept 11
	T_1D_1	102 57 (10 177)	115 06 (10 773)	89 50 (9 513)	111 30 (10 597)	133 17 (11 583)	142 11 (11 963)	106 89 (10 387)	63 59 (8 037)	50 74 (7 193)	37 94 (6 24)	40 95 (6 477)
2	T_1D_2	81 08 (9 06)	89 82 (9 530)	67 28 (8 263)	99 66 (10 033)	79 77 (8 987)	103 18 (10 207)	72 39 (8 567)	43 13 (6 643)	30 89 (5 647)	28 24 (5 407)	29 69 (5 540)
3	T_1D_3	34 13 (5 927)	45 75 (6 837)	28 59 (5 440)	55 66 (7 527)	34 56 (5 963)	46 71 (6 907)	27 23 (5 313)	24 33 (5 033)	15 08 (4 010)	22 49 (4 847)	26 25 (5 220)
4	T_2D_1	45 10 (6 790)	60 58 (7 847)	62 52 (7 970)	68 01 (8 307)	79 95 (8 997)	103 45 (10 220)	93 81 (9 737)	29 99 (5 567)	25 75 (5 172)	23 01 (4 900)	23 24 (4 923)
5	T_2D_2	52 98 (7 347)	72 50 (8 573)	51 52 (7 247)	67 23 (8 260)	67 51 (8 277)	77 38 (8 853)	69 56 (8 400)	21 97 (4 793)	20 18 (4 602)	25 63 (5 160)	29 11 (5 487)
6	T_2D_3	56 30 (7 570)	78 16 (8 897)	28 84 (5 463)	58 29 (7 700)	30 36 (5 600)	30 78 (5 637)	17 15 (4 260)	28 34 (5 417)	21 01 (4 691)	20 28 (4 613)	25 66 (5 163)
7	T_3D_1	58 24 (7 697)	68 11 (8 313)	31 23 (5 677)	62 95 (7 997)	56 76 (7 600)	63 11 (8 007)	43 93 (6 703)	31 30 (5 683)	29 11 (5 487)	27 98 (5 383)	26 07 (5 203)
8	T_3D_2	43 76 (6 69)	63 48 (8 030)	46 43 (6 887)	47 48 (6 963)	39 32 (6 350)	38 44 (6 280)	28 24 (5 407)	21 75 (4 770)	17 13 (4 258)	19 89 (4 570)	21 40 (4 733)
9	T_3D_3	58 40 (7 707)	64 01 (8 063)	29 11 (5 487)	52 48 (7 313)	36 37 (6 113)	25 66 (5 163)	1 55 (3 543)	25 70 (5 167)	23 76 (4 976)	24 63 (5 063)	20 90 (4 68)
F test	Traps	NS	NS	**	**	**	**	**	**	NS	NS	NS
	Dosages	NS	NS	**	NS	**	**	**	**	**	NS	NS
	Interaction	NS	NS	*	NS	*	NS	NS	*	*	NS	NS
CD(0 05)	Traps			1 62	1 87	1 57	57	2 10	27			
	Dosages			1 62		1 57	1 57	2 10	1 27	1 25		
	Interaction			1 14		1 11			0 90	0 87		

(Figures given in parentheses are transformed ($\sqrt{x\ 1}$) values)

** Significant at 1% level
* Significant at 5% level

the others with weevil catch of 45 01 22 07 and 14 68 respectively in the three doses At 6 weeks the effects of doses and trap designs were significant while that due to interaction was not significant Similar trend was seen at 7 weeks after placement Treatment effects due to doses traps and Interaction were not significant 8 9 10 and 11 weeks after placement eventhough the mean weevil catch was more in tin trap

4 1 3 Assessment of efficacy of trap designs and pheromone doses based on the weevil count on daily basis

The analysis of the daily weevil count pooled over the weeks was done and the results were presented in Table 3 and ANOVA was presented in Appendix III

The treatment effects due to trap design doses and interaction were not significant during the first and second periods The effect due to traps was significant at 3 4 5 6 7 and 8 weeks after the installation of traps while that of the doses was significant at 3 5 6 7 8 and 9 weeks after installation The interaction effects were significant at 3 5 8 and 9 weeks after installation In the tin trap peak weevil catches of 142 11 103 18 and 55 66 were recorded at 6 6 and 4 weeks after installation respectively in the three doses 1000 500 and 250 µg This was followed by a general decline in the weevil catch In the mudpot trap the peak weevil counts of 103 45 77 38 78 16 were recorded respectively in 1000 500 and 250 µg

Table 4 Mean morning catch of adult males of C formicarius in different treatments as analysed at 15 days intervals (Moon phase)

Sl No	Fortnights / Treatments	12th to 26th July	27th July to 10th August	11th to 25th August	26th Aug to 9th September	10th to 24th September
1	T_1D_1	236 47 (15 41)	209 54 (14 510)	180 98 (13 490)	100 35 (10 067)	51 32 (7 233)
2	T_1D_2	185 41 (13 653)	164 71 (12 873)	114 78 (10 760)	56 108 (7 557)	43 93 (6 703)
3	T_1D_3	85 30 (9 290)	84 14 (9 227)	45 92 (6 850)	27 02 (5 293)	36 49 (6 123)
4	T_2D_1	123 10 (11 140)	125 95 (11 267)	119 85 (10 993)	52 69 (7 327)	37 01 (6 165)
5	T_2D_2	133 33 (11 590)	116 44 (10 837)	99 52 (10 026)	48 80 (7 057)	39 58 (6 370)
6	T_2D_3	142 59 (11 983)	85 49 (9 300)	36 54 (6 127)	30 03 (5 570)	31 14 (5 669)
7	T_3D_1	131 87 (11 527)	99 66 (10 033)	60 20 (7 823)	40 90 (6 473)	42 0 (6 563)
8	T_3D_2	113 77 (10 713)	94 00 (9 747)	46 20 (6 870)	23 80 (4 980)	32 64 (5 800)
9	T_3D_3	128 28 (11 370)	84 06 (9 223)	43 53 (6 673)	29 55 (5 527)	32 95 (5 827)
F test	Traps	NS	**	**	**	NS
	Dosages	NS	**	**	**	NS
	Interaction	NS	*	**	*	NS
CD (0 05)	Traps		1 71	1 54	1 67	
	Dosages		1 71	1 54	1 67	
	Interaction		1 21	1 09	1 18	

(Figures given in parentheses are transformed ($\sqrt{x+1}$) values)
** Significant at 1% level
* Significant at 5% level

doses at 6 6 and 2 weeks after installation followed by a general decrease in the weevil count In the polythene bag trap the peak weevil catch was seen at 6 2 and 2 weeks after placement in the three doses 1000 500 and 250 µg respectively

4 2 Assessment of the efficacy of the pheromone as influenced by the moon phase

The effects of doses and trap designs as influenced by the moon phases were studied by analysing the number of weevils pooled over fortnightly intervals

4 2 1 Morning catch

The number of weevil caught during the night as recorded in the morning were pooled over fortnightly intervals and analysed The mean values were presented in Table 4 and the ANOVA was presented in Appendix-IV

The effects of traps doses and interactions were not significant during first fortnight All these effects were significant during second third and fourth fortnight During the second fortnight the weevil count was maximum 1000 µg dose in the tin trap (209 54) followed by mudpot trap (125 95) and polythene bag trap (99 66) While the 500 µg dose recorded 164 71 116 44 and 94 weevils respectively in the three traps Similar trend was noticed in the observations recorded during the third and fourth intervals The treatment effects due to traps doses and

Table 6 Mean morning and evening catch of adult males of C formicarius in different treatments as analysed at 15 days intervals (Moon phase)

Sl No	Treatments / Fortnights	12th to 26th July	27th July to 10th August	11th to 25th August	26th Aug to 9th September	10th to 24th September
1	T_1D_1	335 98 (18 357)	271 35 (16 503)	290 39 (17 070)	144 85 (12 077)	91 55 (9 620)
2	T_1D_2	303 40 (17 447)	217 45 (14 780)	200 73 (14 203)	102 57 (10 177)	70 01 (8 427)
3	T_1D_3	41 73 (6 537)	109 52 (10 513)	89 88 (9 533)	45 65 (6 830)	55 70 (7 530)
4	T_2D_1	163 53 (12 827)	163 79 (12 837)	221 40 (14 931)	91 60 (9 623)	57 57 (7 653)
5	T_2D_2	197 05 (14 073)	142 21 (11 967)	60 67 (7 853)	54 55 (7 453)	52 92 (7 343)
6	T_2D_3	186 06 (13 677)	155 18 (12 497)	170 43 (13 093)	71 98 (8 543)	63 21 (8 013)
7	T_3D_1	183 96 (13 600)	129 03 (11 403)	116 44 (10 837)	74 64 (8 697)	66 03 (8 187)
8	T_3D_2	147 60 (12 190)	118 31 (10 923)	83 40 (9 187)	45 83 (6 843)	48 94 (7 067)
9	T_3D_3	168 70 (13 027)	110 56 (10 562)	66 57 (8 220)	48 35 (7 025)	55 25 (7 500)
F test	Traps	NS	**	**	**	NS
	Dosages	NS	**	**	**	NS
	Interaction	NA	*	**	NS	NS
CD (0 05)	Traps		2 49	2 02	1 98	
	Dosages		2 49	2 02	1 98	
	Interaction	-	1 76	1 43		

(Figures given in parentheses are transformed ($\sqrt{x+1}$) values)

** Significant at 1% level

* Significant at 5% level

doses at 6 6 and 2 weeks after installation followed by a general decrease in the weevil count In the polythene bag trap the peak weevil catch was seen at 6 2 and 2 weeks after placement in the three doses 1000 500 and 250 µg respectively

4 2 Assessment of the efficacy of the pheromone as influenced by the moon phase

The effects of doses and trap designs as influenced by the moon phases were studied by analysing the number of weevils pooled over fortnightly intervals

4 2 1 Morning catch

The number of weevil caught during the night as recorded in the morning were pooled over fortnightly intervals and analysed The mean values were presented in Table 4 and the ANOVA was presented in Appendix-IV

The effects of traps doses and interactions were not significant during first fortnight All these effects were signifi cant during second third and fourth fortnight During the second fortnight the weevil count was maximum 1000 µg dose in the tin trap (209 54) followed by mudpot trap (125 95) and polythene bag trap (99 66) While the 500 µg dose recorded 164 71 116 44 and 94 weevils respectively in the three traps Similar trend was noticed in the observations recorded during the third and fourth intervals The treatment effects due to traps doses and

Table 5 Mean evéning catch of adult males of C formicarius in different treatments as analysed at 15 days intervals (Moon phase)

Sl No	Fortnight / Treatments	12th to 26th July	27th July to 10th August	11th to 25th August	26th Aug to 9th September	10th to 24th September
1	T_1D_1	99 54 (10 027)	61 73 (7 920)	109 04 (10 490)	44 47 (6 743)	38 60 (6 293)
2	T_1D_2	72 15 (8 553)	52 44 (7 310)	85 55 (9 303)	46 02 (6 857)	25 49 (5 147)
3	T_1D_3	30 62 (5 623)	25 23 (5 121)	43 89 (6 700)	18 39 (4 403)	18 63 (4 430)
4	T_2D_1	40 35 (6 430)	37 90 (6 237)	101 21 (10 110)	38 48 (6 283)	20 46 (4 632)
5	T_2D_2	52 63 (7 323)	38 60 (6 293)	70 91 (8 480)	22 81 (4 879)	23 21 (4 920)
6	T_2D_3	54 46 (7 447)	10 76 (4 483)	23 67 (4 967)	24 33 (5 033)	21 37 (4 730)
7	T_3D_1	52 14 (7 290)	29 31 (5 505)	56 26 (7 567)	33 34 (5 860)	23 93 (4 993)
8	T_3D_2	33 81 (5 900)	24 13 (5 013)	36 70 (6 140)	21 74 (4 769)	16 17 (4 143)
9	T_3D_3	40 45 (6 438)	26 39 (5 238)	22 59 (4 780)	18 72 (4 440)	22 29 (4 826)
F	Traps	NS	**	**	NS	NS
	Dosages	NS	**	**	**	**
	Interaction	*	NS	NS	NS	*
CD (0 05)	Traps	-	1 32	1 74		-
	Dosages		1 32	1 74	1 43	
	Interaction	1 67				0 700

(Figures given in parentheses are transformed ($\sqrt{x+1}$) values)

** Significant at 1% level
* Significant at 5% level

interaction were not significant during the fifth fortnight after the installation of traps

4 2 2 Evening catch

The number of male weevils caught during the day as recorded in the evening were analysed and the mean values were presented in Table 5 The ANOVA was presented in Appendix V

The treatment effects due to trap designs were not signifi cant during the first fourth and fifth fortnights The effects due to doses were significant during the second third and fourth fortnights while the interaction effects were significant during the first and fifth fortnights only The tin trap recorded higher weevil catch in all the three doses as compared to the mudpot trap and polythene bag trap in general The tin trap in combinat ion with the 1000 μg dose attracted the maximum number of weevils and is significantly superior to all the other combinations

