INTEGRATED CONTROL OF SWEET POTATO WEEVIL *CYLAS FORMICARIUS* FABRICIUS

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THESIS
submitted in partial fulfilment of the
requirement for the degree
DOCTOR OF PHILOSOPHY
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
VELLAYANI - TRIVANDRUM

1987

DECLARATION

I hereby declare that this thesis entitled "Integrated control of sweet potato weevil *Cylas formicarius* Fabricius" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.

(M.S. PALANISWAMI)

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22-7-1987

CERTIFICATE

Cerified that this thesis, entitled "Integrated control of sweet potato weevil *Cylas formicarius* Fabricius" is a record of research work done independently by Sri. M.S. Palaniswami under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, or associateship to him.

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A C K N O W L E D G E M E N T S

I wish to express my deep sense of gratitude and indebtedness to Dr. N. Mohandas Professor and Head of the Department of Entomology, College of Agriculture, Vellayani, for suggesting this problem, for his keen interest, valuable guidance, critical suggestions and constant encouragement throughout the period of study and for the help rendered in the preparation of the thesis.

I am extremely thankful to Dr.(Mrs.) A. Visalakshi, Professor of Entomology, for her sincere and timely help and constructive ideas during the course of the studies.

My sincere thanks are due to Dr. K.V. Mammen, Professor of Entomology, for his valuable help and suggestions during the investigation.

I am very much obliged and thankful to Dr.(Mrs.) P.Saraswathy, Associate Professor of Agricultural Statistics for the kind help and guidance in formulating the techniques for the survey and field experiments and also in the analysis of the data.

I am also indebted to Dr. M. Chandrasekharan Nair, Professor of Plant Pathology, for his help and suggestions during the course of the study.

My sincere thanks are due to Dr.(Mrs.) Swaraj Ghai, Senior systematic Entomologist and Dr. S.I. Farooqui, Taxonomist, Indian

Agricultural Research Institute, New Delhi for identifying the parasitoids.

I also place on record my sincere thanks to Dr. M.M. Koshi, Dean, College of Agriculture, Vellayani, for the facilities provided for the investigations and for the encouragement given throughout the studies.

I am deeply grateful to Dr. S.P. Ghosh, Director and Dr. K.S. Pillai, Head of the Division of Entomology, Central Tuber Crops Research Institute, Trivandrum, for their help and encouragement during the course of the study and for granting the study leave.

I am profoundly recording my thanks to the Joint Director of Agriculture, Deputy Directors of Agriculture and Agricultural Development Officers of Kasaragod, Malappuram, Palghat, Trichur, Quilon and Trivandrum Districts, who extended all possible help in conducting the survey on the incidence of the pest. I also thank all the farmers who wholeheartedly cooperated with me in the survey.

Thanks are also due to Dr. C.T.Abraham, Assistant Professor of Agronomy, College of Horticulture, Vellanikkara and Mrs. Manju, Junior Assistant Professor of Plant Breeding, College of Agriculture, Vellayani, for providing varieties/cultivars of sweet potato. I sincerely extend my thanks to Dr. Lulu Das, Junior Assistant Professor of Plant Pathology, College of Agriculture, Vellayani, for the help given in the studies on soil microflora.

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INTRODUCTION

1. INTRODUCTION

Sweet potato (Ipomoea batatas (L.) Lam.) basically an Asian crop, is most versatile in its adaptations, being grown from temperate to tropical regions. It exceeds many crops in productivity per unit time and ranks seventh in terms of production in the World (Anon., 1981b). Sweet potato is largely used as human food, animal feed and in starch industry. Based on the calorie yields, nutritive value, adaptability and its vegetative propagation, the crop can potentially make a greater contribution to World agriculture in the years to come.

More than 80 per cent of the World's production is from Asia with an annual production of 101.6 million tonnes. India contributes about 15 lakh tonnes annually from two lakh hectares spread throughout the country but mostly concentrated in Uttar Pradesh, Bihar, Orissa and Assam. Among the States in India, in acreage and production, Kerala enjoys seventh and sixth position respectively. The productivity of the crop in India is 7.5 t ha^{-1} which is just half the average productivity of the World or Asia. In advanced countries like Japan the root yield has gone up to 20 t ha^{-1}. Kerala produces 6.6 t ha^{-1} on an average and thus stands even behind the national average in productivity (Anon., 1985; Anon., 1986c).

Among the constraints attributed to the production of sweet potato in India, the havoc caused by the weevil, Cylas formicarius Fabricius (Coleoptera : Curculionidae) is the most important one.

The insect has been recognised as the most destructive pest of sweet potato all over the World.

The high damage potential of <u>C. formicarius</u> invited the attentions of plant protection technologists from very early days and several control measures had been recommended against the pest. With the advent of synthetic insecticides chemical control was given great emphasis. The application of chlorinated hydrocarbons in the soil remained as an accepted technology for fighting the pest. The realisation of the long persistence of the chemicals in soil particularly in tropics, led the banning of these chemicals in many countries. In due course organophosphatic insecticides, carbamates and synthetic pyrethroids took their place. The prohibitive cost of pesticides and the high application cost, for the repeated sprays recommended, deterred the wide adoption of this crop protection technology in developing countries. It was particularly relevant for a crop grown in marginal lands with low cost inputs. Hence a low cost technology was a long felt need for controlling sweet potato weevil in Kerala.

In evolving a cheaper and economically viable control strategy on a scientific footing a lot of basic informations were found essential. The extent and intensity of damage done by sweet potato weevil in Kerala was not known. Detailed studies on the bio-ecology of the pest, its natural enemies, alternate hosts, cultural control and other possible methods of control were also lacking. In this context investigations were carried out on the following aspects:

(1) Detailed survey on the incidence of *C. formicarius* and the extent and intensity of damage caused by the pest, its natural enemies and alternate hosts, the soil types and the cultural practices followed in Kerala

(2) Screening of varieties/cultivars for assessing their resistance to *C. formicarius* and studies on the mechanism of resistance

(3) Distribution of the life stages of the pest at different growth stages of the crop with a view to assessing the vulnerable stages of the pest for control operations

(4) Assessment of reridging as a method of cultural control of the pest and to fix the optimum period for the same

(5) Control of the pest using locally available organic amendments

(6) Control of *C. formicarius* using organic cakes and wood ash

(7) Standardising a technique for trapping the adult weevils and to fix the optimum time and frequency of trapping needed for reducing the weevil incidence in the field

(8) Evaluation of insecticides for the control of *C. formicarius*, improving the method of application to minimise the frequency of treatment and to make the practice economically viable, and

REVIEW OF LITERATURE

(9) Evolving an integrated control technology utilizing the informations gathered from the present investigations and the details available in literature and testing the viability of the technique in field.

2. REVIEW OF LITERATURE

Informations available on various aspects related to the present investigations on *Cylas formicarius* have been briefly reviewed.

2.1. Distribution

Cylas formicarius was first recorded in 1792 in India as *Brenthus formicarius* F. in 1798 (Pierce, 1940). It was renamed as *C. formicarius* by Schoenherr in 1883 (Kissinger, 1968).

The occurrence of the pest was reported from more than 50 countries (Anon., 1970) and is found from West Africa to East Africa and in South Africa, Eastern Australia, Bangladesh, Madagascar, Mauritius, the Seychelles, India, Sri Lanka, China, Papua New Guinea, the Solomon Islands, the Southern United States, the Carribbean Islands, Hawaii, Samoa, Fiji, the Caroline, Gilbert and Mariana Islands, Mexico, Guyana, South East Asia (including Philippines, Japan, Taiwan and Malaysia) and Venezuela (Hill, 1975) and Brazil and Central America (Onwuene, 1978). Sorensen (1984) observed that the pest occurs in all the sweet potato growing areas in the five continents of the world.

In India it was reported from sweet potato growing tracts of Maharashtra (Trehan and Bagal, 1949), Tamil Nadu (Subramanian, 1959), Karnataka (Jayaramaiah, 1975a), Uttar Pradesh, Bihar, West Bengal and Orissa (Anon., 1983a) and North Eastern complex of India (Barwal, 1985).

2.2. Nature of damage

Adults of *C. formicarius* feed on all parts of the plant while the larva feeds on vines and tubers only. The infestation generally starts in the crown region and spreads up or downwards. The grubs emerging from eggs bore into the plant parts and feed by making irregular tunnels which get filled with excreta (Reinhard, 1923). As a result of feeding by the grubs, the crown 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 crown region breaks off (Edmond, 1971; Pillai *et al*., 1987).

Weevil infestation causes characteristic terpenoid odour in tubers which renders them bitter and unpalatable (Akazawa *et al*., 1960; Uritani *et al*., 1975). Sato *et al*. (1977) found that larval feeding in sweet potato roots induced the formation of a terpene, phytoalexin which caused the bitter taste. The phytoalexin was later identified as ipomeamarone (Sato *et al*., 1981). Terpene phytoalexines were seen produced by the feeding of adult weevils also (Sato *et al*., 1982).

Utsu (1940) found that the weevil incidence in tubers favoured the infection of a fungus (*Ceratocystis* (*Endoconidiophora*) *fimbriata* (Ell. 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 percentage of tuber damage was estimated in Formosa as 48 (Fukuda, 1933), in Puerto Rico - 38 (Wolcott and Perez, 1955), in the Solomon Islands - 50 (Anon., 1982a), in Taiwan - 0 to 53 (Anon., 1984c), in U.S.A. - 25 to 75 (Karr, 1984), in Philippines - 10 to 50 (Esguerra, 1982) and in Nigeria - 2 to 42 (Anon., 1986b).

Cockerham *et al.* (1954), Hahn and Leuschner (1981) and Talekar (1982b) observed that the incidence of *C. formicarius* did not cause any significant reduction in total yield. But Mullen (1984b) found significant tuber yield loss due to weevil incidence and that the reduction extended up to 69 per cent. Sutherland (1986b) observed that the infestation of vines by the weevils reduced the vigour of the plant and tuber yield.

In India, the extent of tuber damage was reported to range from 17 to 70 per cent at Coimbatore of Tamil Nadu (Subramanian, 1959; Subramanian *et al.*, 1977), 16 to 40 per cent in Bangalore of Karnataka (Jayaramaiah, 1975a), 4 to 82 per cent in Trivandrum of Kerala (Pillai *et al.*, 1987), 41 per cent in Bihar, 53 per cent in Orissa, 6.7 per cent in West Bengal and 8.8 per cent in Uttar Pradesh (Anon., 1983a).

2.4. Factors influencing the damage

Various factors were reported to influence the incidence of *C. formicarius*.

2.4.1. Temperature

Higher temperature and dry conditions during summer favoured the pest attack (Murakami, 1933b; Eusebio, 1983; Yu, 1983) while lower temperature below 20°C was observed to extend the developmental period and reduce the longevity of the pest and its incidence (Anon., 1981a; Mullen, 1981; 1984a). Lower temperature prevailing in rabi season (winter) in north and north eastern India had been suggested as the cause for lower incidence of the pest (Pillai *et al.*, 1987).

2.4.2. Soil type

The principal route of entry of adult weevils to the tubers was reported to be through soil cracks (Reinhard, 1923; Trehan and Bagal, 1957; Hua, 1970). Red loam and clay soils having a cracking nature were found to show higher incidence of tuber damage (Rabindranath, 1979; Eusebio, 1983).

2.4.3. Soil moisture

Increasing soil moisture through irrigation was reported to reduce weevil damage (Sherman and Tamashiro, 1954; Trehan and Bagal, 1957). This phenomenon was more conspicuous in soils having high water retention capacity (Yu, 1983).

2.4.4. Soil pH

Abella (1982) observed that the weevil incidence declined gradually with decrease in acidity or an increase in alkalinity (8.6 to 9.5 pH).

2.4.5. Delaying harvest

One of the significant factors exacerbating the weevil incidence was the retention of the crop in the field even after maturity. Delaying harvest beyond 110 days was reported to cause heavy damage to the tubers in field (Kemner, 1924; Asokan and Nair, 1984; Pillai *et al*., 1987).

2.5. Dispersal of *C. formicarius*

Reinhard (1923) observed that the beetles flew up to a height of 10 m in a spiral manner. The flight range reported was quarter mile to one mile (Eddy, 1940; Cockerham *et al*., 1954; Butani and Verma, 1976). Dispersal of the weevil was found to be mostly through planting materials and flight was considered as secondary (Sherman and Tamashiro, 1954). The density of population, a known factor inducing dispersal, did not influence the dispersal of *C. formicarius* (Wolfenbarger *et al*., 1974). Jayaramaiah (1975a) reported that the flight activity of adult weevils was restricted to darkness and Sanchez (1980) observed their flight, even when there was heavy rainfall.

The weevils, mostly males, were found active on plants at night with peak activity at 21.00 h (Howard, 1982). Proshold (1983) observed that at nightfall males moved up on the shoots and remained there until sun rise, while females moved to the roots region.

Once established the pest could spread almost 1.5 km per year (Anon., 1981b).

2.6. Biology of the sweet potato weevil

The biology of the pest has been reviewed recently by Mullen (1984a), Sutherland (1986a) and Pillai et al. (1987). They observed that preoviposition and oviposition periods were in general 4 to 9 and 63 to 120 days respectively. The number of creamy white eggs laid varied from one to nine per day and a single female could lay 24 to 340 eggs in its life span. The eggs were seen laid in oval cavities made by the female and covered with grey faecal mass.

Incubation, larval and pupal periods ranged from 4 to 11, 16 to 58 and 4 to 15 days respectively depending mainly on temperature. Pupation occurred inside the crown or tuber and in the pupal chamber excavated by the grub itself. The teneral adults remained inside the pupal chamber for 1 to 3 days. The total life cycle from egg to adult ranged from 23 to 52 days. Adult longevity ranged from 96 to 113 days with food and about a week without food. Sex ratio was 1 : 1. The filiform distal end of the antennae in males and clavate nature in females were identified as distinct sexual dimorphism in C. formicarius (Nair, 1975). Marithiram et al. (1980b) observed these features in pupal instar too.

2.7. Incidence of sweet potato weevil at different growth stages of sweet potato in field

2.7.1. Vine

Remoroza (1978) based on the weevil population studies in Philippines observed that six week old plants were more suitable for the weevil development and múltiplication than younger or older plants, while Sanchez (1981) and Sanchez *et al*. (1984) observed 8 to 11 week old plants were better for the development.

2.7.2. Tuber

Hua (1970) observed higher population of sweet potato weevils in tubers from 50 days after planting (DAP) 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 field as early as 30 DAP, it was noticed in the roots only from 44 DAP.

2.8. Natural enemies of *C. formicarius*

The natural enemies were mostly found on the life stages of the pest occurring on the vines of the plant.

2.8.1. On larva

Microbracon cylasovorus Rohwer and *Bassus cylasovorus* Rohwer were reported as ectoparasitoids on the grubs from Philippines, as early as 1925 by Gonzales, and were found to be effective in controlling *C. formicarius* (Esguerra and Gabriel, 1969). Cockerham (1944) identified three braconids (*Microbracon mellitor* Meusebeck, *M. punctatus* Meusebeck and *Metaplema spectabilis* Westwood) on the grubs found in the vines of sweet potato and the alternate hosts (*Ipomoea quamoclit* L. and *I. hederacea* Jacq.) in Louisiana. Later on a predator, the Argentine ant *Tetramorium guineense* (F.) on the grubs (it also preyed on the eggs) was added to the list (Cockerham *et al*., 1954).

Rajamma (1980) recorded two braconid ecto-parasitoids (Rhaconotus sp. and Bracon sp.) and a gregarious empidid fly predator occurring on the grubs in India. Eusebio (1983), in addition to the braconid parasitoids reported from Philippines, observed an ear wig (Euborella sp.) and an ant (Tetramorium sp.) as predators on the grubs. From Cuba Pheidole megacephala (F.), a predatory ant of the larvae and pupae was also reported (Castineiras and Calderon, 1982; Castineiras et al., 1982, 1985).

The larvae and pupae of C. formicarius were found parasitised by the nematodes, Neoplectana sp. (Swain, 1943), Rhabditis sp. and Aphelenchus sp. in Louisiana (Cockerham et al., 1954) and Heterorhabditis heliothidis in Cuba (Hernandez and Mracek, 1984).

Infection of the grubs by Bacillus thuringiensis Berliner was reported from Tamil Nadu, India by Sundarababu et al. (1970).

2.8.2. On adults

As early as 1924, Kemner observed the infection of a fungus Isaria sp. on adult weevils. Subsequently Cockerham et al. (1954) added two more fungi viz., Fusarium sp. and Beauveria globulifera to the list. Castineiras et al. (1984a, b) found that Metarhizium anisopliae (Metchnikoff) Sororkin and Beauveria bassiana (Bals.) Vuill. could infect the adult weevils.

2.9. Alternate hosts / harbouring plants

As early as 1907 Conradi observed that in the absence of sweet potato the preferred hosts of C. formicarius were other species of Ipomoea. Blatchley and Lang (1916) noted the weevil larvae in I. prescaprae (L.) Sweet. and Newell (1919) on I. paundurata May. and I. littoralis Blume.

Smith (1923) observed eleven species of Ipomoea as hosts or carriers of C. formicarius. Vander-merwe (1926) reported I. biloba as host plant to the weevil in South Africa. Uichanco (1934) noted I. triloba L. as a collateral host for the pest in Philippines. In addition, I. hederacea, I. bonanox (L.), I. dissecta Willd., I. heptaphylla L., I. lacunosa L., I. macrorhiza L., I. muricata Jacq., I. quamoclit, I. sagittata Roxb., I. setosa Ker. and I. trichocarpa Ell. were recorded as alternate hosts in U.S.A. (Cockerham, 1943).

Subramanian (1959) recorded I. lateralis L., I. learii Paxt., I. palmata (L.) Roth., I. sepiaria Koen., I. trichocarpa, I. trifida (Hbk.), I. purpuria Lank., I. prescaprae, I. paundurata, Calonyction aculeata L. and Jacquemontia tamnifolia L. as alternate host plants in India. To this list, I. barleiriodes Benth. and Hook., I. acarica L. and Thunbergia sp. (Jayaramaiah, 1975a) and I. biloba (Pillai and Lal, 1976) were added.

Generally the host range of C. formicarius was considered to be restricted to the various species of Ipomoea. It had also been noted to breed on plants other than Ipomoea species and they were identified as harbouring plants for overwintering adults.

Spanish needle (Boydon, 1927), Calonyction bonanox L. and Manihot palmata (Gowdey, 1928), Calystegia boldanella Br.

(Fukuda, 1933), *Oumoclit vulgaris* L. (Eddy, 1940), Amaranthus sp., *Cuscuta* sp., *Dichondra carolinensis* (Michx.), *Jacquemontia tamnifolia*, *Physalis orinoccensis* L., *Phylolacca americana* L., *Sesbania exaltata* L., *Sida* sp., *Solanum carolinense* L., *S. nigrum* L., *S. tuberosum* L. and *Vigna sinensis* (L.) (Cockerham *et al.*, 1954), were reported as harbouring plants of *C. formicarius*. Ranjith (1985) reported the multiplication of the pest in the vines of *Piper nigrum* L.

2.10. Cultural control of *C. formicarius*

2.10.1. Field sanitation

Collection and removal of the crop residues from the field and burning or deep burying of the same and the use of non-infested planting materials were recommended for limiting the damage caused by the weevil in field (Reinhard, 1923; Murakami, 1933a; Villanueva, 1981; Sanchez *et al.*, 1984).

2.10.2. Destruction of alternate hosts

Removal and destruction of alternate hosts were recommended as one of the means of containing the weevil incidence (Reinhard, 1923; Wood, 1976; Talekar, 1983).

2.10.3. Mulching

Smee (1965) observed that mulching of the soil increased the humidity and in turn reduced the pest damage. Paddy straw mulch or a black plastic cover in the plots was found to be effective against *C. formicarius* (Anon., 1986a).

2.10.4. Reridging

Earthing up and placing an additional layer of soil on the ridges from the furrows (reridging) or hilling up the mounds were suggested as practices to limit the incidence of the weevil on tubers, since the practices closed the crevices through which the weevils gain entry to the host (Passalow and Rossiter, 1962; Remoroza, 1978; Burdeos and Gapasin, 1980). Reridging at 60 DAP for susceptible varieties and at 45 DAP for resistant varieties was found to contain sweet potato weevil damage under Nigerian conditions and in general reridging at 30 DAP was recommended for sweet potato crop as a cultural practice (Anon., 1976). Pardales and Cerna (1987) indicated that hilling up twice at 4 and 6 weeks after planting was adequate to reduce the weevil damage on tubers in Philippines.

2.10.5. Irrigation

Trehan and Bagal (1957) reported that irrigation at 10 day intervals reduced the weevil damage to the crop. Flooding the weevil infested crop residues in harvested fields for 1 to 4 weeks reduced the weevil inoculum effectively (Anon., 1983c).

2.10.6. Early harvesting

Delayed harvest increased the intensity of weevil damage and hence early harvesting was suggested for limiting the extent of damage caused by *C. formicarius* (Rhodes, 1959; Sutherland, 1986b).

2.10.7. Crop rotation

Rotation of sweet potato with other crops was suggested as a means to limit the weevil damage (Newell, 1919; Smee, 1965). In China sweet potato was rotated with rice or wheat, followed by green manures and soybean (Bartolini, 1982). Rotation of sweet potato with a rice crop was found to reduce the weevil incidence in the low lands of India (Pillai *et al*., 1987).

However, Talekar (1983) observed that planting rice after the harvest of weevil infested sweet potato did not reduce the weevil damage in the ensuing crop if other sources of weevil inoculum were found in the vicinity.

2.11. Use of resistant varieties

The search for resistance to *C. formicarius* among sweet potato varieties is in full swing throughout the world. So far no line could be ranked as immune or highly resistant. The lines or varieties identified with less infestation in various countries are mentioned below.

2.11.1. U.S.A.

Cockerham and Deen (1947) reported that they began the search for genes in sweet potato resistant to *C. formicarius*, as early as 1939 but with little success. Two lines L 187 and L 244 were identified with less infestation (Cockerham and Harrison, 1952) but these lines were lost in due course (Edmond, 1971).

Waddil and Conover (1978) could identify a white fleshed 'Picadita' and an orange fleshed W 13 varieties with moderate resistance to the weevil. Rolston *et al*. (1979) could find appreciable weevil resistance in the orange fleshed lines 'cherokee', 'creole', LO-273, L1-268, L4-89, L6-119, L3-64, W 8, W 13, W 71, W 19-3, W 124 and P 104 which were obtained from Louisiana (L), USDA (W), Nigeria and Asia (P) respectively.

The lines W 7-3, W 7-85, W 7-112, W 109, W 113 (Mullen *et al*., 1980), W 119, W 125 (Jones *et al*., 1980, 1982; Mullen *et al*., 1981, 1982), W 182, W 183, W 191, W 193, 80-41, 80-55, 80-65, 80-69, 80-BM9 (Mullen *et al*., 1982), W 71, W 115, W 149 (Jones *et al*., 1980, 1982), W 151, W 152 (Mullen *et al*., 1982; Jones, 1984), W 226 (Mullen *et al*., 1985) were identified as resistant to *C. formicarius* based on different criteria, viz., weevil free tuber yield, percentage of hill infestation, severity of damage index and number of adult weevil emerged from one kilogram roots stored in the laboratory after harvest. The lines W 125 and W 152 were commercially released as 'Resisto' (Jones *et al*., 1983) and 'Regal' (Jones, 1984) respectively.

Martin (1984) selected six lines with moderate resistance to the pest based on the damage of the crown and the tubers and exposition of roots to the weevils and named them WS 27, WS 28, WS 29, WS 30, WS 31 and WS 32.

2.11.2. Nigeria

The work in Nigeria was centered on C.puncticollis Boh.(which is the prevalent species in Africa), although C.formicarius was also considered (Anon., 1984b). The following lines were reported partially resistant to the weevils: Tib 2534 (Anon., 1976, 1980a), Tis 2532 (Anon., 1979, 1980b, c, 1981a; Hahn and Leuschner, 1981; Anon., 1986b), Tis 3017, Tis 3030 (Anon., 1979, 1980a, b; Hahn and Leuschner, 1981), Tis 3053 (Hahn and Leuschner, 1981), Tis 9265 (white), Tis 2498 (red) (Anon., 1983d) and Tis 70357 (Anon., 1986b).

2.11.3. Philippines

Esguerra and Gabriel (1969) reported that the variety 'Samar Big Yellow' was resistant to C. formicarius. Subsequently four accessions viz., 458, 486, 507 and 508 were identified as resistant ones (Bernardo, 1982; Bernardo and Esguerra, 1984).

2.11.4. Taiwan

AVRDC, Taiwan identified the following accessions to have a certain level of resistance to C. formicarius: I 123 (Talekar, 1981; Anon., 1983c), I 152 (Talekar, 1981), I 413, I 416 and Tis 2532 (Anon., 1984a) and it was also indicated that a reliable source of resistance with consistency could not be identified (Talekar, 1982a; Anon., 1986a).

2.11.5. China

Zuxia (1984) communicated that Guang Shu 16, Guang Shu 77-63, Zhan Shu 73-165, N 178 and N 191 were resistant lines.

2.11.6. Indıa

The accessions / varieties V10, B 4004 (Subramanian, 1959), a local red skinned variety of Bangalore (Jayaramaiah, 1975c), S 3, S 13, S 234, S 238, S 248 of CTCRI, Trivandrum (Pillai and Kamalam, 1977), H 268, H 633 (Pillai and Nair, 1981), CO 2 (Thamburaj et al., 1981), RS 5 (Singh et al., 1982), 75 OP 40, 75 OP 59, 76 OP 217 and 5 x 45 of CTCRI (Anon., 1983a; Pillai et al., 1987) were reported as less susceptible to C. formicarius.

2.12. Mechanism of resistance

2.12.1. Physical factors

The resistance seemed to be associated with depth of soil at which fleshy roots develop (Cockerham and Harrison, 1952).

The skin of certain resistant lines was deterrent to adult weevils (Cuthbert and Davis, 1971). Varieties with thin hard crown and long tuber stalk (Jayaramaiah, 1975c) and possessing long necked tubers with spindle shape and high latex content (Pillai and Kamalam, 1977) were seen less attacked by C. formicarius.

Schalk et al. (1982, 1983, 1985) reported the relationship of total periderm thickness and mean cell thickness to the levels of insect resistance.

Martin (1984) observed that the sweet potato varieties with a crown thickness of one cm and less were resistant to the weevil while the crown thickness of more than one cm in diameter, especially when prone to swelling (due to the weevil attack), were highly susceptible to the pest.

2.12.2. Biochemical factors

Cockerham and Deen (1947) hypothesised that high water and carotene contents and low starch content in the tuber influenced the resistance. It was reported from Nigeria that carotene content (in the variety Tis 2534) was associated with the resistance and there was a high positive correlation between the two factors (Anon., 1976).

Pillai and Kamalam (1977) observed that low sugar and high starch content were associated with weevil resistance. Hahn and Leuschner (1981, 1982) reported an association of high dry matter and starch with resistance and they also proposed antibiosis as the likely mechanism of weevil resistance.

The involvement of the factors such as non-preference (antixenosis), antibiosis and/or escape had been suggested as the mechanisms of resistance to C. formicarius (Barlow and Rolston, 1981; Mullen et al., 1981; Hahn and Leuschner, 1982; Prochold, 1986).

Anota and Odebiyi (1984) and Anon. (1986a) observed that there was no significant correlation between nitrogen, starch, dry matter and moisture content of the tubers with resistance but there was correlation with beta carotene.

2.13. Behavioural control of *C. formicarius*

2.13.1. Repellents

Application of punna cake (*Calophyllum inophyllum* L.) and mahwa cake (*Bassia latifolia* Rox.) @ 2000 kg ha^{-1} at the time of planting gave control of *C. formicarius* to certain extent (Johnson *et al.*, 1979). But neem cake (*Azadirachta indica* Juss.) @ 500 and 1500 kg ha^{-1} and lime and cashewnut shell cake @ 2000 kg ha^{-1} were ineffective against the pest (Pillai *et al.*, 1981; Rajamma, 1982).

Good reduction of weevil population was observed when leaves of *Clerodendron infortunatum* L., *Eupatorium odoratum* L. or *Cymbopogon flexuosus* Wats. were applied as basal dose @ 5 t ha^{-1} (Johnson *et al.*, 1979; Rajamma, 1982).

Bartolini (1982) reported that in China, oil tea cake (*Camellia oleosa* Wall.) along with urea applied at the base of plants acted as good repellent to *C. formicarius*.

The use of sweet potato vines for attracting adults was reported by Newell (1917). Eddy (1942), Cockerham and Deen (1948) and Bartolini (1982) suggested the use of fresh sweet potato tubers as an attractant in baits.

2.13.3. Sex pheromone

Though Reinhard (1923) reported no particular attraction of males to virgin females, Coffelt *et al.* (1978), Proshold (1983) and Heath et al. (1986) conclusively reported a positive attraction of males to virgin females and postulated the existence of a sex pheromone. They had successfully used live virgin females to trap the males in field. They also synthesised the female sex pheromone ((z)-3-dodecenyl (E)-2 butenoate) which could be used in traps for collecting weevils (Proshold et al., 1986).

2.13.4. Use of irradiated males

Walker (1966) observed that males of *C. formicarius* exposed to gamma radiations (18,000 r) became sterile. When they were allowed to mate with virgin females, they competed successfully with untreated males, and females mated with sterile individuals laid eggs, the hatching percentage of which was very low.

2.13.5. Use of Juvenile hormone

When juvenile hormone, hydropene, was applied to newly formed pupae of *C. formicarius*, premature emergence of malformed adults was observed in the laboratory (Maruthiram et al., 1980a). Application of hydropene on the ovipositing females caused an initial reduction in fecundity but there was a slow recovery from the effect (Maruthiram et al., 1985).

2.14. Biological control of *C. formicarius*

There was no report of successful biological control of sweet potato weevil, though records of naturally occurring parasitoids, predators and pathogens (vide. para 2.8.) were available.

Attempts in this line were made in Cuba using big headed ant *Pheidole megacephala* along with *Beauveria bassiana* and *Bacillus thuringiensis* (Castineiras and Calderon, 1982; Castineiras *et al.*, 1982, 1984a, b, 1985). It was reported that maximum yield and profit were obtained from the fields protected by the biotic agents against *C. formicarius*.

2.15. Chemical control of *C. formicarius*

Because of the extensive damage done by *C. formicarius* a large number of insecticides have been evaluated for its control. The insecticides reported to be effective in controlling the weevil damage are presented here.

2.15.1. Foliar application

2.15.1.1. Inorganic insecticides

The use of lead arsenate, calcium arsenate, cryolite and barium fluosilicate on the foliage had been recommended from early days (Reinhard, 1923; Frogatt, 1936; Eddy, 1938; Cherian 1944; Cockerham and Deen, 1948; Sherman and Mitchell, 1953; Floyd, 1955).

2.15.1.2. Fumigants

Importance of using weevil free planting materials was recognised early and fumigation with PDB and methyl bromide was recommended for this purpose (Cockerham and Deen, 1936; Easter, 1940; Easter and Phillips, 1943; Phillips *et al.*, 1943; Cherian, 1946; Gaddis, 1953).

2.15.1.3. Chlorinated hydrocarbons

DDT was recommended for vine dipping before planting followed by five rounds of spray @ 0.1 per cent (Jayaramaiah, 1975b). Ingram (1967) suggested a preplant dip of vines in 1.25 per cent suspension of DDT or BHC to reduce the damage by the pest.

Dusting of the foliage with BHC 10 per cent @ 33 lb ac^{-1} (Trehan and Bagal, 1957) and @ 1.2 kg ai ha^{-1} (Anon., 1978) at biweekly intervals were advocated to contain the weevil damage. Kay (1973) recommended BHC spraying against the pest.

Spraying of dieldrin 0.1 per cent six times at weekly intervals from 7 weeks after planting (WAP) (Arenas, 1955); six time at biweekly intervals from 6 WAP (Ananthanarayanan and Subramanian, 1958); twice at 6 and 12 WAP (Rhodes, 1959), thrice at biweekly intervals from tuber formation, i.e., 2½ months after planting (David, 1960; Ramakrishnan and Narayanaswamy, 1960), twice at triweekly intervals from tuber formation (Ramaswamy and Srinivasan, 1965) and four times at biweekly intervals from 40 DAP (Anon., 1978), were recommended to control the damage.

Aldrin @ 0.1 per cent four times at monthly intervals (Wolcott and Perez, 1955) and six rounds at triweekly intervals from 6 WAP (Ananthanarayanan and Subramanian, 1958) were found effective against the pest.

Endrin spray @ 0.1 per cent was recommended by Mistric (1955). Arenas (1955) suggested six sprayings of the same at weekly intervals from 7 WAP. Ananthanarayanan and Subramanian (1958) found weekly sprays of endrin 0.1 per cent from 6 WAP promising. David (1960) recommended biweekly sprayings of the endrin commencing from tuber formation. Ramaswamy and Srinivasan (1965) recommended endrin dusting @ 2 lb ai ac^{-1} at triweekly intervals from tuber formation.