4 2 3 Morning + Evening catch

The totals of male weevils caught during the morning and evening were pooled over fortnights and analysed The results are presented in Table 6 and the ANOVA in the Appendix VI

The treatment effects due to trap designs doses and inter action were not significant during the first and fifth fortnights The effects due to trap designs and doses were highly significant

Table 7 Mean number of eggs of C *formicarious* recovered from vines collected at different intervals n d fferent treatments

Sl No	Treatments / Weeks	17th July 1	24th July 2	31st July 3	7th Aug 4	14th Aug 5	21st Aug 6	28th Aug 7	4th Sep 8	1 th Sep 9	18th Sep 10	25th Sep 1
1	T_1D_1	63 32 (8 020)	74 12 (8 667)	90 34 (9 557)	98 54 (9 977)	93 67 (9 730)	109 82 (0 553)	109 82 (10 527)	109 19 (10 497)	9 91 (9 587)	87 61 (9 413)	53 66 (7 393)
2	T_1D_2	62 09 (7 943)	66 68 (8 227)	76 39 (8 797)	82 91 (9 60)	88 17 (9 443)	84 80 (9 263)	102 17 (10 157)	84 56 (9 250)	89 06 (9 490)	63 27 (8 017)	61 996 (7 937)
3	T_1D_3	62 95 (7 997)	56 00 (7 550)	75 57 (8 920)	83 33 (9 183)	94 65 (9 780)	86 48 (9 353)	102 29 (10 163)	91 99 (9 743)	87 61 (9 413)	94 00 (9 747)	8 94 (9 107)
4	T_2D_1	72 33 (8 563)	60 99 (7 873)	88 68 (9 470)	90 64 (9 573)	89 25 (9 500)	57 78 (7 667)	110 37 (10 553)	102 69 (10 183)	87 30 (9 397)	60 04 (7 813)	72 39 (8 567)
5	T_2D_2	57 83 (7 670)	57 02 (7 617)	81 87 (9 103)	82 05 (9 113)	99 60 (10 03)	83 27 (9 18)	101 27 (10 113)	87 55 (9 410)	96 22 (9 860)	78 62 (8 923)	73 65 (8 640)
6	T_2D_3	65 31 (8 143)	66 85 (8 237)	89 12 (9 493)	87 17 (9 390)	95 69 (9 833)	72 45 (8 57)	102 49 (10 173)	100 47 (10 073)	92 57 (9 673)	117 01 (10 863)	93 93 (9 743)
7	T_3D_1	57 83 (7 670)	57 88 (7 673)	83 95 (9 217)	83 33 (9 183)	91 93 (9 640)	78 26 (8 903)	107 58 (10 420)	98 06 (9 953)	87 93 (9 430)	87 98 (9 433)	67 39 (8 270)
8	T_3D_2	56 96 (7 613)	57 02 (7 617)	71 20 (8 497)	86 55 (9 357)	88 62 (9 467)	72 79 (8 590)	100 95 (10 097)	81 76 (9 097)	100 55 (10 077)	83 09 (9 170)	80 18 (9 010)
9	T_3D_3	64 82 (8 113)	62 41 (7 963)	90 30 (9 555)	90 59 (9 570)	108 27 (10 453)	57 48 (7 647)	93 34 (9 713)	91 55 (9 620)	98 80 (9 990)	106 48 (10 367)	121 17 (11 053)
10	Control	104 06 (10 25)	81 08 (9 06)	107 99 (10 440)	93 09 (9 700)	109 50 (0 540)	107 99 (10 440)	128 05 (11 360)	137 06 (11 750)	153 01 (12 41)	106 48 (12 81)	53 02 (7 350)
F test	Traps	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
	Dosages	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	**
	Interact on	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CD(0 05)	Traps											23
	Dosages			0 58								23
	Interaction											

(Figures given in parentheses are transformed ($\sqrt{x\ 1}$) values)

** S gnificant at 1% level

* Significant at 5% level

170460

during the second third and fourth fortnights while the interaction effects were significant during the second and third fortnights The tin trap fitted with 1000 µg dose was the most efficient combination trapping 335 98 271 35 290 39 144 85 and 91 55 weevils respectively during the five fortnights

4 3 Assessment of the efficacy of synthetic pheromone doses and trap designs on the population build up of *C formicarius*

The number of life stages recorded from the vine samples at different intervals were analysed and presented

4 3 1 Egg

The mean number of eggs recorded from the vine samples collected at weekly intervals from the treatment plots were presented in Table 7 and the ANOVA was presented in Appendix VII

The treatment effects due to trap designs doses and interaction were not significant at weekly intervals except the third and eleventh weeks The number of eggs increased gradually upto the 8th week of observation followed by a gradual decline in T_1D_1 Similar trend is observed in all the treatments In the control plots the increase was seen upto the 9th week where the maximum number (153 01) of eggs was recorded among all the treatments Among the treatments the lower doses recorded higher egg counts

Table 8 Mean number of larva of C formicarius recovered from vines collected at different intervals in different treatments

Sl No	Treatments \ Weeks	7th July 1	24th July 2	31st July 3	7th Aug 4	14th Aug 5	21st Aug 6	28th Aug 7	4th Sep 8	11th Sep 9	18th Sep 11	25th Sep 1
1	T_1D_1	75 27 (8 733)	85 30 (9 290)	92 18 (9 653)	106 39 (10 363)	108 62 (10 470)	63 32 (8 020)	64 01 (8 063)	57 78 (7 667)	45 65 (6 830)	5 22 (2 493)	4 56 (2 357)
2	T_1D_2	65 91 (8 180)	72 67 (8 583)	82 23 (9 123)	72 39 (8 567)	73 31 (8 620)	44 25 (6 727)	45 96 (6 853)	36 54 (6 127)	45 65 (6 830)	7 96 (2 993)	9 32 (3 213)
3	T_1D_3	65 21 (8 137)	67 56 (8 280)	69 61 (8 403)	82 05 (9 113)	34 56 (5 963)	21 35 (4 727)	21 63 (4 757)	20 93 (4 683)	38 28 (6 267)	19 43 (4 520)	33 96 (5 913)
4	T_2D_1	71 59 (8 520)	68 11 (8 313)	87 30 (9 397)	87 61 (9 413)	104 27 (10 260)	32 99 (5 830)	24 00 (5 000)	24 98 (5 097)	27 30 (5 320)	13 31 (3 783)	18 18 (4 380)
5	T_2D_2	68 61 (8 343)	72 96 (8 600)	79 28 (8 960)	70 35 (8 447)	74 64 (8 697)	32 99 (5 830)	25 97 (5 193)	26 67 (5 260)	29 33 (5 507)	19 6 (4 54)	16 3 (4 160)
6	T_2D_3	74 52 (8 690)	88 30 (9 450)	85 62 (9 307)	78 92 (8 940)	12 67 (3 697)	25 18 (5 117)	71 98 (8 543)	24 00 (5 000)	40 47 (6 440)	36 49 (6 123)	31 18 (5 673)
7	T_3D_1	65 31 (8 143)	62 57 (7 973)	78 80 (8 933)	77 68 (8 870)	43 98 (6 707)	40 99 (5 480)	34 61 (5 967)	34 28 (5 940)	33 11 (5 840)	11 51 (3 537)	40 22 (6 420)
8	T_3D_2	65 52 (7 970)	67 67 (8 287)	68 94 (8 363)	73 60 (8 637)	38 56 (6 290)	24 60 (5 060)	13 95 (3 867)	15 65 (4 080)	40 38 (6 433)	14 66 (3 957)	26 14 (5 210)
9	T_3D_3	73 95 (8 657)	76 97 (8 830)	81 57 (9 087)	78 62 (8 923)	11 96 (3 600)	31 91 (5 737)	62 90 (7 937)	25 97 (5 193)	41 34 (6 507)	35 33 (6 027)	34 52 (5 960)
10	Control	91 93 (9 640)	95 04 (9 800)	103 04 (10 200)	113 92 (10 720)	120 00 (11 000)	54 95 (7 480)	81 08 (9 060)	86 05 (9 330)	107 99 (10 440)	118 90 (10 950)	70 07 (8 430)
F test	Traps	NS	NS	*	NS	**	**	**	**	NS	**	**
	Dosages	NS	NS	NS	**	**	**	**	**	NS	**	NS
	Interaction	NS	*	NS	*	**	**	**	**	NS	NS	NS
CD(0 05)	Traps			0 54		0 60	0 56	0 44	1 08		1 46	82
	Dosages				0 71	0 60	0 56	0 44	1 08		46	
	Interaction		0 75		0 50	0 43	0 40	0 31	0 76			

(Figures given in parentheses are transformed ($\sqrt{x\ 1}$) values)

** Significant at 1% level

* Significant at 5% level

4 3 2 Larvae

The mean number of larvae recorded from vine samples collected from the treatment plots were presented in Table 8 The corresponding ANOVA was presented in Appendix VIII

The treatment effects due to trap designs were significant during the third fifth sixth seventh eighth tenth and eleventh week of observation The effects due to doses were significant during the fourth fifth sixth seventh eighth and tenth week of observation while the interaction effects were significant during the second fourth fifth sixth seventh and eighth week of observation The larval number gradually increased upto 4th and 5th week followed by a decline Among the treatments the larval counts were lower as compared to those in the control plots and the build up declined in the treatment plots while it continued to remain high even up to 10 weeks in the control plots

4 3 3 Pupae

The mean number of pupae recovered from the vine samples collected at different intervals were presented in Table 9 The corresponding ANOVA was presented in Appendix IX

The treatment effects due to trap designs were found to be significant during the third fifth sixth eighth and eleventh week observations The effects due to doses were significant at

Table 9 Mean number of pupa of C formicarius recovered from vines collected at different intervals n different treatments

Sl No	Treatments \ Weeks	17th July 1	24th July 2	31st July 3	7th Aug 4	14th Aug 5	21st Aug 6	28th Aug 7	4th Sep 8	11th Sep 9	18th Sep 0	25th Sep 11
1	T_1D_1	66 85 (8 237)	71 37 (8 507)	95 04 (9 800)	101 96 (10 147)	112 36 (10 647)	105 09 (10 300)	64 66 (8 103)	63 64 (8 040)	40 26 (6 423)	9 60 (3 240)	40 (1 550)
2	T_1D_2	54 70 (7 463)	53 91 (7 410)	72 10 (8 550)	80 54 (9 030)	112 70 (10 663)	68 56 (8 340)	42 92 (6 627)	44 29 (6 730)	29 28 (5 503)	13 90 (3 860)	5 02 (2 453)
3	T_1D_3	56 46 (7 580)	36 54 (6 127)	70 79 (8 473)	67 34 (8 267)	41 99 (6 557)	31 64 (5 713)	25 66 (5 163)	20 72 (4 660)	30 19 (5 585)	20 23 (4 607)	25 91 (5 187)
4	T_2D_1	61 57 (7 910)	46 65 (6 903)	82 49 (9 137)	80 54 (9 030)	101 88 (10 143)	100 20 (10 06)	32 99 (5 830)	21 65 (4 759)	33 07 (5 837)	13 90 (3 860)	19 58 (4 537)
5	T_2D_2	58 03 (7 683)	43 32 (6 657)	48 94 (7 067)	57 37 (7 640)	82 36 (9 130)	73 94 (8 657)	36 25 (6 103)	26 01 (5 197)	26 51 (5 245)	19 22 (4 497)	15 73 (4 090)
6	T_2D_3	60 51 (7 843)	29 66 (5 537)	86 48 (9 353)	49 27 (7 090)	31 98 (5 743)	83 64 (9 700)	75 27 (8 733)	22 33 (4 830)	36 49 (6 123)	36 46 (6 120)	27 87 (5 373)
7	T_3D_1	51 52 (7 247)	45 34 (6 807)	66 36 (8 207)	79 82 (8 990)	64 66 (8 103)	44 97 (6 780)	44 97 (6 780)	33 69 (5 890)	35 28 (6 023)	13 31 (3 783)	38 60 (6 293)
8	T_3D_2	50 41 (7 170)	35 93 (6 077)	35 24 (6 020)	45 01 (6 783)	43 32 (6 657)	23 14 (4 917)	26 70 (5 263)	15 95 (4 117)	30 20 (5 586)	11 25 (3 500)	27 55 (5 343)
9	T_3D_3	57 88 (7 673)	34 20 (5 933)	72 10 (8 550)	57 52 (7 650)	51 96 (7 277)	71 98 (8 543)	40 31 (6 427)	23 34 (4 933)	33 34 (5 860)	31 26 (5 680)	24 78 (5 077)
10	Control	69 06 (8 37)	86 99 (9 38)	71 08 (8 490)	105 92 (10 340)	130 10 (11 45)	137 06 (11 75)	84 01 (9 220)	89 06 (9 490)	113 92 (10 720)	142 04 (11 960)	44 02 (6 710)
F test	Traps	NS	NS	**	NS	**	**	NS	**	NS	NS	**
	Dosages	NS	NS	**	**	**	**	NS	**	NS	NS	NS
	Interaction	NS	NS	**	NS	**	**	**	**	NS	NS	*
CD(0 05)	Traps			0 79		0 62	0 67		0 48			1 87
	Dosages			0 79	1 64	0 61	0 67		0 48			
	Interaction			0 56		0 44	0 47	0 83	0 34			1 32

(Figures given in parentheses are transformed ($\sqrt{x\ 1}$) values)

** Significant at 1% level

* Significant at 5% level

Table 10 Mean number of adults (male female) of C formicarius recovered from vines collected at different intervals n different treatments

Sl No	Treatments / Weeks	17th July	24th July	31st July	7th Aug	14th Aug	21st Aug	28th Aug	4th Sep	11th Sep	18th Sep	25th Sep
1	T_1D_1	104 88 (10 290)	158 77 (12 64)	78 21 (8 900)	103 04 (10 200)	118 25 (10 920)	198 18 (14 113)	149 80 (12 280)	84 32 (9 293)	58 40 (7 707)	78 44 (8 920)	8 12 (3 02)
2	T_1D_2	60 78 (7 86)	126 01 (11 27)	72 05 (8 55)	104 06 (10 250)	81 99 (9 100)	111 15 (10 590)	64 82 (8 113)	63 32 (8 020)	64 66 (8 103)	55 40 (7 510)	9 63 (3 262)
3	T_1D_3	80 54 (9 030)	134 65 (11 647)	75 27 (8 741)	119 34 (10 970)	142 52 (11 980)	158 34 (12 623)	93 03 (9 692)	96 28 (9 864)	80 31 (9 017)	67 72 (8 290)	37 35 (6 193)
4	T_2D_1	123 77 (11 170)	178 11 (13 383)	70 18 (8 439)	107 10 (10 397)	85 99 (9 327)	173 58 (13 213)	165 33 (12 897)	86 11 (9 337)	60 94 (7 870)	41 68 (6 533)	35 36 (6 03)
5	T_2D_2	89 88 (9 533)	126 53 (11 293)	142 28 (11 970)	111 30 (10 597)	124 22 (11 190)	205 12 (14 357)	137 70 (11 777)	86 42 (9 350)	72 57 (8 577)	77 55 (8 863)	35 85 (6 07)
6	T_2D_3	84 75 (9 260)	124 82 (11 217)	129 81 (11 437)	148 16 (12 213)	193 950 (13 950)	251 50 (15 893)	225 41 (15 047)	125 18 (11 233)	77 80 (8 880)	62 73 (7 983)	44 12 (6 71)
7	T_3D_1	69 68 (8 407)	102 90 (10 193)	84 19 (9 233)	96 95 (9 897)	92 32 (9 660)	119 28 (10 967)	70 57 (8 463)	55 70 (7 530)	57 98 (7 680)	77 55 (8 863)	61 62 (7 913)
8	T_3D_2	69 39 (8 39)	153 26 (12 42)	152 34 (12 383)	181 71 (13 517)	176 02 (13 305)	228 74 (15 157)	164 38 (12 86)	90 91 (9 587)	105 50 (10 32)	62 36 (7 960)	38 15 (6 257)
9	T_3D_3	169 75 (13 067)	181 87 (13 523)	223 79 (14 993)	210 33 (14 537)	240 80 (15 550)	306 65 (17 540)	234 32 (15 34)	144 37 (12 057)	126 76 (11 303)	96 02 (9 850)	37 28 (6 187)
10	Control	70 07 (8 430)	94 06 (9 750)	81 99 (9 110)	110 10 (10 540)	121 99 (11 090)	126 92 (11 310)	138 95 (11 830)	155 00 (12 490)	138 00 (11 790)	191 93 (13 890)	170 87 (13 110)
F test	Traps	NS	NS	**	**	**	**	**	NS	**	NS	**
	Dosages	**	NS	**	***	**	**	**	**	**	NS	NS
	Interaction	**	**	**	**	**	**	*	**	*	NS	*
CD(0 05)	Traps			1 17	0 97	1 10	1 51	1 42		1 27		1 95
	Dosages	1 84		1 17	0 97	1 10	1 51	1 42	1 20	1 27		
	Interaction	1 30	0 72	0 82	0 69	0 78	1 07	1 07	0 85	0 896		1 38

(Figures given in parentheses are transformed ($\sqrt{x\ 1}$) values)

** Significant at 1% level

* Significant at 5% level

the third fourth fifth sixth and eighth weeks The interaction effects were significant at the third fifth sixth seventh eighth and eleventh week of observation The number of pupae increased gradually and reached the peak at about the fourth to sixth week after the installation of traps The number declined gradually in some treatments while the decline was steep in several treatments The build up continued to be high in control plot upto 8th week

4 3 4 Adults

The number of adult weevils (male and female) recovered from the vine samples collected from the treatments at weekly intervals were analysed and the mean values were presented in Table 10 and the corresponding ANOVA was presented in Appendix X

The treatment effects due to trap designs were found to be significant at 3rd 4th 5th 6th 7th 9th and 11th week after placement of traps The effects due to doses were seen to be significant at the 1st 3rd 4th 5th 6th 7th 8th and 9th week while those of the interactions were found significant at all the stages except the 10th week Peak adult population were recorded 5th and 7th observations after which they declined The adult population remained very high in the control plots throughout the duration of the experiment The population were found to be higher in treatments with lower dose in all the three trap designs

Table 11 Mean number of adult male of <u>C</u> <u>formicarius</u> recovered from vines collected at different intervals n d fferent treatments

Sl No	Treatments \ Weeks	17th July 1	24th July 2	31st July 3	7th Aug 4	14th Aug 5	21st Aug 6	28th Aug 7	4th Sep 8	11th Sep 9	18th Sep 10	25th Sep 1
1	T_1D_1	44 16 (6 720)	77 02 (8 833)	34 05 (5 920)	47 90 (6 993)	56 33 (6 880)	84 69 (9 257)	72 65 (8 583)	34 96 (5 997)	27 70 (5 357)	24 27 (5 027)	7 68 (2 947)
2	T_1D_2	27 38 (5 327)	64 98 (8 123)	27 76 (5 363)	46 61 (6 900)	39 58 (6 190)	43 32 (6 657)	24 30 (5 030)	24 00 (5 000)	21 66 (4 76)	20 93 (4 683)	8 32 (3 107)
3	T_1D_3	34 88 (5 990)	68 67 (8 347)	33 96 (5 913)	54 35 (7 440)	66 95 (8 243)	63 32 (8 020)	35 16 (6 013)	45 00 (6 783)	36 61 (6 133)	30 96 (5 653)	24 30 (5 030)
4	T_2D_1	60 42 (7 837)	82 96 (9 163)	30 96 (5 653)	42 23 (7 110)	33 34 (5 860)	81 03 (9 057)	73 30 (8 620)	31 64 (5 713)	35 32 (5 130)	17 69 (4 657)	16 61 (4 197)
5	T_2D_2	41 99 (6 557)	63 27 (8 013)	59 95 (7 807)	52 33 (7 303)	62 63 (7 977)	84 00 (9 220)	61 30 (7 893)	34 05 (5 920)	29 73 (5 453)	21 80 (4 775)	18 47 (4 413)
6	T_2D_3	31 30 (5 683)	53 61 (7 390)	64 01 (8 063)	63 00 (8 000)	41 21 (9 067)	100 18 (10 059)	99 66 (10 036)	45 65 (6 830)	28 59 (5 440)	19 64 (4 543)	24 57 (5 057)
7	T_3D_1	33 66 (5 887)	47 90 (6 993)	33 34 (5 860)	42 34 (6 583)	40 60 (6 450)	44 66 (6 757)	22 64 (4 800)	24 00 (5 000)	12 57 (3 684)	20 62 (4 650)	40 38 (6 433)
8	T_3D_2	36 95 (6 160)	73 25 (8 617)	71 98 (8 543)	86 98 (9 380)	85 99 (9 327)	108 16 (10 448)	72 32 (8 565)	42 99 (6 633)	39 54 (6 367)	24 98 (5 097)	20 54 (4 641)
9	T_3D_3	82 67 (9 147)	92 32 (9 660)	99 64 (10 032)	98 66 (9 985)	115 65 (10 800)	145 58 (12 107)	109 25 (10 500)	65 05 (8 130)	62 63 (7 965)	34 84 (5 987)	19 08 (4 481)
10	Control	70 07 (8 430)	90 01 (9 540)	92 99 (9 695)	99 00 (10 000)	106 95 (10 380)	104 06 (10 250)	128 05 (11 360)	137 06 (11 750)	138 00 (11 790)	180 98 (13 490)	164 89 (12 880)
F test	Traps	NS	NS	**	**	**	**	**	**	NS	NS	NS
	Dosages	NS	**	**	**	**	**	**	**	**	NS	NS
	Interaction	**	**	**	NS	**	**	**	**	**	NS	*
CD(0 05)	Traps			0 51	1 19	0 38	0 69	0 35	0 25			
	Dosages			0 51	1 19	0 38	0 69	0 35	0 25	1 08		
	Interaction	1 00	0 45	0 36		0 27	0 49	0 25	0 18	0 76		1 06

(Figures given in parentheses are transformed ($\sqrt{x+1}$) values)

** Significant at 1% level

* Significant at 5% level

Table 12 Mean number of adult female of C formicarius recovered from vines collected at different intervals n d fferent treatments

Sl No	Treatments \ Weeks	17th July	24th July	31st July	7th Aug	14th Aug	21st Aug	28th Aug	4th Sep	11th Sep	18th Sep	25th Sep
1	T_1D_1	52 48 (7 312)	81 63 (9 090)	44 20 (6 723)	54 55 (7 462)	71 54 (8 517)	113 36 (10 693)	75 74 (8 760)	49 08 (7 078)	30 46 (5 069)	71 25 (8 50)	0 545 (1 243)
2	T_1D_2	33 35 (5 864)	61 09 (7 880)	44 16 (6 720)	57 32 (7 637)	42 64 (6 530)	67 72 (8 290)	40 18 (6 417)	39 20 (6 34)	42 13 (6 563)	41 47 (6 517)	0 904 (1 38)
3	T_1D_3	45 65 (6 830)	66 35 (8 207)	41 03 (6 483)	64 72 (8 407)	75 44 (8 743)	94 90 (9 793)	56 79 (7 602)	50 37 (7 167)	43 66 (6 683)	46 43 (6 887)	1 60 (3 [illegible])
4	T_2D_1	62 79 (7 987)	95 04 (9 800)	38 53 (6 288)	57 68 (7 660)	52 63 (7 323)	92 68 (9 628)	91 73 (9 63)	54 10 (7 424)	35 36 (6 03)	40 34 (6 43)	12 18 (3 63)
5	T_2D_2	47 90 (6 993)	63 21 (8 013)	82 36 (9 130)	58 95 (7 743)	61 20 (7 887)	121 10 (11 050)	76 14 (8 788)	52 33 (7 303)	43 00 (6 633)	54 56 (7 447)	4 05 (3 58)
6	T_2D_3	52 88 (7 340)	71 13 (8 493)	65 26 (8 140)	85 120 (9 280)	112 06 (10 633)	150 60 (12 313)	125 76 (11 260)	79 59 (8 970)	48 60 (7 043)	21 69 (4 763)	9 43 (4 373)
7	T_3D_1	35 97 (6 080)	54 94 (7 480)	50 74 (7 193)	54 55 (7 453)	51 66 (7 257)	74 46 (8 688)	37 85 (6 233)	31 46 (5 697)	45 20 (6 797)	47 07 (6 933)	21 00 (4 690)
8	T_3D_2	31 64 (5 713)	79 86 (8 992)	80 18 (9 012)	94 55 (9 780)	89 95 (9 539)	120 37 (11 017)	91 79 (9 635)	47 90 (6 996)	65 96 (8 183)	28 16 (5 400	15 81 (4 310)
9	T_3D_3	86 67 (9 363)	89 55 (9 516)	123 75 (11 170)	111 51 (10 609)	125 18 (11 233)	160 72 (12 717)	124 6 (11 209)	78 87 (8 961)	62 94 (7 998)	42 92 (6 627)	17 86 (4 343)
10	Control	70 06 (8 430)	96 99 (9 899)	71 08 (8 490)	121 10 (11 050)	138 00 (11 790)	150 04 (12 290)	150 04 (12 290)	172 98 (13 190)	138 00 (11 790)	213 92 (14 660)	176 96 (3 340)
F test	Traps	NS	NS	**	**	**	NS	**	NS	NS	NS	**
	Dosages	NS	NS	**	**	**	**	NS	**	NS	NS	NS
	Interaction	*	**	**	**	**	**	**	NS	NS	NS	NS
CD(0 05)	Traps			1 5	1 22	1 38		1 93				44
	Dosages			1 5	1 22	1 38	1 81		1 62			
	Interaction	1 29	0 74	1 06	0 87	0 98	1 28	1 36				