Endosulfan was found effective against the weevil @ 0.05 per cent, sprayed at ten day intervals (Butani and Verma, 1976), @ 0.56 kg ai ha^{-1} at weekly intervals (Waddill, 1982), @ 1 lb ai ac^{-1} at weekly intervals (Rolston, 1984), @ 0.1 per cent on 59 and 78 DAP (Sanchez et al., 1984). Rajamma and Pillai (1985) and Ray and Yazdani (1985) recommended spraying of endosulfan @ 0.05 per cent, four times at triweekly intervals, from 30 DAP.

2.15.1.4. Organo phosphorus (OP) compounds

EPN was found effective against C. formicarius @ 1.8 g l^{-1} applied four times during the cropping season (Pablo, 1955). EPN @ 0.5 lb ai ac^{-1} was also advocated by Mistric (1955). Methyl parathion @ 0.5 lb ai ac^{-1} was also found equally effective against the pest (Mistric, 1955).

Ethyl parathion, carbophenothion or phosphomidon spray @ 0.05 per cent at biweekly intervals from planting were found effective against C. formicarius (Mohandas and Nair, 1966). Ethyl parathion (0.05 per cent) spray was recommended by Pillai and

Magoon (1969), Kay (1973) and Anon. (1978) also. Carbophenothion spray (0.05 per cent) was reported effective against the weevil when applied five times at 25 day intervals from planting (Jayaramaiah, 1975b).

Pillai and Magoon (1969) reported that methyl demeton (0.05 per cent) was helpful in checking C. formicarius incidence. The use of methyl demeton and phosphomidan at 30, 60 and 90 DAP was advocated for containing the weevil (Anon., 1978).

Fenitrothion (0.05 per cent) was reported to be effective (Pillai and Magoon, 1969; Anon., 1978). Johnson et al. (1979) recommended two sprays of fenitrothion at 30 and 60 DAP, while Pillai et al. (1981), Pillai and Palaniswami (1984), Rajamma and Pillai (1985), Ray and Yazdani (1985) suggested four sprayings from 30 DAP at triweekly intervals.

Malathion (0.1 per cent) was recommended as foliar spray to be applied at ten day intervals (Singh, 1970) and as preplant dip followed by spraying (Anon., 1978).

Fenthion @ 0.1 per cent was recommended at triweekly intervals from tuber formation (Subramanian et al., 1973; Gunasekharan and Balasubramanian, 1980), as well as at monthly intervals from planting (Anon., 1978). Application of fenthion 0.05 per cent was recommended four times at biweekly intervals from 40 DAP (Sanchez and Medina, 1975; Macfarlane, 1985), twice at 30 and 60 DAP (Johnson et al., 1979), four times at triweekly intervals from 30 DAP (Pillai et al., 1981; Ray and Yazdani, 1985) for controlling C. formicarius.

Tanaka and Sekioka (1976) suggested preplant dipping and spraying of foliage with diazinon (0.3 per cent).

Chlorfenvinfos dusting @ 600 to 900 g ai ha^{-1} or spraying @ 240 g ha^{-1} was recommended against the pest (Anon., 1978).

Monocrotophos @ 0.05 per cent was advocated four times at monthly intervals from planting (Anon., 1978), twice at 30 and 60 DAP (Johnson et al., 1979), four times at triweekly intervals from 30 DAP (Pillai et al., 1981).

Quinalphos was reported to be effective when sprayed @ 0.05 per cent at 30 and 60 DAP (Johnson et al., 1979) and @ 0.1 per cent at triweekly intervals from the time of tuber formation (Gunasekharan and Balasubramanian, 1980).

Triazophos spray @ 0.5 kg ai ha^{-1} applied at fortnightly intervals from 14 DAP was reported effective in controlling the pest damage (Talekar, 1983).

2.15.1.5. Carbamates

Carbaryl was recommended as 0.2 per cent spray (Singh, 1970; Butani and Verma, 1976), as 0.1 per cent spray to be applied at triweekly intervals from tuber formation (Subramanian et al., 1973) and 0.1 per cent at monthly intervals from planting (Anon., 1978). Muruvanda et al. (1986) reported that a preplant dip and triweekly sprays (@ 1.12 kg ai ha^{-1}) from planting checked the weevil incidence effectively.

Carbofuran was found effective when used for preplant dipping and foliar application (@ 2 lb ai ac^{-1} four times at 25 day intervals) (Jayaramaiah, 1975b) and also as a preplant dip alone in 0.05 per cent suspension for two minutes (Talekar, 1983; Anon., 1983b).

Methomyl application (@ 1 kg ai ha^{-1}), four times at fortnightly intervals, from 40 DAP was found to contain the pest (Sanchez and Medina, 1975; Anon., 1978). Methomyl @ 0.5 kg ai ha^{-1} applied at fortnightly intervals from 14 DAP was found to be consistently good in suppressing the weevil damage (Talekar, 1983).

Carbosulfan spray @ 0.025 per cent on 59 and 78 DAP was recommended for reducing the weevil damage (Sanchez *et al*., 1984).

2.15.1.6. Pyrethroids

Permethrin spray @ 0.22 kg ai ha^{-1} (Waddill, 1982), @ 0.4 pints ac^{-1} (Cruz, 1983), and @ 0.03 per cent suspension (Rajamma, 1984) were observed effective against the weevil.

Fenvalerate spray @ 0.4 pints ac^{-1} (Cruz, 1983), decamethrin @ 0.003 per cent emulsion (Rajamma, 1984) showed high toxicity to the adults of *C. formicarius*

2.15.2. Soil application of insecticides

2.15.2.1. Chlorinated hydrocarbons

Sultan (1957) observed that soil application of dieldrin was effective against the pest. The application of dusts of aldrin (2.5 per cent), dieldrin (2.5 per cent or endrin (0.1 per cent) @ 30 lb ac^{-1}, six times at biweekly intervals from 6 weeks after planting was recommended for controlling *C.formicarius* (Ananthanarayanan and Subramanian, 1958).

Dieldrin @ 0.1 per cent applied thrice biweekly from tuber formation (David, 1960) and dieldrin @ 0.1 per cent emulsion applied twice at triweekly intervals from tuber formation (Ramakrishnan and Narayanaswamy, 1960; Ramaswamy and Srinivasan, 1965) reduced the pest incidence significantly.

The incorporation of BHC, dieldrin, heptachlor or chlordane in the soil, @ 0.1 per cent, four times at biweekly intervals from 7 WAP effectively checked the weevil damage (Hua, 1970). Cheng and Li (1973) reported that mixing the soil with 40 kg ha^{-1} of 2.5 per cent heptachlor or 6 kg ha^{-1} of 40 per cent aldrin or heptachlor WP diluted in 1200 l of water, reduced the *C. formicarius* damage significantly.

Gamma BHC @ 0.1 per cent applied at biweekly intervals (Anon., 1978) and granular BHC @ 1 kg ai ha^{-1} applied twice, once at planting and then at tuber formation, controlled the pest effectively (Anon., 1982a).

Drenching endosulfan 0.05 per cent emulsion at 50 and 70 DAP was effective in preventing the pest incidence (Pajamma, 1983).

2.15.2.2. OP compounds

Application of mephosfolan or phorate @ 1.4 kg ai ha^{-1} as basal (Anon., 1974; Anon., 1978), phorate @ 2 kg ai ha^{-1} or disulfoton @ 1.8 kg ai ha^{-1} at 30 DAP (Anon., 1978) was recommended against the weevil. Two drenchings with malathion or fenthion 0.05 per cent emulsion at 30 and 60 DAP (Johnson et al., 1979) and fenthion or fenitrothion (0.05 per cent) at 50 and 70 DAP (Rajamma, 1983) reduced the weevil damage.

2.15.2.3. Carbamates

Applications of carbofuran @ 1.4 kg ai ha^{-1} at planting (Anon., 1974; Anon., 1978) or @ 2 kg ai ha^{-1} at monthly intervals from 14 DAP (Talekar, 1983) were recommended for effective control of the weevil.

2.15.3. Baiting

As early as 1942 Eddy suggested baiting the adults with sweet potato tuber and 0.5 to 1.0 per cent paris green. Cockerham and Deen (1948) mixed 20 parts of tuber, 1 part of paris green and 0.4 per cent sodium benzoate as the bait and recommended @ 120 lb bait per acre for checking the weevil damage.

The use of trichlorfon (1 : 1000) in fresh sweet potato tuber slices was advocated in China for trapping the apionids (Esguerra, 1981; Bartolini, 1982).

2.15.4. Effect of insecticides on the microflora

The fungal population was not seen affected by the application of phorate @ 10 kg ha^{-1} (Chellaian, 1972), @ 2 kg ai ha^{-1} (Sathpathy, 1974), @ 1.5 and 3.0 kg ai ha^{-1} (Visalakshi et al., 1981) and @ 1.68 kg ai ha^{-1} (Varshney and Rana, 1987) and by the application of quinalphos @ 2 kg ai ha^{-1} (Oblisami et al., 1977).

A decrease in the fungal population was noted with carbofuran (Elliot et al., 1972; Tu, 1972) and with phorate @ 20 kg ha^{-1} (Chellaiah, 1972; Murthy et al., 1976) and @ 1.25 kg ai ha^{-1} (Das, 1986). Tewari et al. (1972) and Visalakshi (1977) reported that the fungal population was seen stimulated by phorate application in soil.

Bacterial population in the soil was reported to be unaffected by the application of phorate @ 10 kg ha^{-1} (Chellaiah, 1972), @ 2 kg ai ha^{-1} (Sathpathy, 1974; Murthy et al., 1976) and @ 1.68 kg ai ha^{-1} (Varshney and Rana, 1987) and by the application of carbofuran (Hubbel et al., 1973) and 1.2 kg ai ha^{-1} twice (Kandaswamy et al., 1975).

But a slight reduction in bacterial population was reported to be caused by the application of carbofuran @ 11.2 and 5.2 kg ha^{-1} (Elliot et al., 1972). Tu (1972) noted an initial reduction of bacteria due to carbofuran treatment which recovered afterwards. A definite reduction of bacterial population was reported due to phorate treatment (Chendrayan and Prasad, 1976; Visalakshi, 1977). An increase in the bacterial population was observed with quinalphos @ 2 kg ai ha^{-1} (Oblisami et al., 1977), and with phorate @ 1.5 and 3.0 kg ai ha^{-1} (Visalakshi et al., 1981) and @ 1.25 kg ai ha^{-1} (Das, 1986).

The population of actinomycetes was not seen affected by the application of phorate @ 10 or 20 kg ha^{-1} (Chellaiah, 1972) and

@ 1.68 kg ai ha^{-1} (Varshney and Rana, 1987). A decrease of the actinomycetes was noted with carbofuran @ 11.2 and 5.2 kg ha^{-1} (Elliot et al., 1972), and with phorate (Visalakshi, 1977; Das, 1986). However Tewari et al. (1972) indicated an increase in actinomycetes with phorate application.

2.15.5. Effect of insecticides on the flavour of edible tubers

Gilpin and Geissenhainer (1953) determined the flavour and palatability of baked tubers, obtained from DDT sprayed fields and found no off flavour and the acceptability was good. Ananthanarayanan and Subramanian (1958) also did not note any off flavour in the tubers treated with aldrin, dieldrin and endrin when applied @ 0.1 per cent active ingredient.

2.15.6. Insecticidal residues in tubers

When synthetic insecticides were first used against sweet potato weevil, research workers spoke of 'taint-free' tubers to indicate the lack of harmful insecticidal residues (Sherman, 1951; Sherman and Mitchell, 1953; Wolcott and Perez, 1955).

The residues in sweet potato tubers harvested from the crop treated with aldicarb, carbofuran and disulfoton applied @ 1 kg ai ha^{-1}, at the time of tuber formation, were below tolerance limit (Rajukkannu et al., 1976).

Johnson et al. (1979) and Pillai et al. (1981) reported that residues of fenthion, fenitrothion, malathion, monocrotophos and quinalphos in the tubers were below tolerance, when they were applied 2 to 4 times as 0.05 per cent spray, from 30 DAP and at 3 to 4 week intervals.

2.16. Integrated control of *C. formicarius*

As early as 1970, Haynes stressed the need for an integrated approach to combat the weevil menace. Possible integration of cultural and chemical methods was suggested by Butani and Verma (1976), Subramanian *et al*. (1977), Onwuene (1978), Anon. (1983b), Esguerra (1982) and Rajamma and Premkumar (1984).

In Southern China farmers practised strict field sanitation, trapping of adults, reridging (two or more times), use of oil tea cake and urea mixture, and crop rotation as an integrated approach for weevil control (Bartolini, 1982).

In Taiwan, crop rotation together with field sanitation and dipping of planting materials in carbofuran 0.05 per cent were seen effective in containing the pest (Talekar, 1983).

Yu (1983) recommended an integrated control measure comprising of sanitation, trapping of adults and spraying with insecticides.

An integrated weevil management programme is in progress in Nigeria and it has been found that moderately resistant weevil lines, early planting and early harvesting and the practice of reridging gave satisfactory results (Anon., 1986b).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1. Survey on the occurrence of *Cylas formicarius* and the intensity of damage caused by the pest in major sweet potato growing areas of Kerala

A detailed survey was carried out in the major sweet potato growing areas of Kerala. The cultivation is prevalent in Kasaragod, Malappuram, Palghat, Trichur, Quilon and Trivandrum Districts of the State. The surveyed areas included irrigated lowland and rain-fed upland cultivations. A multistage sampling technique was adopted in the survey.

Agricultural Sub Divisional Units (S.D. Units) having considerable area under sweet potato were selected (purposive sampling) in each of the above Districts. Then the number of sweet potato growing Agricultural Development Units (A.D. Units) in the above S.D. Units were fixed adopting probability proportion to the area under the crop. The required number of A.D. Units were selected at random in each S.D. Unit.

Two villages were randomly selected in each A.D. Unit and two farmers were selected at random from each village. One holding each belonging to each farmer in upland area and in lowland area (where available) were selected at random. The final sample consisted of 48 holdings in lowland and 80 holdings in upland area as detailed in Table 1. From each of the selected holding four plots of 3 x 1 m size were chosen at random and the relevant data were collected from these plots at the time of harvest.

Table 1. Details of sampling adopted in the survey of sweet potato weevil incidence in Kerala

District and area in ha* (1981-82)	S.D.Units and area under sweet potato in ha**		Number of A.D. units selected	Number of villages selected	Number of farmers	
					Lowland	Upland
Kasaragod 980	Kasaragod	955	4	8	16	16
Malappuram 1587	Tirur	400	2	4	8	8
	Manjeri	700	3	6	12	12
	Nilambur	80	1	2	4	4
Palghat 2023	Shoranur	1000	4	8	@	16
	Alathur	750	3	6	@	12
	Mannarghat	100	1	2	@	4
Trichur 135	Wadakkancherry	116	1	2	@	4
Quilon 40	Quilon	40	1	2	4	@
Trivandrum 140	Neyyattinkara	64	1	2	4	4
	Total		21	42	48	80

* Source: Bureau of Economics and Statistics, Trivandrum

** Source: Joint Directors of Agriculture of the respective Districts

@ No cultivation

3.1.1. Observations

The total number of plants, number of infected plants, total weight of tubers and weight of infested tubers obtained from each plot were recorded. The numbers obtained from four plots in each holding were pooled and the percentages of weevil infested plants and tubers were calculated from the data. The number of weevils on the foliage and life stages in the vines and tubers of ten randomly selected plants in each plot were counted and the total of these was treated as the weevil population in the plot. The mean of the weevil population in the four observation plots in each holding was calculated. The types of soil and cultural practices adopted in each holding were noted and their influence on the incidence of weevil and the extent of damage was studied adopting suitable statistical techniques.

3.1.1.1. Assessment of damage grade index (DGI)

3.1.1.1.1. Crown

The intensity of damage on crown (the portion of the stem 10 cm above and 10 cm below the ground level) was assessed in terms of DGI using a six point scale as detailed below.

0 - Free from weevil damage

1 - Visible feeding punctures and oviposition marks

2 - Internal feeding damage by the grubs up to 25 per cent of crown

3 - Internal feeding damage ranging from 25 to 50 per cent of the crown

Plate I

Intensity of damage done to sweet potato tubers by _C_. _formicarius_

A. Grade 0 - No weevil damage

B. Grade 1 - External feeding damage and oviposition marks on less than 25 per cent of tuber surface but without internal damage

4 - 50 to 75 per cent damage with proliferation of tissues in the crown

5 - Above 75 per cent damage with high degree of proliferation and hypertrophy to tissues in the crown and at times the crown breaking from root zone

Grading was done by sectioning the crown. The grade points awarded to the ten random plants collected from each holding, were added and mean calculated was taken as the DGI of the sample.