(Figures given in parentheses are transformed ($\sqrt{x+1}$) values)

** Significant at 1% level

* Significant at 5% level

4 3 5 Male adults

The number of male adults recorded at different intervals were analysed and the mean values were presented in Table 11 The corresponding ANOVA were presented in the Appendix XI

The treatment effects due to trap designs were found to be significant at the 3rd 4th 5th 6th 7th and 8th week after the placement of traps The effect due to doses were significant from 3rd to 9th week while the interaction effects were signifi cant during all the observations except the 4th and 10th week The higher weevil counts were recorded in the mudpot and poly thene bag traps fitted with 250 µg dose as compared to that in the tin trap design In general the higher dosages gave lower weevil count The weevil count was very high in control plots throughout the observation period

4 3 6 Female adults

The data on the number of adult females extracted from the vine samples at different periods were statistically analysed and the mean values were presented in Table 12 and the corres ponding ANOVA was presented in the Appendix XII

The treatment effects due to trap designs were significant during the 3rd 4th 5th 7th and 11th week observations while the effects due to doses were significant during the 3rd 4th

Table 13 Mean vine weight (in kg) in different treatments recorded at different intervals after placement of traps in terms of trap designs

Sl No	Traps / Weeks	Tin trap	Mudpot trap	Polythene bag trap
1	17 7-91	15 2	12 4	11 0
2	24 7 91	29 1	28 2	15 6
3	31-7 91	27 2	23 6	24 9
4	7 8 91	23 8	24 0	26 8
5	14 8 91	26 7	25 0	27 0
6	21 8 91	28 1	28 7	28 0
7	28 8-91	31 1	28 5	31 3
8	4-9 91	26 0	25 7	27 6
9	11 9 91	29 0	27 9	29 2
10	18 9 91	30 8	33 8	31 0
11	25 9 91	38 3	25 7	30 6

F test Weeks NS

Traps NS

CD (0 05) Weeks

Traps

Table 14 Mean vine weight (in kg) in different treatments recorded at different intervals after placement of traps in terms of doses of pheromone

Sl No	Weeks / Dosages	1000 µg	500 µg	250 µg
1	17 7-91	12 5	14 0	12 1
2	24 7 91	24 5	25 3	23 1
3	31 7 91	25 9	26 0	23 8
4	7 8 91	28 6	22 7	23 3
5	14 8 91	31 6	26 7	20 4
6	21 8 91	35 0	26 8	23 0
7	28-8 91	37 0	28 4	25 5
8	4-9 91	30 1	26 7	22 5
9	11-9 91	33 8	28 3	24 0
10	18 9 91	37 6	29 0	29 0
11	25 9-91	36 6	30 0	28 0

F test	Weeks	**
	Traps	**
CD (0 05)	Weeks	2 20
	Traps	4 23

** Significant at 1% level

5th 6th and 8th week observations The interaction effects were significant upto the 7th week after installation of traps The number of female weevils increased gradually and reached their peaks at 6 weeks after installation of traps declining thereafter The weevil count was higher in the control plots throughout the period of observation the peak being recorded at 10th week observation

4 4 Assessment of the efficacy of the pheromone in terms of vine weight

The data on weight of vine samples collected at different intervals after treatment were analysed statistically and the mean values were presented in Table 13 and 14 The corresponding ANOVA were presented in Appendix-XIII and XIV

4 4 1 Vine weight in terms of trap designs

The effects due to trap designs were not significant over 11 weeks of observation

4 4 2 Vine weight in terms of pheromone doses

The effects due to doses were significant The mean vine weight recorded in the 1000 μg dose was significantly higher than that in the other doses from the fourth week onwards The dose 250 μg recorded the lowest mean vine yields among the three treatments during all stages of observation

Table 15 Mean tuber weight (in kg) recorded in different treatments at harvest

Treatments	1000 μg	500 μg	250 μg
Tin trap	28 13	15 87	36 37
Mudpot trap	23 07	26 00	18 73
Polythene bag trap	37 60	6 00	16 37
Control	24 27	24 27	24 27

F test	Traps	NS
	Dosages	NS
	Interaction	NS
CD (0 05)	Traps	-
	Dosages	
	Interaction	

Table 16 Mean vine weight (in kg) recorded in different treatments at harvest

Treatments	1000 µg	500 µg	250 µg
Tin trap	52 00	39 20	47 17
Mudpot trap	59 93	50 73	48 17
Polythene bag trap	57 06	52 97	48 23
Control	33 40	33 40	33 40

F test	Traps	NS
	Dosages	NS
	Interaction	NS
CD (0 05)	Traps	
	Dosages	
	Interaction	

Table 17 Mean root weight (in kg) recorded in different treatments at harvest

Treatments	1000 μg	500 μg	250 μg
Tin trap	20 13	23 47	16 53
Mudpot trap	21 97	20 07	21 73
Polythene bag tap	23 60	21 00	20 67
Control	11 23	11 23	11 23

F test	Traps	NS
	Dosages	NS
	Interaction	NS
CD (0 05)	Traps	-
	Dosages	
	Interaction	

4 5 Assessment of efficacy of pheromone in terms of weight of tubers, vines and roots at harvest

The data on the weight of tubers vines and roots in different treatments recorded at harvest were analysed statistically and the mean values were presented in Tables 15 16 and 17 respectively The corresponding ANOVA were presented in Appendix-XV XVI and XVII The effects of trap design and doses were not significant in terms of tuber weight vine weight and root weight

4 6 Assessment of efficacy of pheromone in terms of Cost Benefit ratios

The Cost Benefit ratios for different trap designs were worked out and presented in Table 18 19 and 20 for tin mudpot and polythene bag traps respectively

4 6 1 Tin trap

The cost of installation of the required number of traps worked out to Rs 288/ Additional yield due to treatments was recorded in 250 and 1000 μg doses The estimated value of the additional yield was Rs 5 054 16 and Rs 1 608 34 giving Cost Benefit ratios of 1 17 55 and 1 5 59 respectively in the two treatments Additional yield was not obtained in the 500 μg dose

Table 18 Cost Benefit Ratio for Tin trap

Sl No	Particulars	250 ug			500 ug			1000 ug		
		Per Unit Rs	No of traps required	Per ha Rs	Per unit Rs	No of traps required	Per ha Rs	Per unit Rs	No of traps required	Per ha Rs
	<u>Cost</u>									
1	Cost of the device	15 20	15	228 00	15 20	15	228 00	15 20	15	228 00
2	Cost of installation and maintenance			60 00			60 00			60 00
3	Total cost			288 00			288 00			288 00
	<u>Yield</u>									
	Yield of tuber in treatment plot (kg)	36 40		7583 33	15 86		3305 56	28 13		5860 42
5	Yield of tuber in control (kg)	24 27		5056 25	24 27		5056 25	24 27		5056 25
6	Increase in yield due to the treatment (kg)	12 13		2527 08	8 47		1750 69	3 60		804 17
7	Value of additional yield (Rs)			5054 16			-			1608 34
8	Cost Benefit Ratio			1 17 55						1 5 59

Table 19 Cost Benefit Ratio for Mudpot trap

Sl No	Particulars	250 µg			500 µg			1000 µg		
		Per unit Rs	No of traps required	Per ha Rs	Per unit Rs	No of traps required	Per ha Rs	Per unit Rs	No of traps required	Per ha Rs
	Cost									
1	Cost of the device	12 00	15	180 00	12 00	15	180 00	12 00	15	180 00
2	Cost of installation and maintenance			60 00			60 00			60 00
3	Total cost			240 00			240 00			240 00
	Yield									
4	Yield of tuber in treatment plot (kg)	18 73		3902 08	26 00		5416 70	23 07		4806 25
5	Yield of tuber in control (kg)	24 27		5056 25	24 27		5056 25	24 27		5056 25
6	Increase in yield due to treatment (kg)	5 50		1154 17	1 73		360 45	1 20		250 00
7	Value of additional yield (Rs)				3 46		720 90			
8	Cost Benefit Ratio						1 3 00			

Table 20 Cost Benefit Ratio for Polythene bag trap

Sl No	Particulars	250 µg			500 µg			1000 µg		
		Per unit Rs	No of traps required	Per ha Rs	Per unit Rs	No of traps required	Per ha Rs	Per unit Rs	No of traps requi red	Per ha Rs
	Cost									
1	Cost of device	5 00	15	75 00	5 00	15	75 00	5 00	15	75 00
2	Cost of installation and maintenance			60 00			60 00			60 00
3	Total cost			135 00			135 00			135 00
	Yield									
4	Yield of the tuber in treatment plot (kg)	16 36		3408 33	40 20		8375 00	36 60		7833 33
5	Yield of the tuber in control plot (kg)	24 27		5056 25	24 27		5056 25	24 27		5056 25
6	Increase in yield due to the treatment (kg)*	-7 91		1647 92	15 93		3318 75	13 33		2777 08
7	Value of additional yield (Rs)						6637 50			5554 16
8	Cost Benefit Ratio						1 49 17			1 41 14

Table 21 Mean percentage catch on marked adult males caught at different intervals in traps with different dose of pheromone when released at different distances from the trap

Sl No	Distance of release (m)	Number of adult males released	250 µg		500 µg		1000 µg	
			Ist day after release	2nd day after release	1st day after release	2nd day after release	1st day after release	2nd day after release
1	25	40	11 25	18 75	48 75	56 25	82 50	88 75
2	50	40			32 50	40 00	60 00	65 00
3	100	40			7 50	6 25	35 00	37 50
4	200	40		-	-		3 75	
5	400	40						

4 6 2 Mudpot trap

The cost of installation of the required number of traps was Rs 240/- Additional yield was obtained only in the 500 µg dose The value of additional yield was Rs 720 90 per ha giving a Cost Benefit ratio of 1 3 0

4 6 3 Polythene bag trap

The cost of installation of the required number of traps per hectare worked out to Rs 135/- Additional yield due to treatments was recorded from 500 and 1000 µg doses only The estimated value of the additional yield worked out to be Rs 6 637 50 and Rs 5 554 16 respectively for the doses 500 µg and 1000 µg giving Cost Benefit ratio of 1 49 17 and 1 41 14 respectively

4 7 Assessment of the efficacy of pheromone with influence to the range of attraction of adult males

The data on the mean percentage of recapture of marked adults after release at different distances from the trap were presented in Table 21 The efficacy of the attraction showed a decrease with increasing distance of release Maximum recapture was obtained from 25 m while no recapture was noticed when the weevils were released at 400 m Among the doses the efficiency was maximum in the 1000 µg dose which could attract weevils upto a distance of 200 m while the 250 µg dose could attract weevils at 25 m distance only

Discussion

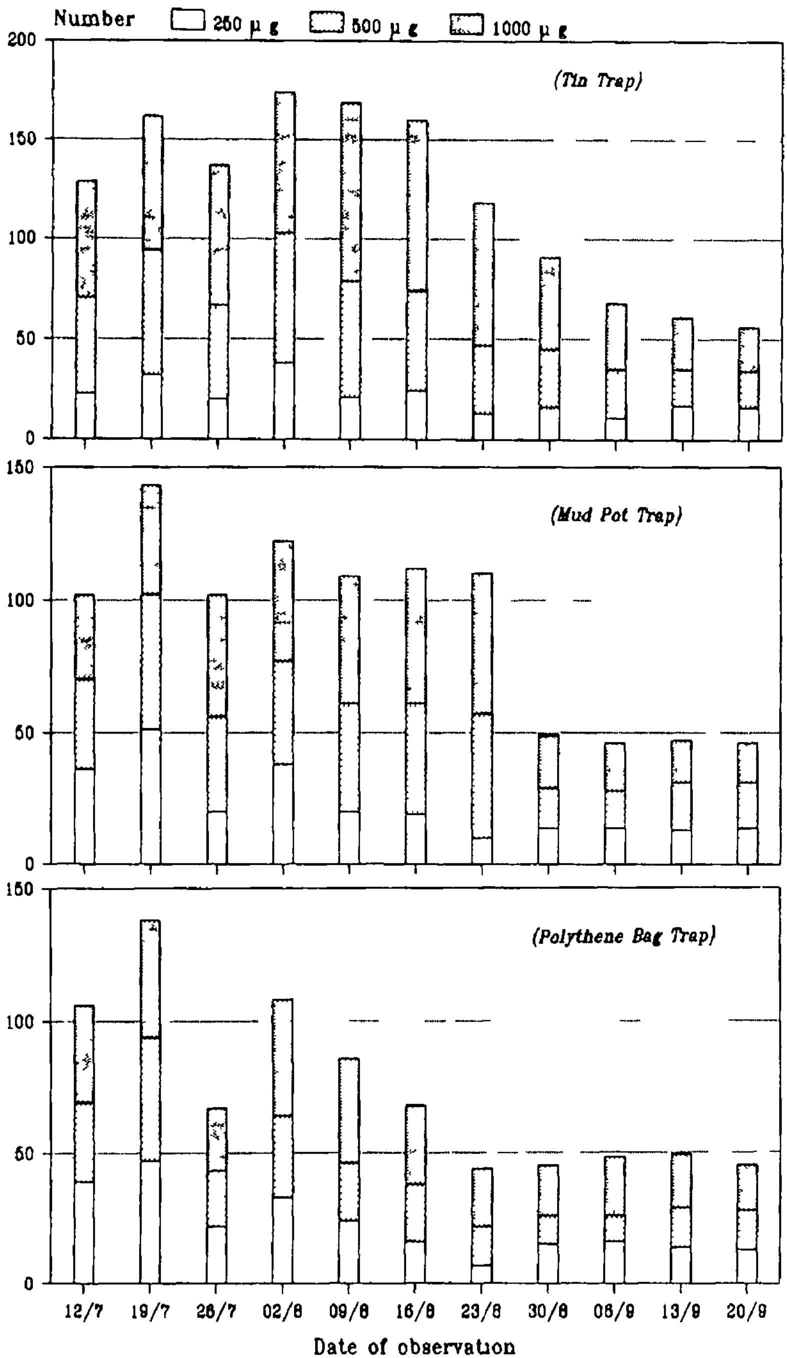
DISCUSSION

The sweet potato weevil *Cylas formicarius formicarius* F is a serious pest of sweet potato attacking the vines and tubers causing extensive economic loss The weevil is at present kept under check by high insecticidal application The recommendations include the use of granular insecticides soil drenching etc Desired level of control of this pest is difficult since the life stages attack underground portions of the plant Moreover use of heavy doses of insecticides add to the cost of cultivation The crop being relatively less remunerative higher cost of plant protection renders the cultivation even less remunerative Thus the use of female sex pheromone as a component of integrated management of the sweet potato weevil is highly desirable