3.1.1.2. Tuber

The intensity of damage in tubers of the ten random plants from each holding was assessed and the DGI was worked out as done in the case of the crown and adopting a six point scale detailed below.

0 - No weevil damage (Plate I)

1 - External feeding damage and oviposition marks on less than 25 per cent of tuber surface but without internal damage (Plate I)

2 - External feeding damage on more than 25 per cent tuber surface but without internal damage (Plate II)

3 - Internal damage extending over less than 25 per cent portion of tuber (Plate II)

4 - Internal damage 25 to 50 per cent (Plate III)

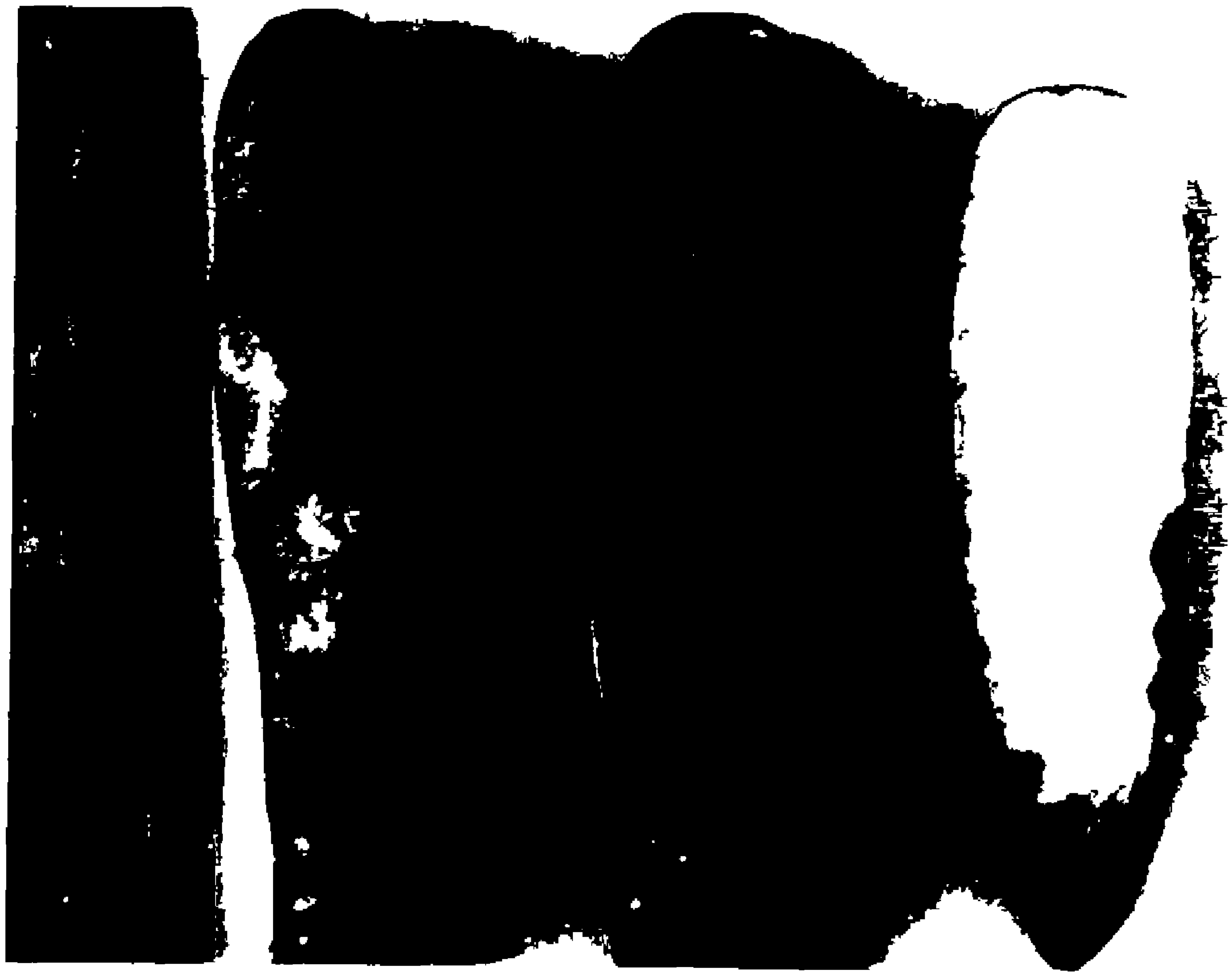
5 - Internal damage above 50 per cent (Plate III)

Plate II

Intensity of damage done to sweet potato tubers by *C. formicarius*

A. Grade 2 - External feeding damage on more than 25 per cent tuber surface but without internal damage

B. Grade 3 - Internal damage extending over less than 25 per cent portion of tuber



3.1.2. Incidence of natural enemies of *C. formicarius*

The number of immature stages of parasites and predators occurring on the host larvae in the plants selected for observations (vide. para 3.1.1.) were recorded and these were presented in the results as the number of parasites and predators.

3.1.3. Occurrence of alternate hosts/harbouring plants in field

The plants with adults and immature stages of the insect were treated as alternate hosts and those with adults alone were taken as harbouring plants. Such plants found in and around each holding were identified and recorded. The biology of the insect on the alternate hosts and the longevity of adults on the harbouring plants were studied in the laboratory.

3.2. Raising the crop and lay out for various field experiments

The field experiments were conducted in the Instructional Farm attached to the College of Agriculture, Vellayani, during 1984-1986. The soil in the area was sandy clay loam consisting of 34.70 per cent course sand, 33.21 per cent fine sand, 4.14 per cent silt, 27.81 per cent clay and the pH was 6.3.

Ridges and furrows were taken 60 cm apart, in well prepared land. Sweet potato vine cuttings (25 cm long) were planted on the ridges at a spacing of 20 cm in plots of 3 x 2 m. In the varietal screening experiments 30 cm spacing and 3 x 2.1 m plot size were adopted. Farm yard manure @ 10 t ha^{-1} and NPK @ 75:50:75 kg ha^{-1} were applied. Half dose of N and full P and K were applied as basal dose and the remaining half N as top dressing at 30 days

Plate III

Intensity of damage done to sweet potato tubers by *C. formicarius*

A. Grade 4 - Internal damage 25 to 50 per cent

B. Grade 5 - Internal damage above 50 per cent

after planting (DAP). The number of plants in each plot was maintained by gap filling. One weeding and earthing up were done at the time of top dressing. Irrigation was done daily for one week after planting and then at weekly intervals making adjustments for the rainfall received during the period. The crop was harvested at 105 DAP. Kanhangad local was the cultivar used for all the experiments. One row of plants on either side of each plot as shown in Fig. 1 were treated as border and the remaining plants (net plot) were used for collecting data relating to the experiment.

3.3. Ensuring adequate population of *C. formicarius* in experimental plots

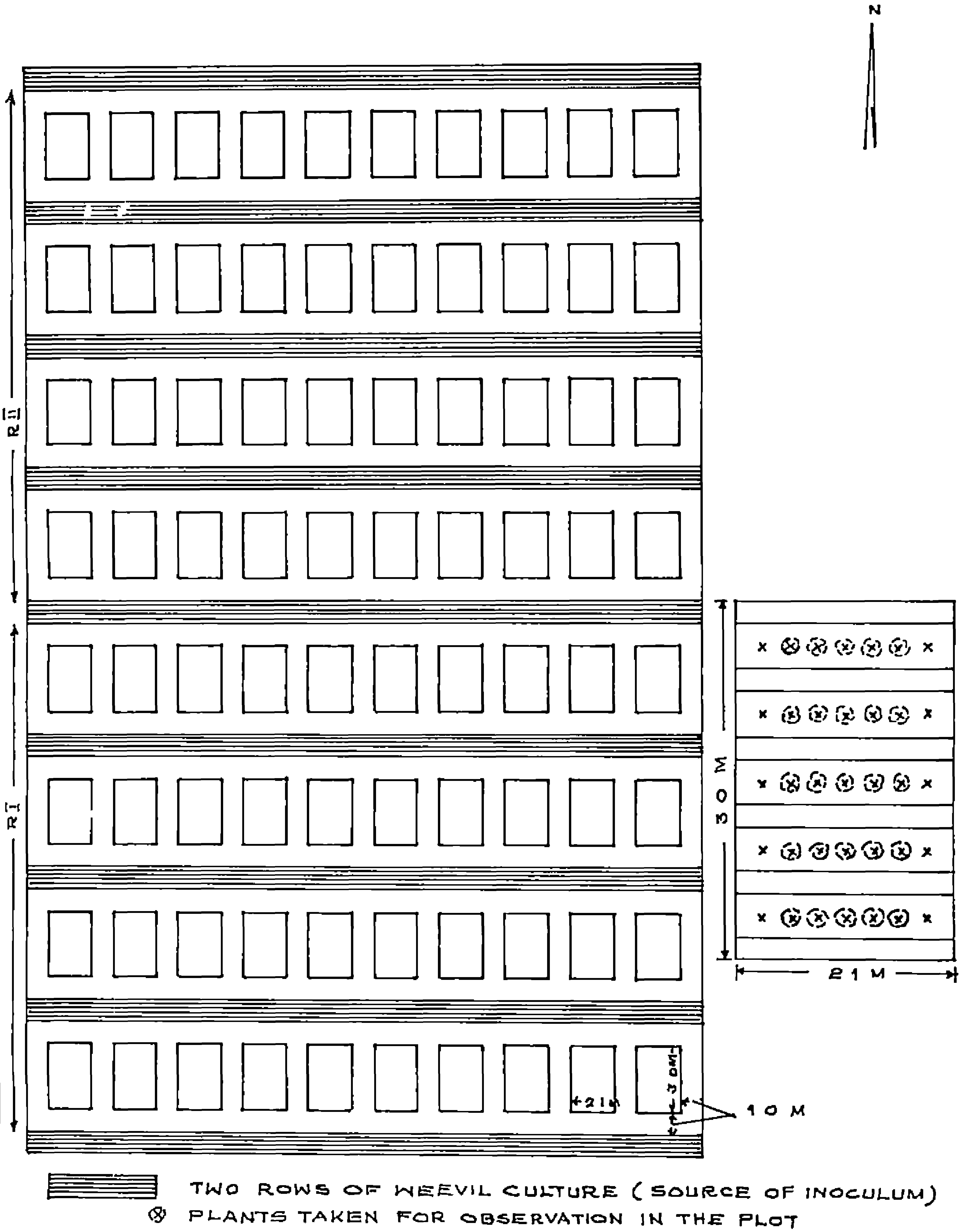
Two rows each of sweet potato plants were raised 30 to 40 days prior to the lay out of the experiment on either side of each row of the experimental plot (Fig. 1) and adult weevils were released on these plants @ 25 insects per metre row at 30 DAP. The population built up from this served as a source of inoculum for the plants raised in the experimental plots subsequently.

3.4. Screening of sweet potato varieties/cultivars for resistance

Forty varieties/cultivars were evaluated for their resistance to *C. formicarius* during the three seasons (January-April, June-September and October-February) of 1985-'86.

The hybrids 75 OP 1, 75 OP 5, 75 OP 57, 76 OP 217, 76 OP 219, H 268, H 506, H 620 and H 633 of Central Tuber Crops Research Institute, Trivandrum, H 2743, H 4021, H 4126 of Kerala Agricultural University, Vellanikkara, CO 1, CO 2, CO 3, IB 440 and

FIG 1 LAYOUT OF FIELD EXPERIMENT 341



IB 700 of Tamil Nadu Agricultural University, Coimbatore, S 30 (Samrat) of Andhra Pradesh Agricultural University, Rajendranagar and X 4, X 5, X 24, C 43, C 71, V 35 and Kalmegh (pink) of Rajendra Agricultural University, Dholi and the local cultivars viz., Anacomban, Bhadrakalichuvala, Chedivella, Ethenvella, Kaavivella, Kadukkavella, Kanhangad local, Kottaramchuvala, Maruthipooven, Muttavella, Nedinjilchuvala, Panineervella, Parinkamavinchuvala, Poineervella and Selopia were included in the experiment.

The experiment was laid out as described in para 3.2 and 3.3 in randomized block design with two replications for each treatment (Fig. 1).

3.4.1.1. Assessment of results

3.4.1.1.1. Extent of damage caused by *C. formicarius*

The total number of plants, number of infested crowns, total weight of tubers and weight of infested tubers in each net plot were recorded at the time of harvest. The mean percentage of crown, the percentage of weight of infested tubers were calculated from the data. The damage grade indices of the crown and tubers of ten plants selected at random from each net plot were worked out as explained in para 3.1.1.1. Adult weevils emerging from one kilogram sample of infected tubers taken from each plot and stored in the laboratory for 30 days were counted and recorded. The entire data were subjected to statistical analysis.

Based on relative resistance to *C. formicarius* the varieties were grouped into six categories using mean ($\bar{x}$) and standard deviations (SD) (the property of normal distribution of fiducial limits or confidence limits, Snedecor and Cochran, 1967). The varieties showing crown DGI, percentage of tuber damage and number of adult weevils emerging from stored tubers below the level $\bar{x}$ - 2SD were considered as moderately resistant (MR), between $\bar{x}$ - 2SD and $\bar{x}$ - 1SD as less resistant (LR), between $\bar{x}$ - 1SD and $\bar{x}$ as less susceptible (LS), between $\bar{x}$ and $\bar{x}$ + 1SD as susceptible (S), between $\bar{x}$ + 1SD and $\bar{x}$ + 2SD as highly susceptible (HS) and above $\bar{x}$ + 2SD as most susceptible (MS).

3.4.1.1.2. Mechanism of resistance

3.4.1.1.2.1. Physical factors

The plant characters viz., pigmentation of leaf, vine, petiole, tuber skin and tuber flesh, leaf lobing, shape of tubers, latex content of tubers, and depth of tubers of five plants selected at random from each plot were recorded.

The latex content of tuber was rated as 'high' when a pinch of the tuber caused an immediate flow of latex and as 'low' when the flow was slow and very little. The depth of tuber formation was the distance from soil surface to the neck of tuber.

The association of the above plant characters with the variations in each criterion adopted for assessing the varieties was studied through 'F'-test, for qualitative characters and through simple correlation for quantitative characters.

3.4.1.1.2.2. Biochemical factors

Moisture, dry matter, sugar, starch, total phenols, OD phenols and catotenoid content of some selected varieties were determined. The varieties chosen included one moderately resistant (Selopia), one less resistant (76 OP 217), one less susceptible (Kanhangad local) and two most susceptible (Anacomban and Ethenvella) ones. Two weevil free tubers were selected from each variety. The tubers were sliced into small bits and pooled to draw samples for the analysis. Four replications were taken for the estimation of each constituent.

Moisture and dry matter percentages were ascertained by the oven drying method. Starch, sugar, total phenols and OD phenols were estimated by the methods suggested by Mahadevan and Sridhar (1986) and the method of Constantin et al.(1975) was adopted to determine carotene content.

3.4.1.1.2.3. Antibiosis

The five varieties used for the biochemical analysis were used for the study of antibiosis in the laboratory. Five pairs of four day old adult weevils were exposed on one kilogram of noninfested tubers, taken in a glass jar and four such replications were maintained for each variety. The weevils were removed after four days of egg laying. The number of adults emerging from each replication was recorded separately. From the data the antibiosis, if any, was assessed.

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

Sweet potato crop was raised in 30 plots in two equal rows (15 each constituting a replication) as explained in para 3.2. and

3.3. The weevil incidence on the crop and the extent of damage were assessed at weekly intervals from the time of planting up to 105 days after planting (fifteen observations).

The experiment was conducted during July-October '84 and was repeated during January-April '85. Twenty plants at random were selected from one plot in each row for every observation. Plots used for one observation were not considered for subsequent samplings.

Observations described in para 3.4.1.1.1. were recorded. Besides, the populations of the life stages of the pest on the foliage, in the crown and also in the tuber were recorded. The data were subjected to statistical analysis.

3.6. Effect of reridging on the incidence of *C. formicarius*

The experiment was laid out as described in para 3.2 and 3.3 in randomized block design with two replications for each treatment. The treatments were

1. One reridging at 30 DAP
2. Two reridgings at 30 and 40 DAP
3. Three reridgings at 30, 40 and 50 DAP
4. Four reridgings at 30, 40, 50 and 60 DAP
5. Five reridgings at 30, 40, 50, 60 and 70 DAP
6. Six reridgings at 30, 40, 50, 60, 70 and 80 DAP
7. Seven reridgings at 30, 40, 50, 60, 70, 80 and 90 DAP
8. Six reridgings at 40, 50, 60, 70, 80 and 90 DAP
9. Five reridgings at 50, 60, 70, 80 and 90 DAP

10. Four reridgings at 60, 70, 80 and 90 DAP
11. Three reridgings at 70, 80 and 90 DAP
12. Two reridgings at 80 and 90 DAP
13. One reridging at 90 DAP
14. Control - without reridging

The experiment was conducted during July-October '84 and was repeated during January-April '85. Observations explained in para 3.4.1.1.1. were made and the data were subjected to statistical analysis.