The female sex pheromone isolated from *C formicarius elegantulus* was characterised and synthesised by Heath *et al* (1986) It was found to attract males of *C formicarius formicarius* by Talekar (1983) Thus in the present study an attempt has been made to study the effectiveness of three doses of female sex pheromone synthesised at the Regional Research Laboratories of CSIR at Trivandrum in mass trapping the males of the sweet potato weevil in the field An attempt has been made to test the effectiveness of traps fabricated from locally available and cheap materials and their influence on the effectiveness of phero mone in mass trapping of the adult males The effectiveness of

Fig 1 Mean number of adult males of SPW caught during morning at different periods in different treatments

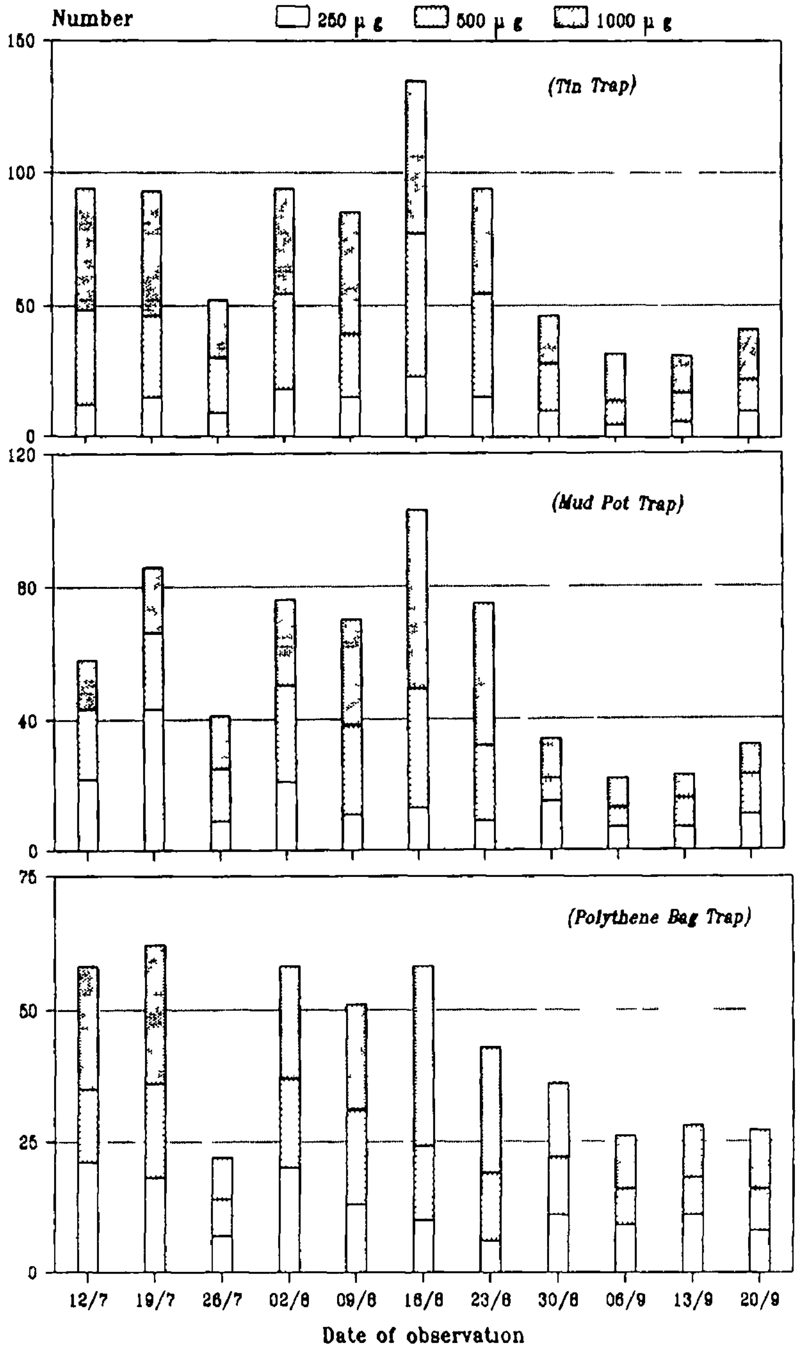
Fig 1



Number
250 µ g
500 µ g
1000 µ g
(Tin Trap)
(Mud Pot Trap)
(Polythene Bag Trap)
0
50
100
150
200
12/7
19/7
26/7
02/8
09/8
16/8
23/8
30/8
06/9
13/9
20/9
Date of observation

Fig 2 Mean number of adult males of SPW caught during evening at different periods in different treatments

Fig 2


Number
250 µ g
500 µ g
1000 µ g
150
100
50
0
(Tin Trap)
120
80
40
0
(Mud Pot Trap)
75
50
25
0
(Polythene Bag Trap)
12/7
19/7
26/7
02/8
09/8
16/8
23/8
30/8
06/9
13/9
20/9
Date of observation

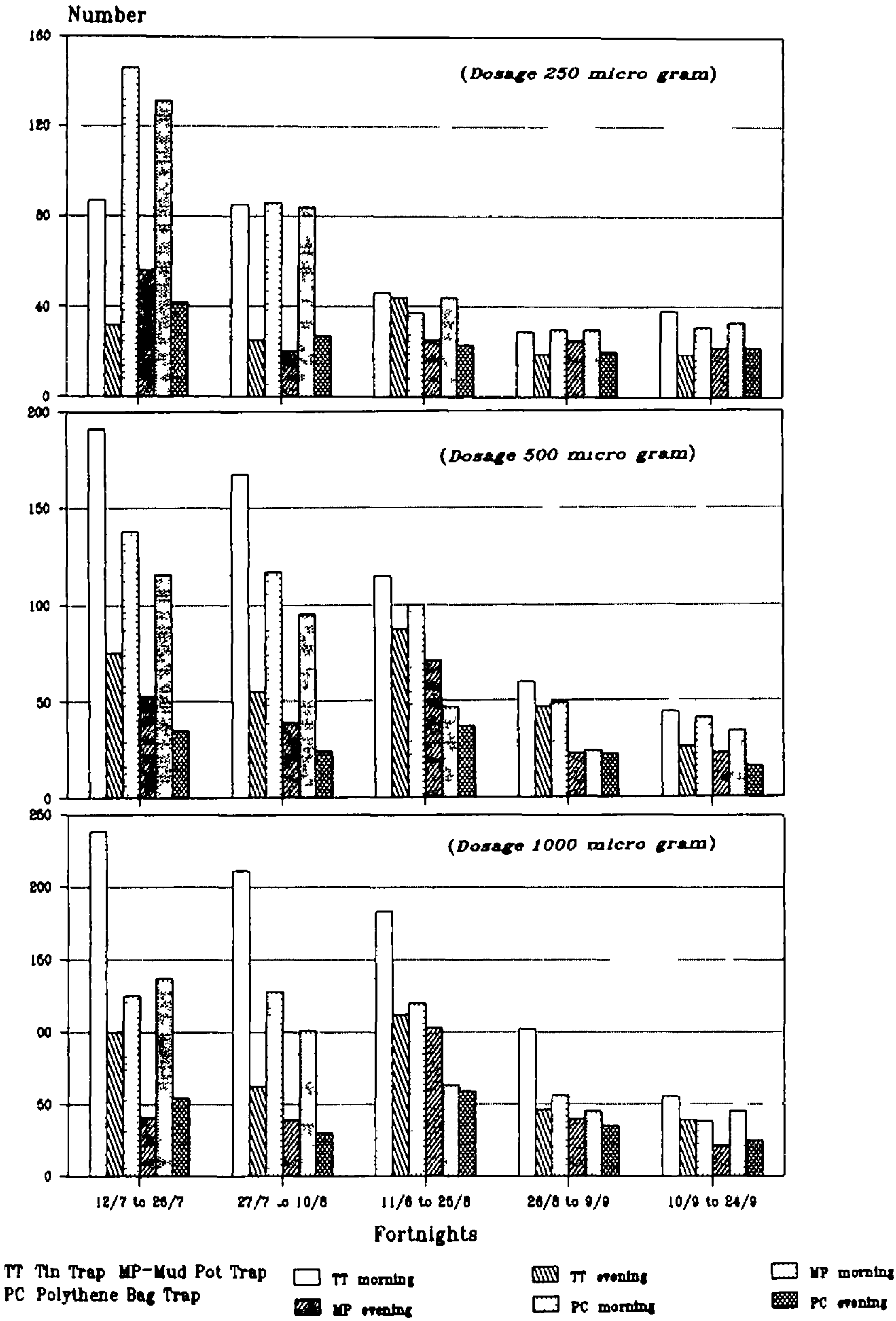
of the pheromone in terms of range of attraction was also studied The results presented in chapter 4 are discussed here

5 1 Assessment of the efficiency of synthetic pheromone against the males of *C formicarius formicarius* F in the field

The efficiency of the synthetic pheromone and the efficiency of trap designs in terms of capture of adult male weevils as influenced by their activity during the night and day was investigated The pattern of male weevils caught in different treatments both in the morning and evening are depicted in Figs 1 and 2 The results presented in para 4 1 indicated that there was no marked incremental effect of doses on the number of weevils caught However there were notable differences in the number of weevils captured during the morning and evening The number of weevils caught during the night as represented by the weevil catch recorded in the mornings was invariably high as compared to that during the day as represented by the weevil catch recorded in the evening throughout the 11 weeks of observation Thus the activity of the weevils was found to be greater during the night than during the day This finding is in agreement with the earlier findings of Proshold (1983) who reported that the adults were active during night He further reported that male weevils moved up on the shoots and remained there until sunrise while females moved to the root region Similarly Howard (1982) reported that the weevils mostely males were found active on

Fig 3 Mean number of adult SPW caught during different periods in different treatments

Fig 3



Number
(Dosage 250 micro gram)
(Dosage 500 micro gram)
(Dosage 1000 micro gram)
12/7 to 26/7
27/7 to 10/8
11/8 to 25/8
26/8 to 9/9
10/9 to 24/9
Fortnights
TT Tin Trap MP-Mud Pot Trap
PC Polythene Bag Trap
TT morning
MP evening
TT evening
PC morning
MP morning
PC evening