3.7. Effect of organic amendments on the incidence of *C. formicarius*

Efficacy of organic amendments in controlling the weevil was assessed in two field experiments conducted during June-September and September-December '85. The experiments were laid out as described in para 3.2 and para 3.3 in randomized block design with nine treatments, each replicated thrice. The leaves of the following plants were incorporated @ 3 t ha^{-1} at 30 DAP, at the time of first weeding and top dressing.

1. Neem - *Azadirachta indica* Juss. (family meliaceae)
2. Karanj - *Pongamia glabra* Vent. (leguminoceae)
3. Punna/Undi - *Calophyllum inophyllum* L. (guttiferae)
4. Kataavanakku/ratanjy - *Jatropha glandulifera* Roxb. (euphorbiaceae)
5. Communist pacha - *Eupatorium odoratum* L. (compositae)
6. Peruvalam - *Clerodendron infortunatum* L. (verbenaceae)
7. Lemongrass - *Cymbopogan flexuosus* Wats. (graminae)

8. Erukku - *Calotropis gigantea* R.Br. (asclepiadeae)
9. Control - without any treatment

The extent of damage caused by the pest was assessed in various treatments as detailed in 3.4.1.1.1. and the data were statistically analysed.

3.8. Control of sweet potato weevil using repellents

The effect of neem cake (*A. indica*), punna cake (*C.inophyllum*) and mahwa cake (*Bassia latifolia* Roxb., sapotaceae) as well as wood ash, were evaluated in two field experiments for the control of *C. formicarius*. Each material was tried at three different doses and was applied at two different intervals. The experiments were conducted during July-October '85 and January-April '86. There were 25 treatments as detailed below:

1.	Neem cake @	500	kg ha^{-1} applied	at 30 DAP
2.	,,	1000	,,	,,
3.	,,	1500	,,	,,
4.	Punna cake @	500	,,	,,
5.	,,	1000	,,	,,
6.	,,	1500	,,	,,
7.	Mahwa cake @	500	,,	,,
8.	,,	1000	,,	,,
9.	,,	1500	,,	,,
10.	Wood ash @	1000	,,	,,
11.	,,	2000	,,	,,
12.	,,	3000	,,	,,

13. Neem cake @	500 kg ha^{-1}	applied at 50 DAP	
14. ,,	1000	,,	,,
15. ,,	1500	,,	,,
16. Punna cake @	500	,,	,,
17. ,,	1000	,,	,,
18. ,,	1500	,,	,,
19. Mahwa cake @	500	,,	,,
20. ,,	1000	,,	,,
21. ,,	1500	,,	,,
22. Wood ash @	1000	,,	,,
23. ,,	2000	,,	,,
24. ,,	3000	,,	,,

25. Control - without any treatment

The experiment was laid out as described in para 3.2. and 3.3. in randomised block design with two replications for each treatment. The effect of treatment was assessed by recording observations detailed in para 3.4.1.1.1. The data were subjected to statistical analysis.

3.9. Standardization of technique for trapping adults of *C. formicarius*

3.9.1. Evaluation of different materials as attractants to the adults of *C. formicarius*

The following materials were screened in the laboratory for selecting a suitable bait material for trapping the adult weevils:

1. Whole sweet potato tubers 200 g
2. Fresh sweet potato cut tubers 200 g

3. Fresh sweet potato tubers crushed 200 g
4. Vinegar alone 25 ml
5. Yeast 4 g in 25 ml water
6. Jaggery 10 g
7. Vinegar 25 ml + yeast 4 g
8. Vinegar 25 ml + jaggery 10 g
9. Vinegar 25 ml + jaggery 10 g + yeast 4 g
10. Crushed tubers 200 g + vinegar 25 ml
11. Crushed tubers 200 g + yeast 4 g
12. Crushed tubers 200 g + jaggery 10 g
13. Crushed tubers 200 g + yeast 4 g + vinegar 25 ml
14. Crushed tubers 200 g + yeast 4 g + vinegar 25 ml + jaggery 10 g
15. Fermented cocoa pulp alone 200 g
16. Fermented cocoa pulp 200 g + vinegar 25 ml
17. Fermented cocoa pulp 200 g + yeast 4 g
18. Fermented cocoa pulp 200 g + jaggery 10 g
19. Fermented cocoa pulp 200 g + vinegar 25 ml + yeast 4 g
20. Fermented cocoa pulp 200 g + vinegar 25 ml + yeast 4 g + jaggery 10 g
21. Fresh toddy 25 ml
22. Fresh toddy 25 ml + vinegar 25 ml
23. Fresh toddy 25 ml + yeast 4 g
24. Fresh toddy 25 ml + jaggery 10 g
25. Fresh toddy 25 ml + vinegar 25 ml + yeast 4 g
26. Fresh toddy 25 ml + vinegar 25 ml + yeast 4 g + jaggery 10 g
27. Fresh vines of Ipomoea purpuria (alternate host) 200 g
28. Fresh vines of sweet potato 200 g

Each treatment was taken in 9 cm petri dish and the dishes were arranged in a circle of 3 m radius on the floor of an insect proof room (20' x 20' x 15') and 500 freshly emerged adults of C. *formicarius* were released at the centre of the circle. The number of adults attracted to each treatment was recorded at the end of 24 h. The experiment was repeated five times and the data collected from each experiment were taken as one replication for the purpose of statistical analysis.

3.9.2. Activity of adults of C. *formicarius* in the field

Five traps were distributed in the field 5 m apart. The number of adults collected in each trap was counted and recorded at 2 hour intervals for 24 hours, commencing at 06.00 h. The experiment was carried out in four different locations. The data collected from each location was taken as one replication for the purpose of statistical analysis.

Another experiment was conducted to assess the desirability of setting up the traps in the evening and collecting the weevils next day morning without losing the beetles trapped. Three lots of traps were set up at 16.00 h and the weevils trapped were counted and removed at two hour intervals till 06.00 h, at 06.00 h only and at 22.00 h (the end of the peak activity of the weevil). The experiment was carried out in seven different locations having severe infestation during September-October '85. The data collected from one location was taken as one replication for the statistical analysis. The bait used in each trap was 200 g sweet potato cut tuber.

3.9.3. <u>Assessment of the effect of the size of sweet potato tubers (cut and whole) used as bait material and the optimum frequency of changing the bait for collecting the adults of *C. formicarius*</u>

An experiment was laid out in bulk planting where severe incidence of the pest was noticed. The following materials were included as treatments:

1.	Whole tuber		9 cm	diameter	kept unchanged
2.	,,		6 cm		,,
3.	,,		3 cm		,,
4.	,,		9 cm	diameter	changed daily
5.	,,		6 cm		,,
6.	,,		3 cm		,,
7.	Tubers cut	– lengthwise	– 9 cm	diameter	kept unchanged
8.	,,	– crosswise	– 9 cm	,,	,,
9.	,,	– lengthwise	– 6 cm	,,	,,
10.	,,	– crosswise	– 6 cm	,,	,,
11.	,,	– lengthwise	– 3 cm	,,	,,
12.	,,	– crosswise	– 3 cm	,,	,,
13.	,,	– lengthwise	– 9 cm	diameter	changed daily
14.	,,	– crosswise	– 9 cm	,,	,,
15.	,,	– lengthwise	– 6 cm	,,	,,
16.	,,	– crosswise	– 6 cm	,,	,,
17.	,,	– lengthwise	– 3 cm	,,	,,
18.	,,	– crosswise	– 3 cm	,,	,,

19. Tubers cut - lengthwise - 9 cm diameter chipped daily
20. ,, - crosswise - 9 cm ,, ,,
21. ,, - lengthwise - 6 cm ,, ,,
22. ,, - crosswise - 6 cm ,, ,,
23. ,, - lengthwise - 3 cm ,, ,,
24. ,, - crosswise - 3 cm ,, ,,

The bait materials were kept in spherical traps made of G.I. wire net (four mesh per $inch^2$) to avoid rat damage and distributed in the field 10 m apart. The traps were distributed in the evening and weevils collected in the traps were recorded at 06.00 h. The collections were done daily for five days. The experiment was repeated five times. In analysing the data the count obtained in each experiment was treated as one replication.

3.9.4. Assessment of the optimum quantity of sweet potato tuber to be used for trapping adults of *C. formicarius*

The experiment was done in an infested field during July to October '85. Tubers of 6 cm diameter (at the middle) cut into pieces of 25, 50, 100, 200 and 300 g weight were kept as mentioned in para 3.9.3. and were distributed 10 m apart in the field at 16.00 h and catches were recorded next day at 06.00 h. The experiment was done in five different locations having more or less similar infestation. The count obtained from each location was taken as one replication for statistical analysis.

3.9.5. Assessment of optimum distance to be maintained among traps for collecting adults of *C. formicarius*

The experiment was conducted in an infected field during July-October '85. Sweet potato tubers of 6 cm diameter cut to

100 g weight were used in the traps. They were distributed at varying distances of 3, 5, 10 and 15 m. This was done in five different locations. The collection of data and statistical analysis of the same were done as explained in para 3.9.4.

3.9.6. Fixing optimum interval at which trapping of adults of *C. formicarius* have to be done for controlling the pest

The experiment was laid out as described in para 3.2 and 3.3. in completely randomised design with a plot size of 10 x 10 m^2. The following treatments were included in the experiment and each treatment replicated four times.

1. Trapping of adults at 3 day intervals from 50 DAP to 80 DAP
2. Trapping of adults at 7 day intervals from 50 DAP to 80 DAP
3. Trapping of adults at 10 day intervals from 50 DAP to 80 DAP
4. Trapping of adults at 15 day intervals from 50 DAP to 80 DAP
5. Drenching fenthion 0.05 per cent at 50 DAP and 80 DAP
6. Control (untreated)

One trap (vide. para 3.9.3.) was set up in each replication at intervals varying according to above treatments. The trap was set at the centre of the plot at 16.00 h and the number of weevils trapped were counted at 06.00 h next day. The observations mentioned in para 3.4.1.1.1. also were recorded at harvest from an area of 3 x 1.6 m^2 at the centre of each plot. The data were subjected to statistical analysis.

3.10. Chemical control of *C. formicarius*

3.10.1. Relative efficacy of different insecticides used as soil drench in controlling *C. formicarius*

The experiment was conducted during January to April '85 in a field planted with sweet potato as explained in para 3.2. and 3.3. There were eight treatments each replicated thrice and distributed in a randomized block design. Quinalphos, fenthion, endosulfan, monocrotophos and fenitrothion were used as 0.05 per cent emulsions, drenching the soil around the plants at 50 and 80 DAP, and carbofuran and phorate @ 1.5 kg ai ha^{-1} were applied as granules at 50 DAP. An untreated control also was maintained.

The quantity of insecticidal emulsions used for drenching was two litres per plot ($3 \times 2\ m^2$). The data were collected and analysed as described in para 3.4.1.1.1.

The effect of different treatments on soil microflora in the experimental plots was assessed at 50, 52, 80 and 82 DAP. A composite rhizosphere soil sample was taken from each plot. The populations of fungi, bacteria and actinomycetes in each sample were assessed following the serial dilution plate technique (Johnson and Curl, 1972). Peptone dextrose agar with Rose Bengal and streptomycin (Martin, 1950), soil extract agar (Lochhead, 1940) and Keknight's agar (Rangaswamy, 1966) were used for plating fungi, bacteria and actinomycetes respectively.

The residues of the insecticides used in the experiment in tubers, at the time of harvest, were assessed colorimetrically following the methods of Maitlen *et al*. (1963) adopting extraction and clean up procedure of Katpal and Dewan (1975) for endosulfan, Getz and Watts (1964) modified by Jain *et al*. (1974) for OP compounds and Gupta and Dewan (1973) for carbofuran.

3.10.2. Assessment of the optimum frequency of soil drenching with insecticides for the control of *C. formicarius*

The raising of the crop and lay out of the experiment were done as described in para 3.2. and 3.3. Endosulfan @ 0.05 per cent fenthion @ 0.05 per cent, fenitrothion @ 0.05 per cent and tobacco decoction @ 1 per cent were used as soil drench at different intervals after planting. The treatments were:

1.	Endosulfan at	50 DAP
2.	,,	65 DAP
3.	,,	80 DAP
4.	,,	50 and 65 DAP
5.	,,	50 and 80 DAP
6.	,,	50, 65 and 80 DAP
7.	,,	60 and 90 DAP
8.	Fenthion at	50 DAP
9.	,,	65 DAP
10.	,,	80 DAP
11.	,,	50 and 65 DAP
12.	,,	50 and 80 DAP
13.	,,	50, 65 and 80 DAP
14.	,,	60 and 90 DAP

15. Fenitrothion at 50 DAP
16. ,, 65 DAP
17. ,, 80 DAP
18. ,, 50 and 65 DAP
19. ,, 50 and 80 DAP
20. ,, 50, 65 and 80 DAP
21. ,, 60 and 90 DAP
22. Tobacco decoction at 50 DAP
23. ,, 65 DAP
24. ,, 80 DAP
25. ,, 50 and 65 DAP
26. ,, 50 and 80 DAP
27. ,, 50, 65 and 80 DAP
28. ,, 60 and 90 DAP
29. Control drenched with water alone

The experiment was laid out during September-December '85 in a randomized block design with three replications for each treatment. Quantity of insecticidal emulsion used, observations recorded and the analysis of data were the same as described in para 3.10.1.

The persistent toxicity of the 28 insecticidal treatments in the soil to the adults of C. formicarius was also studied. Soil samples from around the treated plants were collected in petri dishes one day after drenching and subsequently at weekly intervals. In each petri dish, 25 day old adult weevils were introduced along with a 10 g piece of fresh tuber and the same was kept closed with muslin cloth. Mortality was recorded at the end of 48 h. The data were subjected to statistical analysis.

3.11. Integrated control of sweet potato weevil

The methods found effective in the different experiments for limiting the pest population and for reducing the damage caused by the pest were integrated in different combinations and two field experiments were conducted, one using a less susceptible variety (Kanhangad local) and the other using a moderately resistant variety (Selopia). The experiments were conducted during June-September '86. The treatments given in the experiments were:

1. Cultural practices alone

   Removal and destruction of alternate hosts

   Selection of pest free planting materials

   Mulching with *Eupatorium* leaves @ 3 t ha^{-1} at 30 DAP

   Reridging at 50 DAP and 80 DAP

   Trapping of adult weevils from 50 to 80 DAP at 10 day intervals (total four times) using traps with 100 g sweet potato (6 cm diameter) and placed 5 m apart

   Timely harvest (105-110 DAP)

   Disposal of crop residues

2. Cultural and chemical methods combined

   All cultural practices in treatment 1, excluding reridging at 80 DAP

One soil drenching with endosulfan 0.05 per cent emulsion at 65 DAP

3. Chemical control alone

Soil drenching with endosulfan 0.05per cent emulsion at 50 and 80 DAP

4. Control with earthing up at 30 DAP as practised by farmers

The crop was raised as described in para 3.2. Each treatment was done in 10 x 4 m^2 plots. The plots were placed 10 m apart for avoiding the dilution effect of trapping by migration of weevils from nearby plots. Adequate population in the experimental area was ensured by releasing 500 number of *C. formicarius* beetles in each plot at 30 DAP.

From each main plot, sub plots (3 x 1.6 m^2) were marked at random and five such plots were considered as replications for each treatment. Observations as described in para 3.9.6. were recorded. The effect of treatments on the natural incidence of parasitoids of *C. formicarius* was also assessed by counting their population at the time of harvest as described in para 3.1.2. The data were statistically analysed and the cost-benefit ratio was also calculated.

3.12. Assessment of the reliability of different criteria adopted for evaluation of *C. formicarius* incidence

The coefficient of variations found in the data obtained in the different experiments were estimated for comparing the reliability of various criteria adopted for the evaluation of results in the present investigations.

RESULTS

4. RESULTS

4.1. Occurrence of *C. formicarius* on irrigated sweet potato grown in the wet/low lands

4.1.1. Extent and intensity of damage by *C. formicarius*

Data relating to the survey are presented in Table 2, Table 2a and Fig. 2. As is shown in the figure the crop is grown in the Kasaragod and Malappuram Districts in the northern region and Trivandrum as well as Quilon Districts in the southern region of Kerala. The pest was seen distributed in all the Districts and the extent of damage also was fairly high in most of the holdings covered in the survey.

Among the Districts, Malappuram had the maximum area under the crop and it was followed by Kasaragod, Trivandrum and Quilon. The extent and intensity of damage caused by *C. formicarius*, based on different criteria presented in Table 2a, showed limited variations among the above different Districts. The crown infestation in Kasaragod (20.99 per cent), Quilon (20.45 per cent) and Malappuram (20.33 per cent) Districts were on par but significantly higher than that of Trivandrum District (12.75 per cent). The intensity of crown damage, shown by the damage grade indices and the mean percentages of tuber infestation did not show significant variation among the Districts. With reference to the intensity of tuber damage as shown by the damage grade indices, Malappuram, Trivandrum and Quilon Districts (0.71, 0.68 and 0.55 respectively) did not show statistically significant variations. But the DGI of tuber in Kasaragod District (0.97) was significantly higher.

Table 2. Incidence of *C. formicarius* and its natural enemies on irrigated sweet potato crop grown in low/wet land of different sweet potato growing tracts of Kerala (January-May 1985)

Location		Mean infestation in Crown %	Crown DC	Tuber %	Tuber DGI	Mean population of (per 10 plants) Weevils	Parasites*	Predators**	Soil type	Method of planting	Harvesting time	Crop rotation
Kasaragod Dist.												
Village	holding											
Periye	1	24.73	0.8	14.29	0.7	90	6	5	Bl	Be	La	R-R-SP
Periye	2	11.11	0.6	7.69	0.8	30	12	0	Al	Be	Ea	T-SP
Pullur	1	25.20	2.0	15.52	1.9	55	7	2	Bl	Ri	La	R-R-SP
Pullur	2	17.50	2.3	15.39	1.7	67	6	3	Bl	Ri	La	R-SP-F
Chithari	1	24.20	1.6	10.08	0.7	24	2	0	Al	Ri	La	T-SP
Chithari	2	15.47	1.2	16.19	0.7	26	6	6	Al	Ri	La	T-SP
Hosdrug	1	15.45	1.7	10.70	0.9	36	3	0	Al	Ri	Ea	T-SP
Hosdrug	2	14.50	1.6	13.51	1.3	66	7	0	Al	Ri	Ea	T-SP
Uduma	1	25.00	0.6	17.64	0.8	44	4	4	Bl	Be	La	R-SP-F
Uduma	2	23.08	0.8	20.00	0.6	44	4	0	Bl	Be	La	R-SP-SP
Paniyal	1	15.39	1.4	15.79	1.2	74	12	6	Re	Be	La	R-SP-SP
Paniyal	2	20.69	1.4	9.52	1.0	50	6	4	Bl	Mo	La	R-R-SP
Pady	1	22.22	1.2	9.09	0.8	66	4	6	Re	Be	La	R-R-SP
Pady	2	26.92	1.2	9.68	0.8	50	8	4	Re	Ri	La	R-R-SP
Chengala	1	25.00	0.8	8.57	0.8	36	6	8	Re	Be	La	R-R-SP
Chengala	2	29.35	1.2	18.42	0.8	50	4	0	Re	Be	La	R-R-SP
Mean		20.99	1.3	13.38	1.0	50.5	6.1	2.7				
Malappuram Dist.												
Village	holding											
Ariyalur	1	21.74	0.8	12.00	0.6	32	12	4	Al	Ri	Ea	R-SP-F
Ariyalur	2	23.08	0.6	12.50	0.4	22	0	0	Al	Mo	Ea	R-SP-F
Parappanangadi	1	24.00	1.2	12.50	0.5	48	4	0	Al	Mo	La	R-SP-F
Parappanangadi	2	23.08	0.6	10.00	0.4	36	10	0	Al	Ri	Ea	R-SP-F
Paroor	1	21.43	0.6	7.14	0.6	32	4	0	Re	Mo	Ea	R-SP-F
Paroor	2	20.00	0.4	4.00	0.4	20	10	4	Al	Mo	Ea	R-SP-F
Kottackal	1	18.52	0.6	4.35	0.6	26	4	10	Al	Ri	Ea	R-SP-F
Kottackal	2	23.08	0.4	10.00	0.6	36	4	0	Al	Mo	Ea	R-SP-F
Elankur	1	6.25	0.6	9.80	0.8	40	2	8	Re	Mo	Ea	R-SP-F
Elankur	2	20.51	1.6	7.68	1.0	58	6	0	Re	Be	La	R-SP-F
Payyanad	1	13.50	0.6	11.86	0.5	40	6	2	Re	Be	La	R-SP-F
Payyanad	2	18.39	1.0	11.09	0.5	40	0	8	Bl	Mo	La	R-SP-F
Kootilangadi	1	21.44	1.6	16.25	1.3	110	10	6	Bl	Be	La	R-R-SP
Kootilangadi	2	24.44	1.8	15.60	1.4	72	6	0	Bl	Ri	La	R-SP-F
Perinthalmanna	1	28.00	1.4	22.22	1.2	96	8	8	Bl	Ri	La	R-SP-F
Perinthalmanna	2	24.83	1.4	16.67	0.6	54	18	8	Al	Mo	La	R-R-SP
Puzhakattiri	1	24.66	1.0	6.00	0.8	66	4	6	Al	Mo	La	R-SP-F
Puzhakattiri	2	24.72	1.2	10.53	0.7	68	8	8	Al	Mo	La	R-SP-F
Moorkanad	1	19.54	0.4	7.22	0.6	60	4	6	Al	Mo	La	R-SP-F
Moorkanad	2	16.04	1.0	6.52	0.5	50	0	8	Al	Mo	La	R-R-SP
Porur	1	16.13	0.6	12.25	0.4	38	4	0	Re	Be	La	R-SP-F
Porur	2	18.68	1.2	10.23	0.6	56	0	0	Re	Be	La	R-SP-F
Vaniyambalam	1	20.48	1.4	8.48	0.8	52	4	10	Re	Mo	La	R-R-SP
Vaniyambalam	2	15.48	0.5	15.07	1.2	94	2	8	Bl	Be	La	R-SP-F
Mean		20.33	0.9	10.83	0.7	52.2	5.4	4.3				
Quilon Dist.												
Village	holding											
Eravipuram	1	21.05	1.0	11.11	0.6	42	10	0	Al	Be	Ea	R-R-SP
Eravipuram	2	22.22	0.6	9.68	0.6	34	8	0	Al	Be	Ea	R-R-SP
Mayyanad	1	13.53	0.4	6.66	0.4	40	3	10	Al	Be	Ea	R-R-SP
Mayyanad	2	25.00	0.6	13.75	0.6	78	2	2	Al	Be	Ea	R-R-SP
Mean		20.45	0.7	10.30	0.6	48.5	5.8	3.0				
Trivandrum Dist.												
Village	holding											
Venganoor	1	17.97	2.0	18.00	1.0	96	12	0	Re	Be	La	R-SP-SP
Venganoor	2	14.29	1.2	8.76	0.6	40	8	5	Al	Mo	La	R-R-SP
Kottukal	1	18.75	1.1	10.42	1.1	54	5	4	Bl	Be	Ea	R-R-SP
Kottukal	2	0.00	0.0	0.00	0.0	0	0	0	Al	Be	Ea	R-R-SP
Mean		12.75	1.1	9.30	0.7	47.5	6.3	2.3				

Al = Alluvial; Bl = Black loam; Re = Red loam

Be = On beds; Ri = On ridges and furrows; Mo = On mounds

Ea = Early; La = Late

R = Rice; SP = Sweet potato; T = Tobacco; F = Fallow

* Parasites – *Rhaconotus* sp. and *Bracon* sp.

** Predator – *Drapetis* sp.

DGI = Damage grade index

Table 2a. Distribution of holdings covered in the survey of C. formicarius with reference to the extent of damage/incidence (Low land)

Criteria/class interval	Kasaragod No.of holdings (16)	Kasaragod Mean score	Malappuram No.of holdings (24)	Malappuram Mean score	Quilon No.of holdings (4)	Quilon Mean score	Trivandrum No.of holdings (4)	Trivandrum Mean score
Crown infestation %								
0 - 5	-		-		-		1	
6 - 12	1		1		-		-	
13 - 18	5		8		1		3	
19 - 24	5		14		2		-	
25 - 30	5	20.99	1	20.33*	1	24.45*	-	12.75
Crown DGI								
0.0 - 0.4	-		3		1		1	
0.5 - 0.9	5		9		2		-	
1.0 - 1.4	6		9		1		2	
1.5 - 1.9	3		3		-		-	
2.0 - 2.4	2	1.28	-	0.94	-	0.65	1	1.08
Tuber infestation %								
0 - 4	-		2		-		1	
5 - 9	5		7		2		1	
10 - 14	4		10		2		1	
15 - 19	6		4		-		1	
20 - 23	1	13.38	1	10.83	-	10.30	-	9.30
Tuber DGI								
0.0 - 0.3	-		-		-		1	
0.4 - 0.7	4		16		4		1	
0.8 - 1.1	8		4		-		2	
1.2 - 1.5	2		4		-		-	
1.6 - 1.9	2	0.97*	-	0.71	-	0.55	-	0.68
Weevil population per 10 plants								
0 - 24	1		2		-		1	
25 - 48	6		10		3		1	
49 - 72	7		9		-		1	
73 - 96	2		2		1		1	
97 - 120	-	50.50	1	52.20	-	48.50	-	47.50

Figures in parentheses are number of holdings selected for the survey in the District

* Significantly higher based on 't' test / Cochran and Cox's test

Mean number of weevils, observed on 10 plants did not show statistically significant variations among the different Districts.

The incidence of C. formicarius in holdings within each District showed considerable variations. With reference to the mean percentage of crown damage, the incidence in Kasaragod District ranged from 11.11 to 29.35. The lowest level of 11.11 per cent was observed in the second holding of Periye village while in the other holding in the same village the incidence was as high as 24.73 per cent. Fifty six per cent of the holdings in the District had crown damage above the mean level of 20.99 per cent.

The damage grade indices of the crown ranged from 0.6 to 2.3. The lowest index of 0.6 was observed in one holding each of Uduma and Periye villages and in the other holdings of the above villages also it was 0.8 only. Forty five per cent of the holdings in the District recorded damage grade indices above mean level of 1.28.

The percentage of tuber infestation in the District ranged from 7.69 to 20.00. The lowest level (7.69 per cent) was observed in the second holding in Periye village while in the first holding of that village the damage was as high as 14.49 per cent. In Pady village the percentage incidence was below ten. Fifty six per cent of the holdings in the District had tuber infestation above the mean level of 13.38 per cent.

With reference to the intensity of attack the damage grade indices of the tubers in the District ranged from 0.6 to 1.9. The lowest level of DGI (0.6) was observed in the second holding of

Uduma village and in the first holding of that village the index was 0.8 only. Pullur and Paniyal are the two villages in the District in which both the holdings showed damage grade indices above one while in other villages the damage grade indices were below one only. Thirtyone per cent of the holdings in the District had the damage indices above the mean level of 0.97.

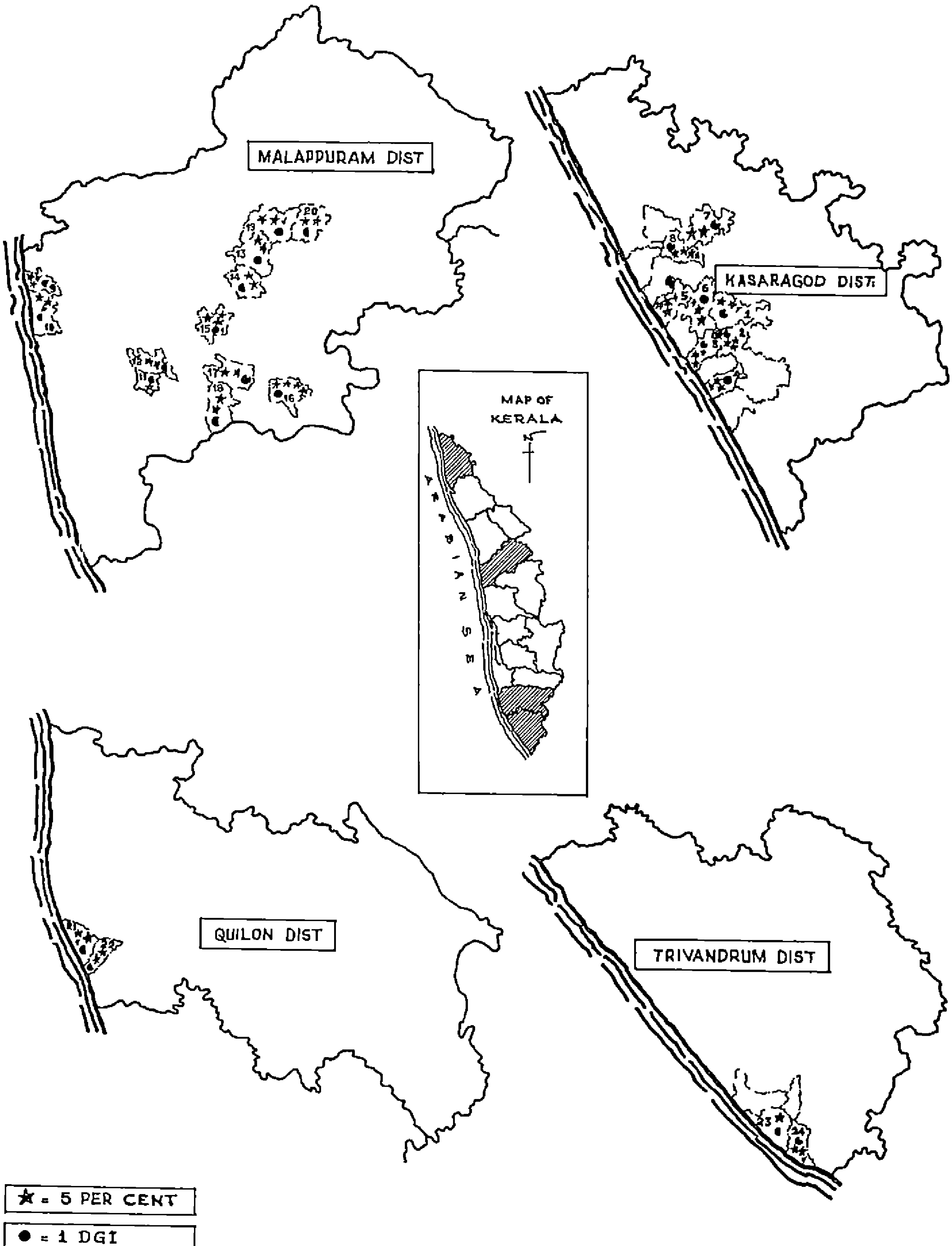
The mean weevil population per ten plants in the District ranged from 24 to 90. The low levels of 24 and 26 numbers of weevils were observed in Chithari village. In both the holdings in Udma village the population was 44. The maximum number of 90 weevils was observed in one holding of Periye village while in the other holding of that village the population was 30 only. Thirty eight per cent of the holdings in the District had the population above the mean level of 51 weevils per ten plants.

In Malappuram District the percentage of crown infestation ranged from 6.25 to 28.00. The lowest incidence of 6.25 per cent was observed in the first holding in Elankur village while in the second holding of the same village the incidence was as high as 20.51 per cent. Fifty eight per cent of the holdings had the incidence above the mean level of 20.33 per cent.

The damage grade indices of crown in the District ranged from 0.4 to 1.8. The lowest index (0.4) was observed in the second holdings of Kottackal and Paroor and in the first holding of Moorkanad village while the indices in the other holdings of the above villages were 0.6, 0.6 and 1.0 respectively. The damage

Fig. 2. Incidence of *C. formicarius* in the low/wet lands of different sweet potato growing tracts of Kerala

1. Periye
2. Pullur
3. Chithari
4. Hosdrug
5. Uduma
6. Paniyal
7. Pady
8. Chengala
9. Ariyallur
10. Parappanangadi
11. Paroor
12. Kottackal
13. Elankur
14. Payyanad
15. Kootilangadi
16. Perinthalmanna
17. Puzhakattiri
18. Moorkanad
19. Vaniyambalam
20. Porur
21. Eravipuram
22. Mayyanad
23. Kottukal
24. Venganoor



MALAPPURAM DIST
KASARAGOD DIST.
MAP OF KERALA
N
ARABIAN SEA
QUILON DIST
TRIVANDRUM DIST
★ = 5 PER CENT
● = 1 DGI

FIGURE. 2

grade indices in 50 per cent of the holdings in the District were above the mean level of 0.94 DGI.