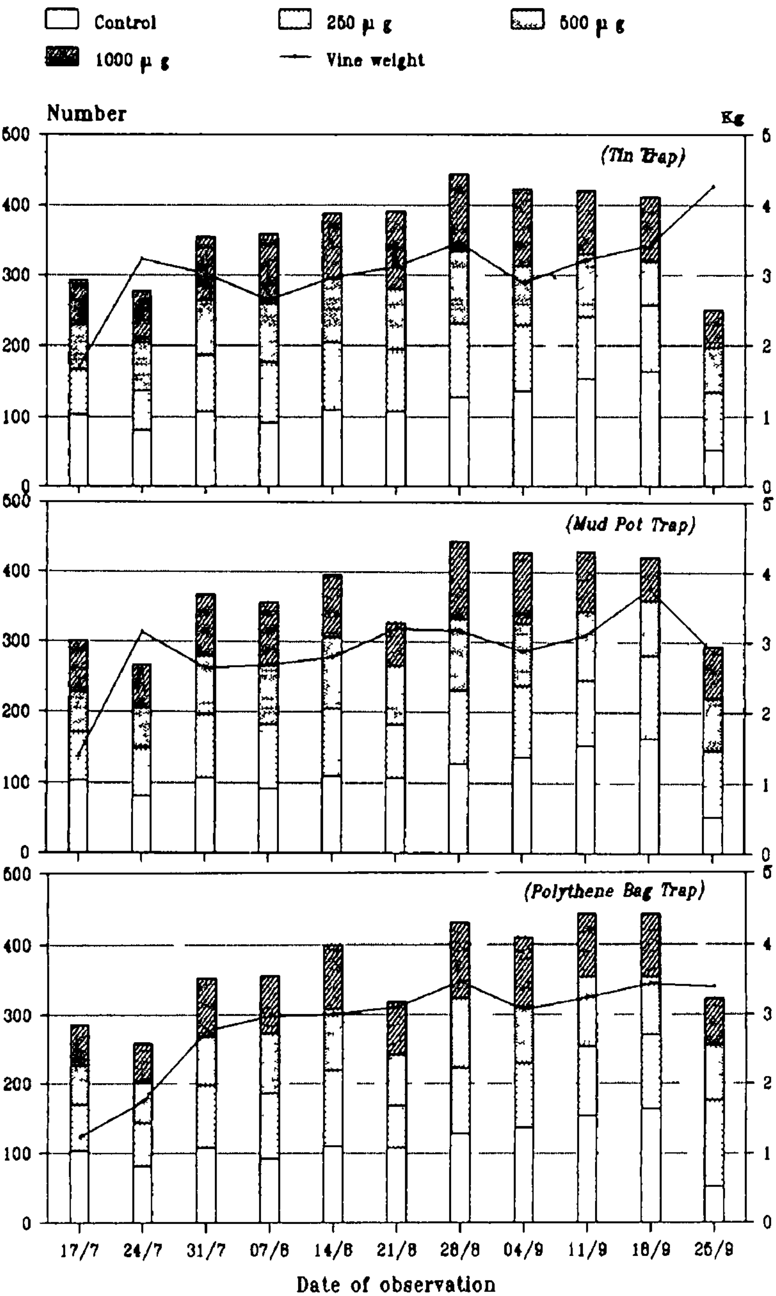
the plants at night with peak activity at 21 00 hours According to Proshold _et al_ (1986) the adults were most active just after sunset and again just before sunrise and that the traps placed at evening captured maximum males This appears to be the main reason for the higher catch of males in traps in the morning than in the evening irrespective of the dosage of pheromone and the trap design throughoutt the present study Similarly Talekar and Lee(1989) found that the synthetic pheromone at 0 1 μg was more attractive to males than were 5 virgin females placed in a trap In the present study the males were caught throughout the day and night indicating the overpowering attraction of males towards the synthetic pheromone Thus a considerable level of mating reduction can be expected due to the continued presence of high doses of pheromone in the field

5 2 Effect of moon phase on the activity of adult males of _C formicarius formicarius_ F

The results of analysis of the number of weevils caught during the night (morning catch) and during the day (evening catch) pooled over fortnights are presented in para 4 2 and depicted graphically in Fig 3 The first third and fifth periods (fortnights) correspond to the wax while the second and fourth period correspond to the wane of the moon The differences in weevil counts can be attributed chiefly due to the effect of dosages and traps rather than the moon light Thus it can be

Fig 4 Mean number of eggs and vine weight recorded at different periods in different treatments

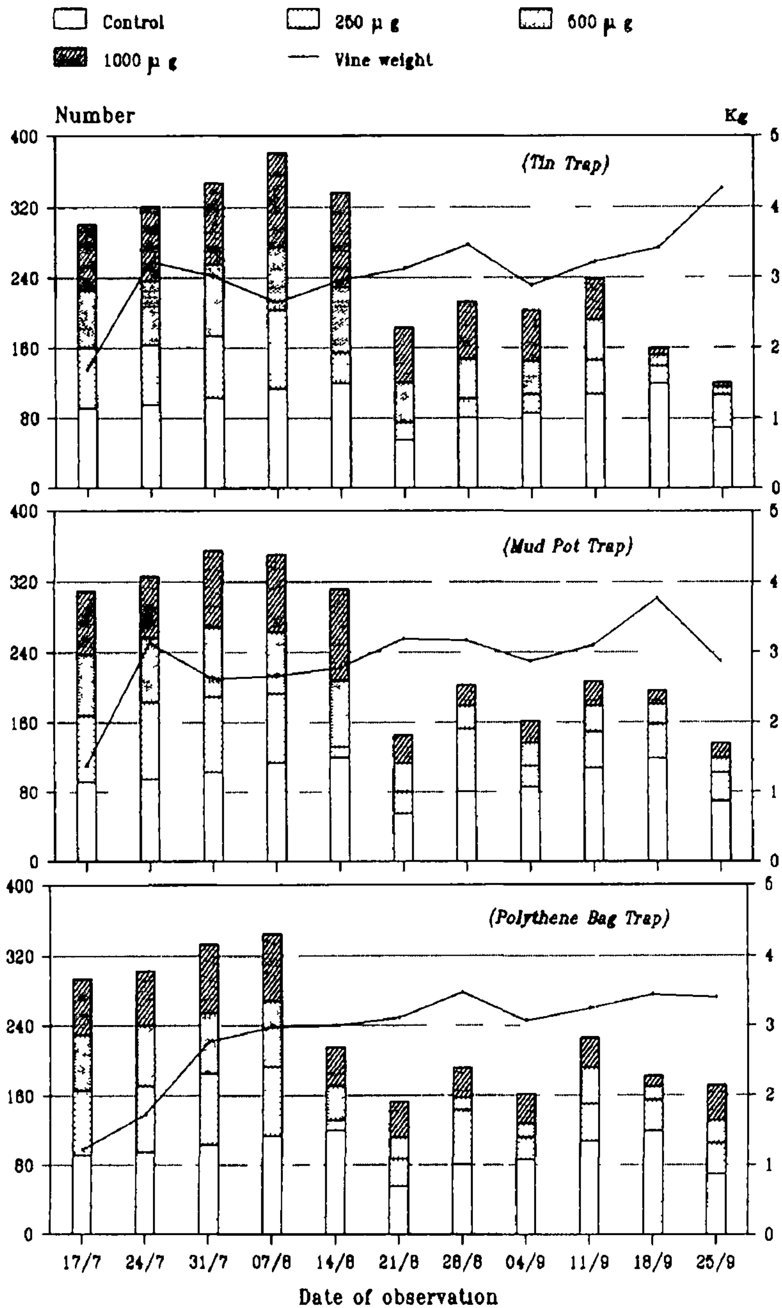
Fig 4



Control
250 µ g
500 µ g
1000 µ g
Vine weight
Number
Kg
(Tin Trap)
(Mud Pot Trap)
(Polythene Bag Trap)
0
100
200
300
400
500
0
1
2
3
4
5
17/7
24/7
31/7
07/8
14/8
21/8
28/8
04/9
11/9
18/9
25/9
Date of observation

Fig 5 Mean number of larvae and vine weight recorded at different periods in different treatments

Fig 5



Control
250 µ g
500 µ g
1000 µ g
Vine weight
Number
Kg
(Tin Trap)
(Mud Pot Trap)
(Polythene Bag Trap)
0
80
160
240
320
400
0
1
2
3
4
5
17/7
24/7
31/7
07/8
14/8
21/8
28/8
04/9
11/9
18/9
25/9
Date of observation

Fig 6

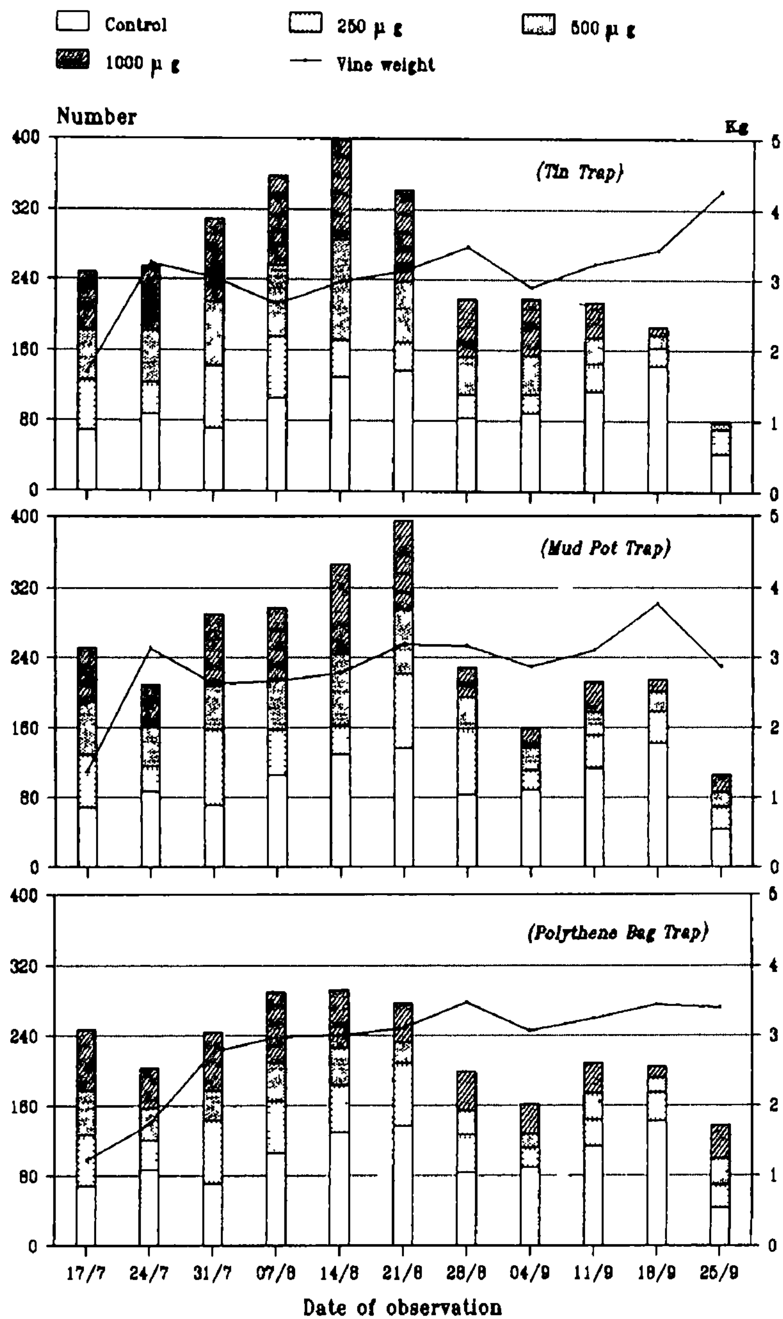
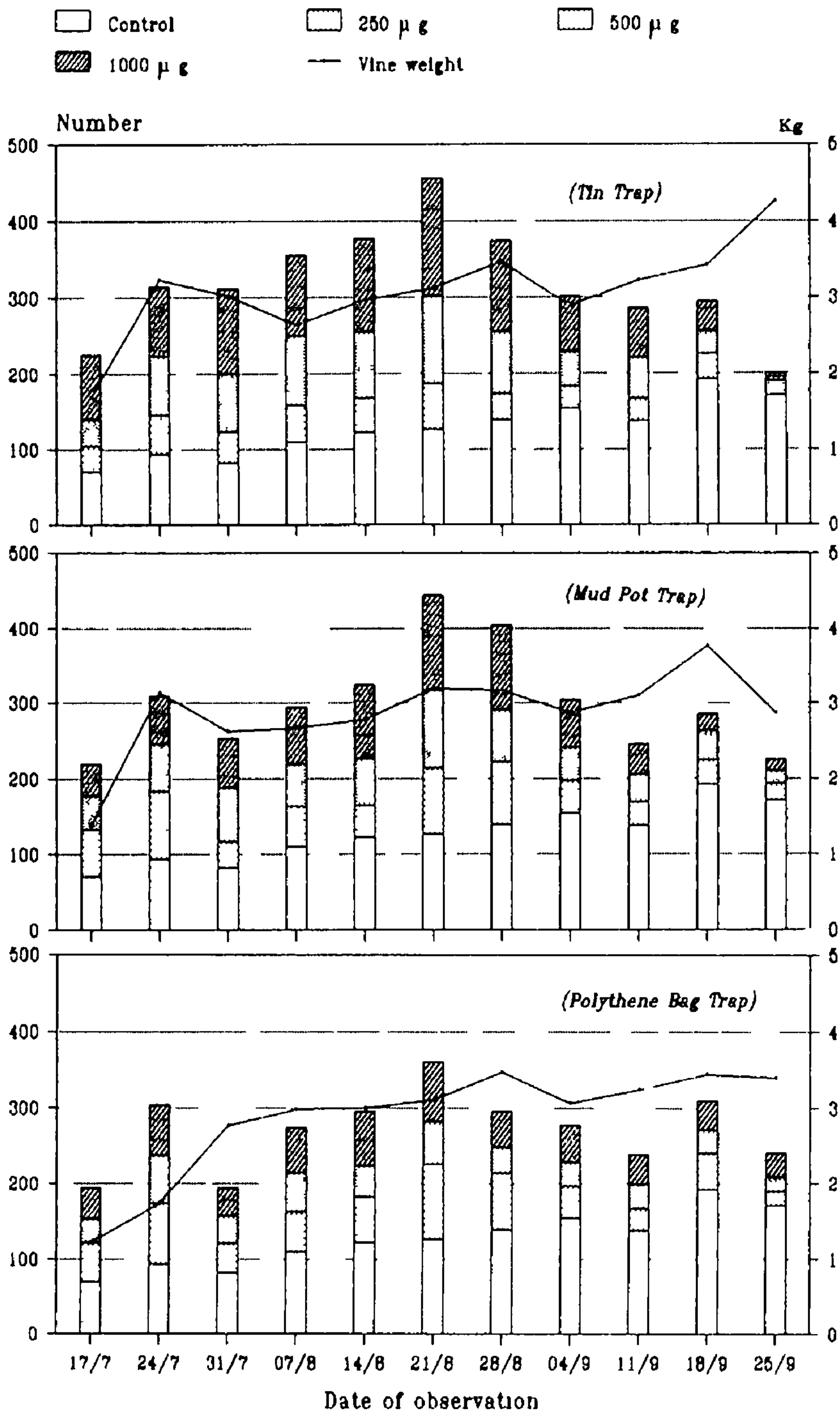