The percentage of tuber infestation in the District ranged from 4.00 to 22.22. The lowest level of infestation (4.00 per cent) was observed in the second holding of Paroor village and in the first holding of that village the incidence was 7.14 per cent. In the first holding of Kottackal village the percentage of tuber infestation was 4.35 only while the second holding in that village had 10 per cent incidence. Elankur was the only village in which the incidence in the both holdings was below 10 per cent. Forty six per cent of the holdings in the District had tuber infestation above the mean level of 10.83 per cent.

The tuber damage grade indices in the District ranged from 0.4 to 1.4. The lowest index (0.4) was noted in one each of the holdings of Ariyalur, Paroor, Parappanangadi and Moorkanad villages. The damage grade indices in the second holdings of the above villages were in the range of 0.5 to 0.6 only. Kootilangadi was the only village in which the damage grade indices of both the holdings exceeded one. Thirty eight per cent of the holdings in the District showed DGI above mean level of 0.75.

The mean weevil population in the District ranged from 20 to 110 per 10 plants. Forty two per cent of the holdings in the District had the population above the mean level (52.2).

In Quilon District one holding in Mayyanad village had the lowest level of crown infestation (13.53 per cent) while the incidence in the second holding of the same village was the highest (25.00 per cent). Three fourth of the holdings in the District showed incidence above the mean level of 20.45 per cent.

The damage grade indices of crown ranged from 0.4 to 1.0 in the District. The lowest index (0.4) was observed in the first holding of Mayyanad and the index in the second holding in the village was 0.6. Twenty five per cent of the holdings showed the damage grade indices above the mean level of 0.65.

The percentage of tuber infestation in the District ranged from 6.66 to 13.75. The minimum infestation (6.66 per cent) was observed in the first holding in Mayyanad but the maximum incidence of 13.75 per cent was in the second holding of the same village. Similarly in the second holding of Eravipuram village the percentage of tuber infestation was 9.66 while in the first holding in the same village the incidence was at a higher level of 11.11 per cent. Fifty per cent of the holdings recorded tuber infestation above the mean level of 10.30 per cent.

The damage grade indices in the District ranged from 0.4 to 0.6 only. The lowest index (0.4) was observed in the first holding in Mayyanad village. In the second holding of the above village and also in both the holdings of the other village (Eravipuram) the indices were at the same level of 0.6. Three fourth of the holdings surveyed in the District had DGI of above the mean level of 0.55.

The mean weevil population in the District was ranging from 34 to 78 only. Twenty five per cent of the holdings in the District had the population above the mean level of 48.5.

In Trivandrum District one of the holdings in Kottukal village had no incidence of C. formicarius while the crown damage in the second holding in the above village was as high as 18.75 per cent. The remaining holdings (three fourth) surveyed in the District had the incidence ranging from 14.29 to 17.97 per cent and these were above the mean level of infestation (12.75 per cent).

The crown DGI ranged from 1.1 to 2.0. One holding in Kottukal village of the District was free from the pest, but in the other holding of the same village the DGI was as high as 1.1. Three fourth the number of holdings in the District showed the damage grade indices above the mean level of 1.08.

The tuber infestation in the District ranged from 8.76 to 18.00 per cent. In the second holding in Venganoor village, the incidence was 8.76 per cent whereas the first holding of the village had a high infestation of 18.00 per cent. In the first holding of Kottukal village the percentage of tuber infestation was 10.42 whereas the second holding of the village was free from the pest. Fifty per cent of the number of holdings surveyed in the District showed tuber infestation above the mean level of 9.30 per cent.

The tuber DGI in the District ranged from 0.6 to 1.1. The second holding of Venganoor village had the tuber DGI of 0.6.

The first holding of Kottukal village had the maximum index of 1.1. There was no pest incidence in the second holding of Kottukal village. About 50 per cent of the holdings in the District had the tuber DGI above the mean level of 0.68.

The mean weevil population in the District ranged from 40 to 96 and fifty per cent of the holdings surveyed had the population above the mean level of 47.5.

4.1.2. Influence of soil type and cultural practices on the incidence of *C. formicarius*

Sweet potato growing tracts of Kasaragod, Malappuram and Trivandrum Districts had alluvial, red loam and black loam types of soil whereas Quilon District had alluvial type of soil only. In Kasaragod and Malappuram Districts the crop was cultivated on beds, on ridges and furrows or on mounds, while in Quilon the cultivation was exclusively on beds and in Trivandrum District the crop was raised on beds or on mounds. In some areas the harvesting was done early (prior to 110 days after planting) while in some the harvest was delayed significantly (up to 130 days). The cropping pattern also showed significant variations in the areas covered in the survey. Hence associations of these varying factors with the incidence of *C. formicarius* was estimated with appropriate statistical methods and the results are presented in Table 3.

The crown infestation, based on percentage of incidence as well as damage grade indices, was not seen significantly influenced by the different types of soil, methods of planting and the crop

Table 3. Association of soil type and cultural practices on the incidence of *C. formicarius* on sweet potato grown in low lands of Kerala

Soil type and cultural practices	% of holdings	Mean weevil infestation (per holding) in				Mean weevil population per 10 plants
		Crown		Tuber		
		% based on number	DGI	% based on weight	DGI	
Soil type						
Alluvial	50.00	19.12	0.89	9.61	0.60	41.38
Black loam	25.00	22.31	1.35	14.70	1.08	64.50
Red loam	25.00	19.18	1.03	11.95	0.83	56.12
x^2 (P=0.05)		0.56^{NS}	3.08^{NS}	6.57*	19.84**	5.49^{NS}
Method of planting						
Beds	43.75	19.05	0.92	12.12	0.75	55.90
Ridges	25.00	21.25	1.40	12.94	1.02	48.83
Mounds	31.25	20.10	0.92	9.38	0.63	45.20
x^2 (P=0.05)		0.56^{NS}	5.55^{NS}	4.83^{NS}	4.79^{NS}	0.74^{NS}
Time of harvest						
Early	37.50	17.39	0.74	9.00	0.63	36.89
Late	62.50	21.45	1.22	13.28	0.87	59.13
x^2 (P=0.05)		0.82^{NS}	7.62**	6.57*	3.78^{NS}	7.41**
Crop rotation						
Rice-Rice-Sweet potato	35.42	20.33	0.95	10.24	0.73	49.47
Rice-Sweet potato-Fallow	45.83	20.27	0.98	11.01	0.76	50.23
Rice-Sweet potato-Sweet potato	8.33	21.11	1.40	19.00	1.00	77.50
Tobacco-Sweet potato	10.42	16.15	1.34	11.63	0.88	36.40
F (P=0.05)		0.88^{NS}	1.66^{NS}	5.66**	0.80^{NS}	1.103^{NS}

* Significant at 5 per cent NS Nonsignificant

** Significant at 1 per cent DGI Damage grade index rotation practices. But delayed harvest practised in some areas resulted in significant increase in the intensity of damage to the crown as shown by the higher mean DGI (1.22) when compared to early harvest (0.74). However the percentage of crown infestation did not vary significantly in relation to the time of harvest.

The percentage of tuber infestation (based on weight) by C. formicarius was seen significantly influenced by the different types of soil. The incidence was least in alluvial soil (9.61 per cent) and was in an ascending scale in red loam (11.95 per cent) and black loam (14.70 per cent) types of soil. The same trend was seen with reference to the tuber DGI (0.60, 0.83 and 1.08 for alluvial, red loam and black loam types of soil respectively). The extent and intensity of tuber damage was not significantly influenced by the planting methods. Delayed harvest increased the percentage of tuber infestation significantly while the intensity of tuber damage was not significantly associated with this practice. The mean weevil population on the crop was also seen positively influenced by the delayed harvest. A crop sequence of rice - sweet potato - sweet potato significantly increased the mean per cent of tuber infestation (19.00). The damage grade indices of tubers and mean weevil population did not show any significant association with the crop sequence.

4.1.3. Natural enemies of C. formicarius

Rhaconotus sp. and Bracon sp. were seen parasitising the grubs of C. formicarius in the aerial parts of the plants. The only known predator recorded in the survey was Drapetis sp. The mean population of the parasitoids and predator are shown in Table 2.

The mean number of parasitoids in Kasaragod, Malappuram, Quilon and Trivandrum Districts were 6.1, 5.4, 5.8 and 6.3 respectively and the ranges of population were 4 - 12, 2 - 18, 2 - 10 and 5 - 12 respectively. The mean population of the predator in the above four Districts were 2.7, 4.3, 3.0 and 2.3 respectively and the ranges were 2 - 8, 2 - 10, 2 - 10 and 4 - 5 respectively.

4.2. Occurrence of *C. formicarius* on rainfed sweet potato crop grown in uplands

4.2.1. Extent and intensity of damage by *C. formicarius*

Data relating to the survey are presented in Table 4, Fig. 3. As seen in the figure the crop is grown in Kasaragod and Malappuram Districts in the northern, Palghat and Trichur Districts in the central and Trivandrum District in the southern regions of Kerala. The pest was seen distributed in all the Districts and the extent and intensity of damage also were high in most of the holdings covered in the survey.

Among the Districts, Palghat had the maximum area under the crop and it was followed by Malappuram, Kasaragod, Trichur and Trivandrum. The incidence of *C. formicarius*, based on different criteria presented in Table 4a viz., the percentage of crown infestation, damage grade indices of crown, percentage of tuber infested, damage grade indices of tubers and mean weevil population showed variations in the different Districts.

Table 4 Incidence of *C formicarius* and its natural enemies on rainfed sweet potato crop grown in the upland of different sweet potato growing tracts of Kerala

Location		Mean infestation in				Mean population of (per 10 plants)			Soil type	Method of planting	Harvesting time	Crop rotation
		Crown		Tuber		Weevils	Parasites*	Predators**				
		%	DGI	%	DGI							
Kasar god Dist												
Village	holding											
Per'ye	1	18.00	1 0	14.00	0.8	36	8	1	Le	Ri	Ea	SP-F-C-F
Periye	2	15 00	1 0	10.00	0 4	27	12	6	Le	Ri	Ea	SP-F-C-F
Pullur	1	͵15 00	0 8	15 39	0.9	64	8	8	Re	Be	La	SP-F
Pullur	2	15.33	1 0	11 50	0 6	36	8	4	Re	Ri	Ea	SP-F
Madikai	1	27 00	1 6	33 33	2.7	228	4	0	Re	Be	La	SP-F
Madikai	2	20 00	1 6	14 29	0 8	40	0	0	Re	Be	La	SP-F
Chithari	1	26 67	1.6	27.28	1 8	142	13	9	Le	Be	La	SP-F-C-F
Chithari	2	28 40	1 2	28.81	1.9	166	18	0	Le	Ri	La	SP-F-C-F
Uduma	1	29 27	1.2	22 58	1 6	178	24	2	Le	Ri	La	SP-F-C-F
Uduma	2	24.00	1 6	25 93	3 0	298	0	0	Le	Ri	La	SP-F-C-F
Pan yal	1	20 00	2 0	23 08	2.0	210	0	0	Le	Ri	La	SP-F C-F
Paniyal	2	25 30	1 1	25 00	2.0	222	0	0	Le	Ri	La	SP-F-C-F
Kasaragod municipality	1	33 33	2 0	30 77	2 6	290	27	0	Le	Ri	La	SP-F-C-F
Kasaragod municipality	2	42 86	1 5	22.22	2.0	219	0	0	Le	Ri	La	SP-F-C-F
Mathur	1	38 46	1 4	33 33	1 7	224	0	0	Le	Ri	La	SP-F-C-F
Mathur	2	37 50	1.8	31 71	2 3	278	10	0	Le	Ri	La	SP-F C-F
Mean		26.00	1 4	23 07	1 7	166 1	8.3	1 9	-	-	-	-
Malappuram Dist												
Village	holding											
Iriyallur	1	27 30	1 5	16 67	1 1	116	0	0	Al	Ri	La	[illegible]
Ariyallur	2	25 00	1.2	20 00	1 8	150	24	0	Al	Ri	La	S[illegible]
Parappanangadi	1	30 00	1 6	30 77	2 6	280	18	0	Al	Ri	La	S[illegible]-C-F
Parappanangadi	2	25 93	1.5	17.78	1.8	184	0	0	Al	Ri	Ea	S[illegible]-C-F
Paroor	1	29 03	2 6	22.23	2 6	340	24	16	Al	Ri	La	SP-F
Paroor	2	30 33	2 4	26 77	2 7	386	0	0	Re	Ri	La	SP-F
Kottackal	1	42 30	2 8	27 27	2 7	300	0	0	Re	Ri	La	SP-F
Kottackal	2	19 38	1 4	15.00	1.4	136	31	2	Al	Ri	Ea	SP-F
Elankur	1	28 52	1 2	21 74	1 6	172	27	8	Le	Ri	La	SP-F-C-F
Elankur	2	29 14	1 6	21 88	1 6	186	30	10	Le	Ri	La	SP-F-C-F
Payyanad	1	33.75	1 4	25 25	1 4	178	0	10	Re	Ri	La	SP-F-C-F
Payyanad	2	33 55	1 6	21 67	2 2	270	24	5	Le	Ri	La	SP-F-C-F
Kootilangadi	1	17 19	1 4	14.30	1 0	72	16	6	Al	Ri	Ea	SP-F
Kootilangadi	2	18 27	1 4	16 83	1 1	74	18	8	Al	Be	Ea	SP-F
Perinthalmanna	1	20 74	1 2	17.78	1 2	132	22	0	Al	Ri	Ea	SP-F-C-F
Perinthalmanna	2	24 62	1.4	12 22	1 6	166	19	0	Al	Ri	Ea	SP-F-C-F
Puzhakkattiri	1	24.55	1.2	17.29	1 4	106	23	9	Al	Ri	La	SP-F-C-F
Puzhakkattiri	2	26 92	1 8	22.41	1.6	184	17	0	Le	Ri	La	SP-F-C-F
Moorkanad	1	25 88	1.8	24.19	1.8	287	0	18	Le	Be	La	SP-F-C-F
Moorkanad	2	28 12	1 8	20.46	2.0	276	12	20	Le	Ri	La	SP-F-C-F
Porur	1	28 13	1.4	22.30	1 4	72	19	0	Le	Ri	La	SP-F-C-F
Porur	2	32 00	1 8	23.46	1 4	70	16	4	Le	Ri	Ea	SP-F-C-F
Vaniyambalam	1	29.73	1.2	28 00	1.6	160	27	6	Le	Be	La	SP-F-C-F
Vaniyambalam	2	27 50	2 6	26 39	2 4	290	36	16	Le	Be	La	SP-F-C-F
Mean		27 41	1 7	21 35	1.8	191.1	16.8	5 8	-	-	-	-
Palghat Dist												
Village	holding											
Erimayur	1	21 50	1.8	16 50	1 9	192	21	12	Al	Ri	Ea	SP-F-C-F
Erimayur	2	48.90	2.0	39 07	1.9	168	18	12	Re	Ri	La	SP-F-C-F
Alathur	1	38.24	1.8	37 88	2 5	292	38	18	Re	Be	La	SP-F-C-F
Alathur	2	46.14	2.0	44 00	2.4	288	12	0	Re	Be	La	SP-F-C-F
Peringottukurrussi	1	26.02	2.0	16 13	2.1	202	29	12	Al	Ri	Ea	SP-F-C-F
Peringottukurrussi	2	26 10	2.0	21.57	2.1	265	36	12	Al	Be	La	SP-F-C-F
Mathur	1	20.46	1.6	16.20	1 4	196	48	18	Al	Ri	Ea	SP-F-C-F
Mathur	2	46 00	2.5	42.93	2 2	246	54	16	Re	Ri	La	SP-F-C-F
Kuzhalmannam	1	36 50	1 5	39 16	[illegible]	226	57	19	Le	Ri	La	SP-F-C-F
Kuzhalmannam	2	47 60	1 9	45 50	2.5	294	30	8	Le	Ri	La	SP-F-C-F
Kuthanur	1	38.71	1 6	34.25	2.5	300	31	0	Re	Be	La	SP-F-C-F
Kuthanur	2	43.33	2.4	44 90	2.6	324	18	24	Re	Be	La	SP-F-C-F
Pattambi	1	48 91	1.4	46 15	1.4	92	17	0	Re	Be	La	SP-F-C-F
Pattambi	2	48 00	1.6	46.15	1.5	114	41	0	Re	Ri	La	SP-F-C-F
Muthuthala	1	50 00	1 4	46 67	2 7	306	36	16	Re	Ri	La	SP-F-C-F
Muthuthala	2	45 83	1.2	48.28	3 0	352	40	0	Re	Be	La	SP-F-C-F
Koodallur	1	19 00	1 8	15 40	1.8	154	18	0	Al	Ri	Ea	SP-F
Koodallur	2	22 31	1.6	21 21	1 8	186	16	0	Al	Ri	La	SP-F
Anakkara	1	37 93	1 6	34 32	2 4	252	32	8	Al	Ri	La	SP-F-C-F
Anakkara	2	24 07	1.6	24 14	1 8	196	16	8	Al	Ri	Ea	SP-F-C-F
Trittala	1	18 00	1.0	18 00	1 2	49	10	10	Al	Be	Ea	SP-F-C-F
Trittala	2	38 90	1 6	32 57	1 4	83	10	8	Le	Ri	La	SP-F-C-F
Pattithara	1	39 39	1 1	35 00	2.4	296	27	8	Le	Ri	La	SP-F-C-F
Pattithara	2	16 20	1 8	16.04	1 6	196	16	0	Al	Be	Ea	SP-F-C-F
Chalisseri	1	19 35	1 0	17.65	1 2	57	0	0	Al	Be	Ea	SP-F-C-F
Chalisseri	2	19 00	1 2	16 67	1 2	66	0	0	Al	Ri	Ea	SP-F-C-F
Nagalasseri	1	18.50	1 2	17.00	1 4	170	0	0	Al	Ri	Ea	SP-F-C-F
Nagalasseri	2	27 04	1 6	21 00	1 4	96	14	12	Al	Be	Ea	SP-F-C-F
Mundur	1	33 33	1.0	20 00	0.8	68	12	12	Al	Ri	Ea	SP-F-C-F
Mundur	2	27 27	1 2	18 18	0.9	64	0	18	Al	Ri	Ea	SP-F-C-F
Kongad	1	25 00	1 2	22.73	1 2	78	4	12	Al	Ri	La	SP-F-C-F
Kongad	2	27 93	1 2	25 00	1 6	184	40	0	Al	Ri	La	[illegible] F-C-F
Mean		32.67	1.6	29 38	1 8	189 1	23.2	8.2	-	-	-	-
Trichur Dist												
Village	holding											
Pilakadu	1	28 72	1 6	26.23	1.9	156	18	15	Re	Ri	La	SP-F-C-F
Pilakadu	2	27 33	1 0	30 28	2.9	308	38	10	Re	Be	La	SP-F-C-F
Desamangalam	1	33 33	1 0	30.77	1 5	160	18	18	Re	Ri	La	SP-F-C-F
Desamangalam	2	20 70	1 8	27 50	1.6	141	14	8	Al	Ri	Ea	SP-F-C-F
Mean		27.52	1.4	28 70	2 0	191 3	22 0	12 8	-	-	-	-
Trivandrum Dist												
Village	holding											
Panangod	1	18 00	1 8	16.25	1.2	123	4	4	Re	Be	Ea	SP-F
Panangod	2	22.14	2 2	22 80	1 6	144	16	0	Re	Be	Ea	SP-F
Thiruvallom	1	23 50	1 3	21.11	1.4	135	27	0	Al	Ri	Ea	SP-F
Thiruvallom	2	25.00	1 2	20 00	1 2	113	18	9	Al	Ri	Ea	SP-F
Mean		22 16	1 6	20.04	1.4	123 8	16.3	3 3	-	-	-	-