Control
250 µ g
500 µ g
1000 µ g
Vine weight
Number
Kg
(Tin Trap)
(Mud Pot Trap)
(Polythene Bag Trap)
0
80
160
240
320
400
0
1
2
3
4
5
17/7
24/7
31/7
07/8
14/8
21/8
28/8
04/9
11/9
18/9
25/9
Date of observation

Fig 7 Mean number of adult (male + female) and vine weight recorded from plant sample at different periods in different treatments

Fig 7



Control
250 μ g
500 μ g
1000 μ g
Vine weight
Number
Kg
(Tin Trap)
(Mud Pot Trap)
(Polythene Bag Trap)
0
100
200
300
400
500
0
1
2
3
4
5
17/7
24/7
31/7
07/8
14/8
21/8
28/8
04/9
11/9
18/9
25/9
Date of observation

concluded that the irrespective of the presence or absence of moon light, the night flight of the male weevils continued as indicated by continued high morning catch The day light though appear to have definite influence on the flight behaviour of the weevils

5 4 Effect of mass trapping of adult males on the population build up of the weevil in the field

The results presented in para 4 3 are graphically represented in Figs 4 5 6 and 7 in which the number of eggs larvae purpae and adults respectively in the treatments and control along with the corresponding vine weights were also shown The vine weight increased gradually in all the treatments which is due to the increase in vegetative growth The presence of life stages did not appreciably affect the growth of vines in the plots According to Edmond (1971) and Pillai et al (1987) the vigour and growth of vines could be affected because of severity of attack of the weevil However in the present study the steady increase in vine weight suggested that the weevil damage was not severe so as to cause appreciable reduction in the growth of vines This can only be at ributed to the continued presence of the pheromone in the field which probably reduced the build up of the population of the weevil

5 5 Economics of installation of pheromone traps for the control of the weevil

The results of the cost benefit analysis of the trap designs as presented in para 4 6 indicated that among the three designs, the polythene bag trap appeared to be the cheapest to fabricate install and maintain Additional yield obtained in treatments with this trap resulted in the highest C B ratio of 1 49 2 which is very favourable The tin trap with a C B ratio of 1 17 6 though far inferior to the polythene bag trap can be adopted considering its compactness and versatility in handling The mudpot trap being much inferior and having no added advantages of cheapness or handling ease cannot be considered for recommendation Earlier several workers have reported varying degrees of effectiveness with different trap designs for the capture of males of C formicarius formicarius (Proshold et al 1986 Hwang et al 1989 Jansson et al 1989 and Talekar and Lee 1989)

In some of these studies the traps were designed and used as tools for accurate monitoring of field populations of the weevil without taking the cost factor into consideration Hwang et al (1989) and Talekar and Lee (1989) tried to design and test models for the mass trapping of the weevil In comparison the materials used by these authors for fabricating the traps are undoubtedly costlier and hence unaffordable by sweet potato farmers Thus the polythene bag trap and tin trap designed and tested in the present study appear to be better alternatives to the more costlier unitrap and plastic funnel and aluminium funnel traps

5 6 Efficiency of synthetic pheromone in terms of distance of attraction

The results of analysis of marked released and recaptured male weevils presented in para 4 7 clearly indicated that the efficiency of attraction decreased with increasing distance of release from the trap No recapture was noticed at 400 m while maximum recapture was recorded at 25 m Similar results were reported by Hwang et al (1989) where the attraction drastically decreased from 69 1 per cent to 0 4 per cent when the distance of release was increased from 5 m to 40 m from the pheromone trap However Talekar and Lee (1989) reported that 1 mg pheromone dose could capture 94 7 per cent of marked males released at 10 m distance while 11 4 per cent males were captured when released at 100 m away from the pheromone trap

The results clearly indicate the need for the placement of pheromone baited traps in such a way that the distance between them shall not exceed 25 m for effective mass trapping of male weevils Thus 15-16 traps will be sufficient to cover an area of one hectare of sweet potato field for the purpose of mass trapping of adult males of sweet potato weevil

Summary

SUMMARY

Studies were conducted to determine the effectiveness of three doses of indegenously synthesised pheromone in mass trapping of males of C formicarius formicarius in the field The impact of mass trapping of males on the population build up of the pest in the field was assessed Low cost traps were designed fabricated and tested under field conditions and their influence on the effectiveness of pheromone doses was also assessed The cost of installation of the three different trap designs and the benefit derived by way of increased yield of tubers was worked out to arrive at the economic feasibility of the technique The range of attraction of the synthetic pheromone was assessed by the extent of recapture of marked adult males released at different distances from the baited traps

The results of the studies can be summarised as follows

The number of male weevils caught in different treatments did not show marked incremental effects due to increase in doses indicating that 250 µg doses can be used effectively However there was marked increase in the number of weevils caught in the morning as compared to the evening catch This indicated that the weevils were most active during night time The synthetic pheromone was quite effective in attracting the male weevils inspite of the presence of virgin females in the field

2 A comparison of the number of male weevils caught during the night (moning counts) over fortnightly intervals indicated no perceptible differences between wax and wane of the moon This showed that irrespective of the presence or absence of moon light the pheromone doses were effective in attracting the adult males Significantly lower day catches indicated that the day light affected the flight pattern of the weevils

3 The vine weight recorded in different treatments showed a steady increase during the cropping period This indicated that the weevil build up was not appreciable as to affect the growth of vines The pheromone doses by their continuous presence and consequent trapping of males were effective in preventing appreciable reduction in vine weight

4 Among the three trap designs tested the polythene bag trap proved to be the cheapest one to fabricate instal and maintain It also recorded the highest C B ratio The tin trap though more effective than the polythene bag trap in terms of weevil catch was slightly costlier However considering the versatility in handling and compactness it can be considered for adoption

5 When adult males were marked and released at different distances from the pheromone baited traps it was found that the attract ion was maximum at a range of 25 m The attraction drastically decreased with increase in distance of release There was no attraction at 400 m distance This indicated that the

pheromone baited traps should be placed in the field in such a wayy that the distance between two traps should not exceed 25 m This ensures effective trapping of adult males By fabricating traps from cheap and locally available materials This requirement can be met at reasonable cost

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Coppedge J R Bull D L House V S Ridgway R L Bottrell D G and Cowan C B 1973 Formulations for controlling the release of synthetic pheromone (grandlure) of the boll weevil 2 Biological studies Environ Entomol **2**(5) 837 843

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Appendices

APPENDIX-I

Summary of analysis of variance tables of the mean morning catch of adult males of C formicarius in different treatments as analysed at weekly intervals

Sl No	Source	df	MSS 12th 18th July	MSS 19th 25th July	MSS 26th 1st Aug	MSS 2nd 8th Aug	MSS 9th 15th Aug	MSS 16th 22nd Aug	MSS 23rd 29th Aug	MSS 30th 5th Sep	MSS 6th 12th Sep	MSS 13th 19th Sep	MSS 20th 26th Sep
1	Replication	2	2 500	0 549	0 230	4 082*	5 907**	1 922*	1 841	10 422**	6 727**	8 496**	1 968
2	Traps	2	0 899	0 651	0 073**	6 402	8 029**	11 505**	12 953**	5 334	1 330	0 650	0 707
3	Dosage	2	1 209	1 230	9 927**	3 003	18 142**	19 350**	31 314**	3 860**	3 256**	0 888	0 232
4	Interaction	4	2 987	2 797	2 707*	1 197	3 273**	1 456**	2 428	1 476	1 437*	0 138	0 162
5	Treatment Vs Control	1	69 261**	97 741**	60 492**	85 981**	72 676**	68 387**	46 934**	31 800**	27 910**	27 132**	25 916**
6	Error	16	1 286	1 903	0 738	0 929	0 529	0 291	1 050	0 524	0 388	0 494	0 562

** Significant at 1% level

* Significant at 5% level

APPENDIX II

Summary of analysis of variance tables of evening catch of adult males of C formicarius in different treatments as analysed at weekly intervals

Sl No	Source	df	MSS 12th 18th July	MSS 19th 25th July	MSS 26th 1st Aug	MSS 2nd 8th Aug	MSS 9th 15th Aug	MSS 16th- 22nd Aug	MSS 23rd 29th Aug	MSS 30th 5th Sep	MSS 6th 12th Sep	MSS 13th 19th Sep	MSS 20th 26th Sep
1	Replication	2	2 631	0 634	0 927	0 245	6 032**	3 016*	5 342*	2 120**	2 950**	2 975*	0 020
2	Traps	2	3 060	1 709	4 618	2 932**	2 683	10 404**	7 115**	0 639	0 328	0 227	1 117
3	Dosage	2	1 954	2 103	2 195	2 045	8 897**	20 633**	16 730**	0 489	1 432	0 268	0 427
4	Interaction	4	3 907*	3 127*	0 579	1 047	1 290	0 917	0 714	0 898*	0 679	0 668	0 543
5	Treatment Vs Control	1	37 811**	43 303**	17 531**	44 181**	36 845**	56 299**	36 095**	18 860**	11 401**	11 953**	15 818**
6	Error	16	1 249	0 839	0 888	0 423	0 587	0 716	0 817	0 288	0 397	0 249	0 236
7	Total	27											

** Significant at 1% level
* Significant at 5% level

APPENDIX-III

Summary of analysis of variance tables of morning and evening ctach of adult males of C formicarius in different treatments as analysed at weekly intervals

Sl No	Source	df	MSS 12th-18th July	MSS 19th 25th July	MSS 26th 1st Aug	MSS 2nd-8th Aug	MSS 9th 15th Aug	MSS 16th 22nd Aug	MSS 23rd 29th Aug	MSS 30th 5th Sep	MSS 6th 12th Sep	MSS 13th 19th Sep	MSS 20th 26th Sep
1	Replication	2	4 882	0 940	2 605	2 869	11 379**	5 300**	5 670*	12 117**	9 771**	9 457*	1 406
2	Traps	2	3 587	1 937	6 508**	8 960**	10 525**	23 245**	20 545**	5 388	1 717	1 072	1 758
3	Dosage	2	3 002	2 656	13 985**	4 845	27 736**	39 611**	48 901**	3 897**	4 876**	1 190	0 595
4	Interaction	4	6 535	5 216	2 901*	2 167	3 761*	1 470	1 464	2 017*	2 073*	0 647	0 587
5	Treatment Vs Control	1	119 853**	153 514**	93 648**	143 805**	121 887**	137 563**	94 781**	59 125**	45 714**	46 385**	49 221**
6	Error	16	2 332	2 556	0 873	1 166	0 821	0 827	1 474	0 542	0 525	0 484	0 472
7	Total	27											

** Significant at 1% level
* Significant at 5% level

APPENDIX-IV

Summary of analysis of variance tables of morning catch of ad lt males of C formicarius in different treatments as analysed at fortnightly intervals

Sl No	Source	df	MSS 12th 26th July	MSS 27th 10th Aug	MSS 11th 25th Aug	MSS 26th 9th Sep	MSS 10th 26th Sep
1	Replication	2	5 009	7 043**	3 990*	17 299**	11 366**
2	Traps	2	6 161	15 105**	24 069**	8 811**	1 155
3	Dosage	2	7 499	17 179**	41 013**	14 071**	1 377
4	Interaction	4	11 622	4 239*	6 740**	3 715*	0 249
5	Treatment Vs Control	1	318 024**	258 264**	166 317**	86 191**	75 088**
6	Error	16	4 923	0 974	0 795	0 928	0 932
7	Total	27					

** Significant at 1% level
* Significant at 5% level

APPENDIX VI

Summary of analysis of variance of morning and evening catch of adult males of *C formicarius* in different treatments as analysed at fortnightly intervals

Sl No	Source	df	MSS 12th 26th July	MSS 27th 10th Aug	MSS 11th 25th Aug	MSS 26th 9th Sep	MSS 10th 26th Sep
1	Replication	2	2 521	11 064*	10 518**	23 022**	11 550**
2	Traps	2	19 718	19 849**	40 029**	10 654**	2 438
3	Dosage	2	10 655	15 395**	75 680**	20 675**	2 452
4	Interaction	4	17 211	7 124*	6 584**	3 573	1 078
5	Treatment Vs Control	1	461 174**	353 523**	306 714**	155 411**	129 580**
6	Error	16	8 710	2 066	1 360	1 311	0 716
7	Total	27					

** Significant at 1% level
* Significant at 5% level

APPENDIX V

Summary of analysis of variance tables of evening catch of adult males of C formicarius in different treatments as analysed at fortnightly intervals

Sl No	Source	df	MSS 12th-26th July	MSS 27th 10th Aug	MSS 11th 25th Aug	MSS 26th 9th Sep	MSS 10th-26th Sep
1	Replication	2	1 904	3 519*	8 443**	6 634**	1 290*
2	Traps	2	5 403	5 679**	16 406**	2 197	1 185
3	Dosage	2	4 498	6 421**	35 211**	6 289**	1 215
4	Interaction	4	6 486*	1 695	1 308	1 457	1 201*
5	Treatment Vs Control	1	104 651**	64 898**	118 153**	54 063**	40 689**
6	Error	16	1 854	0 578	1 007	0 679	0 328
7	Total	27					

** Significant at 1% level
* Significant at 5% level

APPENDIX VII

Summary of analysis of variance tables of the number of eggs of <u>C formicarius</u> recovered from the vines collected at different intervals from different treatments

Sl No	Source	df	MSS 17th July	MSS 24th July	MSS 31st July	MSS 7th Aug	MSS 14th Aug	MSS 21st Aug	MSS 28th Aug	MSS 4th Sep	MSS 11th Sep	MSS 18th Sep	MSS 25th Sep
1	Replication	2	3 648**	0 724	0 901**	2 347*	0 127	0 010	1 068	0 881	0 821	0 161	0 884
2	Traps	2	0 242	0 359	0 211	0 012	0 094	5 069	0 125	0 214	0 254	0 877	3 896**
3	Dosage	2	0 351	0 144	0 993**	0 285	0 451	0 759	0 581	2 068	0 263	7 107	8 783**
4	Interaction	4	0 239	0 600	0 263	0 290	0 348	1 915	0 050	0 089	0 146	1 879	0 529
5	Treatment Vs Control	1	14 032**	3 442*	4 269**	0 273	1 624*	6 754	3 552*	10 985**	20 452**	33 162**	6 136**
6	Error	16	0 290	0 453	0 114	0 512	0 216	1 848	0 525	0 348	0 493	1 535	0 506
7	Total	27											

** Significant at 1% level
* Significant at 5% level

APPENDIX VIII

Summary of analysis of variance tables of the number of larvae of *C formicarius* recovered from the vines collected at different periods in different treatments

Sl No	Source	df	MSS 17th July	MSS 24th July	MSS 31st July	MSS 7th Aug	MSS 14th Aug	MSS 21st Aug	MSS 28th Aug	MSS 4th Sep	MSS 11th Sep	MSS 18th Sep	MSS 25th Sep
1	Replication	2	0 084	0 253	0 991**	0 210	0 299	0 298	0 017	0 216	0 698	18 570**	1 173
2	Traps	2	0 158	0 466	0 418*	0 713	18 977**	2 054**	1 073**	3 344**	1 780	5 486**	9 356**
3	Dosage	2	0 301	0 361	0 649	2 232**	53 791**	5 704**	7 581**	4 284**	0 384	12 776**	7 373
4	Interaction	4	0 252	1 028*	0 564	0 532*	2 702**	2 297**	12 138**	2 596**	0 707	0 088	3 045
5	Treatment Vs Control	1	6 415**	3 742**	3 726**	7 704**	40 121**	6 333**	21 156**	40 717**	48 100**	122 319**	35 487**
6	Error	16	0 182	0 334	0 098	0 167	0 120	0 106	0 065	0 389	0 682	0 707	1 100
7	Total	27											

** Significant at 1% level
* Significant at 5% level

APPENDIX IX

Summary of analysis of variance tables of the number of pupae of C formicarius recovered from the vines at different intervals in different treatments

Sl No	Source	df	MSS 17th July	MSS 24th July	MSS 31st July	MSS 7th Aug	MSS 14th Aug	MSS 21st Aug	MSS 28th Aug	MSS 4th Sep	MSS 11th Sep	MSS 18th Sep	MSS 25th Sep
1	Replication	2	4 964**	6 026**	0 364	3 123	0 258	0 047	0 185	0 047	0 211	1 265	1 993
2	Traps	2	0 542	3 195	4 285**	4 969	8 113**	14 746**	1 245	6 971**	0 028	1 921	14 516**
3	Dosage	2	0 309	5 355	8 896**	8 167**	23 176**	7 194**	2 170	4 630**	0 971	8 713	4 152
4	Interaction	4	0 237	0 576	1 599**	0 610	5 627**	10 043**	6 960**	3 295**	0 277	0 503	4 552*
5	Treatment Vs Control	1	1 419**	19 947**	0 053	11 323**	26 128**	36 809**	19 183**	43 803**	65 396**	156 364**	14 063**
6	Error	16	0 102	0 877	0 210	0 903	0 130	0 148	0 463	0 076	0 305	1 284	1 165
7	Total	27											

** Significant at 1% level
* Significant at 5% level

APPENDIX-X

Summary of analysis of variance tables of adults (males & females) of C formicarius recovered from vines collected at different intervals from different treatments

Sl No	Source	df	MSS 17th July	MSS 24th July	MSS 31st July	MSS 7th Aug	MSS 14th Aug	MSS 21st Aug	MSS 28th Aug	MSS 4th Sep	MSS 11th Sep	MSS 18th Sep	MSS 25th Sep
1	Replication	2	0 502	0 484	0 312	0 097	0 039	21 370	2 461*	0 602	2 049*	3 491	1 501
2	Traps	2	2 493	0 085	27 182**	11 389**	10 807**	12 975**	24 170**	2 102	5 015**	2 743	17 441**
3	Dosage	2	8 325**	0 587	19 849**	13 078**	34 934**	16 498**	16 011**	14 795**	9 027**	1 078	3 113
4	Interaction	4	10 549**	7 041**	8 037**	4 146**	7 069**	15 767**	20 947*	3 410**	1 832*	3 627	4 776*
5	Treatment Vs Control	1	4 134	13 116**	5 343**	1 985*	0 894	17 120**	0 002	22 862**	23 676**	84 123**	146 737*
6	Error	16	1 129	0 348	0 453	0 311	0 404	0 765	0 677	0 479	0 536	1 339	1 262
7	Total	27											

** Significant at 1% level
* Significant at 5% level

APPENDIX XI

Summary of analysis of variance tables of adult males of C formicarius recovered from vines collected at different intervals from different treatments

Sl No	Source	df	MSS 17th July	MSS 24th July	MSS 31st July	MSS 7th Aug	MSS 14th Aug	MSS 21st Aug	MSS 28th Aug	MSS 4th Sep	MSS 11th Sep	MSS 18th Sep	MSS 25th Sep
1	Replication	2	0 145	0 074	0 072	0 089	0 184*	0 824*	0 199*	0 040	0 087	0 418	0 130
2	Traps	2	2 562	0 173	13 265**	8 877**	7 287**	8 229**	13 032**	1 015**	1 190	0 859	5 039
3	Dosage	2	2 269	0 106	11 136**	3 494**	19 900**	7 095**	6 746**	7 267**	7 227**	1 021	1 463
4	Interaction	4	6 259**	4 067**	3 917**	1 047	3 016**	10 668**	11 827**	1 770**	4 166**	0 567	3 348*
5	Treatment Vs Control	1	9 152**	3 831**	19 361**	12 423**	17 201**	3 782**	32 446**	71 250**	103 865**	194 251**	190 588**
6	Error	16	0 667	0 137	0 086	0 476	0 049	0 159	0 040	0 021	0 386	0 383	0 749
7	Total	27											

** Significant at 1% level
* Significant at 5% level

APPENDIX XII

Summary of analysis of variance tables of adult females of *C formicarius* recovered from the vines collected at different intervals from different treatments

Sl No	Source	df	MSS 17th July	MSS 24th July	MSS 31st July	MSS 7th Aug	MSS 14th Aug	MSS 21st Aug	MSS 28th Aug	MSS 4th Sep	MSS 11th Sep	MSS 18th Sep	MSS 25th Sep
1	Replication	2	1 165	0 500	0 641	0 264	0 416	1 827	3 841	1 488	4 125*	3 624	1 701
2	Traps	2	1 349	0 337	13 865**	6 053**	4 494**	5 230	12 188**	2 582	4 761	3 236	14 357**
3	Dosage	2	6 219	0 669	8 962**	4 830**	16 911**	9 260**	9 536	7 490**	3 246	3 383	2 430
4	Interaction	4	4 160*	3 216**	4 613**	2 950**	4 447**	6 423	9 340**	1 986	0 123	3 717	1 579
5	Treatment Vs Control	1	5 182*	4 497**	1 027	13 657**	26 975**	8 987**	32 217*	92 678**	66 185**	72 406**	263 804**
6	Error	16	1 109	0 367	0 754	0 500	0 637	1 093	0 875	1 237	0 694	2 213	0 694
7	Total	27											

** Significant at 1% level
* Significant at 5% level

APPENDIX XIII

Analysis of variance tables of vine weight in different treatments recorded at different intervals after the placement of traps in terms of trap designs

Source	df	SS	MSS	F ratio
Weeks	10	814 56	81 456	8 04 NS
Trap	2	29 48	14 740	1 45 NS
Error	20	202 75	10 138	
Total	32			

APPENDIX XIV

Analysis of variance table of vine weight in different treatments recorded at different intervals after placement of traps in terms of doses of pheromone

Source	df	SS	MSS	F ratio
Weeks	10	814 56	81 46	13 64 **
Dosage	2	286 22	143 11	23 97 **
Error	20	119 31	5 97	
Total	32			

** Significant at 1% level

APPENDIX-XV

Analysis of variance of tuber weight in different treatments as recorded at harvest

Source	df	SS	MSS	F ratio
Dosages	2	114 265	57 1325	0 026 NS
Traps	3	369 02	123 01	0 44 NS
Interaction	6	1652 46	275 41	0 99 NS
Error	24	6650 705	277 11	
Total	35	8786 45		

APPENDIX XVII

Analysis of variance of root weight recorded in different treatments at harvest

Source	df	SS	MSS	F ratio	
Dosages	2	19 625	9 82	0 014	NS
Traps	3	660 24	220 08	0 32	NS
Interaction	6	74 44	12 41	0 018	NS
Error	24	16435 35	684 81		
Total	35	17189 65			

MASS TRAPPING OF THE SWEET POTATO WEEVIL, *Cylas formicarius formicarius* Fabr (COLEOPTERA CURCULIONIDAE) MALES USING SEX PHEROMONE

By

E. S. MINI

ABSTRACT OF A THESIS

Subm tted n part al fulfilment of the
requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agr cultural University

Department of Agricultural Entomology
COLLEGE OF HORTICULTURE
Vellan kkara Thrissur
Kerala

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ABSTRACT

The efficacy of the synthetic pheromone of C formicarius elegantulus in attracting the males of C formicarius formicarius was tested in the field The effect of continuous mass trapping of adult males on the population build up of the pest in the field was assessed The effect of different doses of pheromone as influenced by the trap designs was also assessed Low cost traps designed and fabricated out of locally available materials were tested in the field and incremental benefit of treatments was worked out The range of attraction of pheromone doses was assessed by analysing the recapture data of marked males released at different distances from the pheromone baited traps The results indicated that the weevils were most active druing the night as is evidenced by higher capture of weevils at morning observations than those in the evening observations The weevil catch was not significantly influenced by the higher doses of pheromone Day light affected the flight pattern of weevils while the moon phases have no significant effect Continued attraction of males towards the pheromone baited traps indicated their effectiveness inspite of the presence of virgin females in the field The pheromone doses were effective in checking the rapid build up of the pest in the field as evidenced by the non reduction in vine weight Among the three trap designs polythene bag trap was the cheapest one to install and resulted in the most favourable

C B ratio The attraction of the pheromone doses decreased with increase in the distance of release from the pheromone source A distance of 25 m was found to be ideal for placement of traps in the field The cheapness of traps facilitate installation of large number of traps at reasonable increase in cost