Al - Alluvial
Re = Red loam
Le Laterite

Be On beds
Ri On ridges and furrows
Ea Early harvest
La = Late harvest

SP-F Sweet potato-Fallow
SP-F C-F Sweet potato-Fallow Crop-Fallow
*Parasites: *Rhaconotus* sp and *Bracon* sp

DGI Damage grade index
**Predator: *Drapetis* sp

Table 4a. Distribution of holdings covered in the survey of *C. formicarius* with reference to the extent of damage/incidence (Upland)

Criteria/ class interval	Kasaragod No.of holdings (16)	Kasaragod Mean score	Malappuram No.of holdings (24)	Malappuram Mean score	Palghat No.of holdings (32)	Palghat Mean score	Trichur No.of holdings (4)	Trichur Mean score	Trivandrum No.of holdings (4)	Trivandrum Mean score
Crown infestation										
15 - 21	6		4		8		1		1	
22 - 28	5		11		8		2		3	
29 - 35	2		8		1		1		-	
36 - 42	3		1		6		-		-	
43 - 50	-		-		9		-		-	
		26.00		27.43		32.67		27.52		22.16
Crown DGI										
0.8 - 1.1	5		-		3		2		-	
1.2 - 1.5	4		13		10		-		2	
1.6 - 1.9	5		7		13		2		1	
2.0 - 2.3	2		-		4		-		1	
2.4 - 2.8	-		4		2		-		-	
		1.40		1.65		1.57		1.35		1.63
Tuber infestation %										
10 - 17	5		8		8		-		1	
18 - 25	5		11		9		-		3	
26 - 33	6		5		1		4		-	
34 - 41	-		-		6		-		-	
42 - 49	-		-		8		-		-	
		23.07		21.35		29.38*		28.70*		20.04
Tuber DGI										
0.4 - 0.8	4		-		1		-		-	
0.9 - 1.4	1		9		10		-		3	
1.5 - 1.9	4		8		8		3		1	
2.0 - 2.5	4		3		10		-		-	
2.6 - 3.0	3		4		3		1		-	
		1.69*		1.75*		1.83*		1.98*		1.35
Weevil population per 10 plants										
27 - 98	5		4		9		-		-	
99 - 170	2		7		4		3		4	
171 - 242	5		5		8		-		-	
243 - 314	4		6		9		1		-	
315 - 326	-		2		2		-		-	
		166.12*		191.12*		189.06*		191.25*		128.75

Figures in parentheses are the numbers selected for the survey in each District

* Significantly higher based on 't' test / Cochran and Cox's test

The mean crown infestation in Kasaragod (26.00 per cent), Malappuram (27.41 per cent), Palghat (32.67 per cent), Trichur (27.52 per cent) and Trivandrum (22.16 per cent) Districts did not show significant variations. Similarly the intensity of crown damage as shown by the damage grade indices also did not show any significant variation among the Districts. The mean percentage of tuber infestation in Palghat (29.38) and Trichur (28.70) Districts were on par and significantly higher than the infestation in other Districts. The intensity of tuber damage, as assessed by the damage grade indices, in Kasaragod, Malappuram, Palghat and in Trichur Districts (1.69, 1.75, 1.83 and 1.98 respectively) were on par and were significantly higher than that of Trivandrum District (1.35). Similarly mean weevil populations of Kasaragod, Malappuram, Palghat and Trichur Districts (166.12, 191.12, 189.06 and 191.25 weevils per ten plants respectively) were on par but were significantly higher than that of Trivandrum District (128.75).

Among the different holdings within each District, there was considerable variations in the extent and intensity of damage caused by C. formicarius. With reference to the mean percentage of crown infestation, the incidence in Kasaragod District ranged from 15.00 to 42.86. The lowest level of 15.00 per cent was observed in the second holding in Periye and in the first holding in Pullur villages, while in the other holdings of Periye and Pullur the percentages of infestation were 18.00 and 15.33 respectively. Fifty per cent of the holdings had the crown infestation above the mean level (26.00 per cent).

Fig. 3. Incidence of *C. formicarius* in the uplands of different sweet potato growing tracts of Kerala

1. Periye
2. Pullur
3. Madikai
4. Chitnari
5. Uduma
6. Paniyal
7. Kasaragod
8. Mathur
9. Ariyallur
10. Parappanangadi
11. Paroor
12. Kottackal
13. Elankur
14. Payyanad
15. Kootilangadi
16. Perinthalmanna
17. Puzhakkattiri
18. Moorkanad
19. Vaniyambalam
20. Porur
21. Erimayur
22. Alathur
23. Peringothukurussi
24. Mathur
25. Kuzhalmannam
26. Kuthanur
27. Pattambi
28. Muthuthala
29. Koodallur
30. Anakkara
31. Trittala
32. Pattithara
33. Chaliserri
34. Nagalaserri
35. Mundur
36. Kongad
37. Pilakadu
38. Desamangalam
39. Panangod
40. Thiruvallom

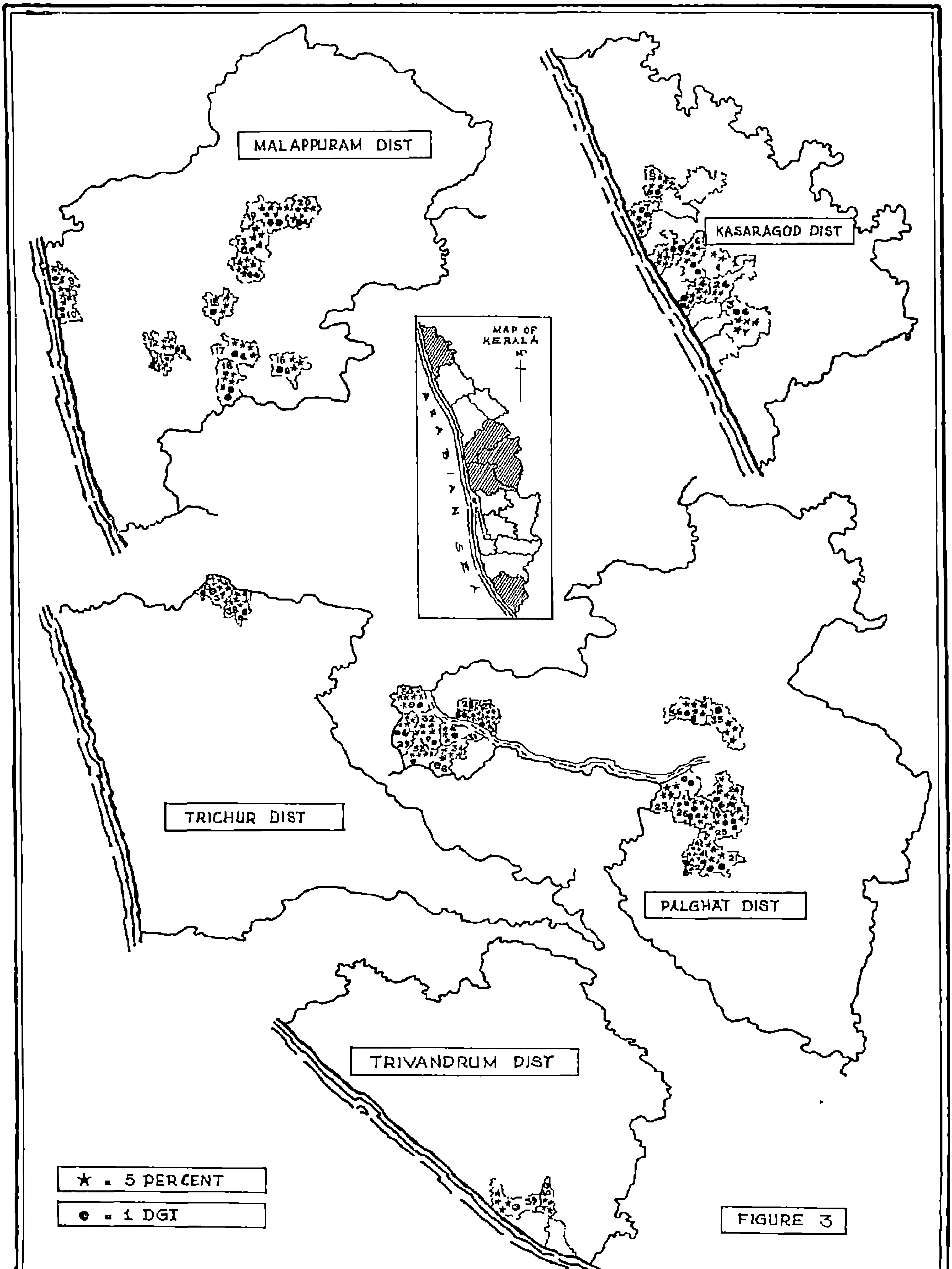

MALAPPURAM DIST
KASARAGOD DIST
MAP OF KERALA
ARABIAN SEA
TRICHUR DIST
PALGHAT DIST
TRIVANDRUM DIST
★ = 5 PERCENT
● = 1 DGI

FIGURE 3

The damage grade indices of the crown ranged from 0.8 to 2.0 in the District. The minimum index of 0.8 was observed in one of the holdings in the Pullur village, while in the other holding of the village it was 1.0. The damage grade indices of 55 per cent of the holdings in the District were above the mean level of 1.40.

The mean percentage of tuber infestation in the District ranged from 10.00 to 33.33. The lowest level of infestation (10.00 per cent) was noted in the second holding in Periye village while the first holding in the same village had 14.00 per cent tuber infestation. In Chithari village both the holdings recorded the tuber infestation of 26.67 and 28.40 per cent. Fifty six per cent of the holdings in the District had tuber infestation above the mean level of 23.07 per cent.

The intensity of weevil damage as shown by the tuber damage grade indices ranged from 0.4 to 3.0. The lowest index was observed in one of the holdings of Periye village while in the other holding of the same village it was 0.8. Both the holdings of Paniyal village had the damage index of 2.0. Sixty three per cent of the holdings in the District had tuber DGI above the mean level of 1.69.

The mean weevil population in the District ranged from 27 to 298 per ten plants. The minimum level of population (27) was observed in one of the holdings of Periye village while in the other holding of the village it was 36. Fifty six per cent of the holdings surveyed in the District had the weevil population above mean level of 166.12 per ten plants.

In Malappuram District the lowest incidence on crown was 17.19 per cent and the highest was 33.75. The lowest percentage of crown infestation was observed in the first holding of Kootilangadi village while the second holding of this village had an incidence of 18.27 per cent only. Fifty four per cent of the holdings had the incidence above the mean level of infestation of 27.41 per cent.

The damage grade indices of crown ranged from 1.2 to 2.8. The lowest index (1.2) was recorded in the second holding of Ariyallur village and in the first holdings of Elankur, Perinthalmanna, Puzhakattiri and Vaniyambalam villages. The other holdings in these villages had the indices of 1.5, 1.6, 1.4, 1.8 and 2.6 respectively. Paroor was the only village in which the crown damage grade indices in both holdings exceeded 2.0. One third the number of holdings in the above District showed tuber damage grade indices above the mean level of 2.65.

The per cent of tuber infestation in the District ranged from 12.22 to 30.77. The lowest level of infestation (12.22 per cent) was recorded in the second holding of Perinthalmanna while in the first holding of that village there was 17.78 per cent tuber infestation. In Elankur, Porur and Vaniyambalam villages both holdings had more or less similar levels of tuber infestation and were above 20 per cent. Fifty eight per cent of the holdings surveyed in the District had tuber damage above the mean level of 21.35 per cent.

The tuber damage indices in the District ranged from 1.0 to 2.7. The lowest index (1.0) was observed in one of the holdings of Kootilangadi village, while in the other holding of the village the tuber DGI was 1.1 only. Paroor village had the maximum DGI (2.6 and 2.7 in the two holdings). Forty two per cent of the number of holdings in the District had tuber damage indices above the mean level of 1.75.

The weevil population in the District ranged from 70 to 386 per ten plants. The lowest level of population was observed in the second holding of the Porur village while the other holding of the village had 72 numbers only. Both the holdings of the Kootilangadi village also had a low population (72 to 74). One third the number of holdings in the District had a weevil population of above the mean level of 191.12 per ten plants.

In Palghat District the percentage of crown infestation ranged from 16.20 to 50.00. One holding in Pattithara had the lowest level of 16.20 per cent crown infestation while in the other holding of the above village the incidence was as high as 39.39 per cent. The highest incidence of 50.00 per cent was observed in Muthuthala. Fifty per cent of the holdings in the District had the incidence above the mean level of 32.67 per cent.

The damage grade indices of crown in Palghat District ranged from 1.0 to 2.5. The lowest index (1.0) was observed in the first holding of Trittala, Chaliceeri and Mundur villages. The damage grade indices in the other holding of these villages were in the range of 1.2 to 1.6 only. Fifty nine per cent of the holdings in the District had crown damage grade indices above the mean level of 1.97.

The percentage of tuber infestation in the District ranged from 15.40 to 48.28. The lowest level (15.40 per cent) was observed in the first holding of Koodallur village while in the other holding of the same village it was 21.21 per cent. In Pattambi and Muthuthala villages both holdings had more or less same level of tuber infestation and were in the range of 46.15 to 48.28 per cent. Forty seven per cent of the holdings in the District had the percentage of tuber infestation above the mean level of 29.38.

The tuber damage grade indices in the District ranged from 0.8 to 3.0. The lowest level of DGI (0.8) was observed in the first holding of Mundur village. The next lower level of DGI (0.9) was observed in the second holding of the same village (Mundur). The damage grade indices of both the holdings in Chalisseri (1.2), Koodallur (1.8), Erimayur (1.9) and Peringottukurrussi (2.1) villages were the same. The damage grade indices of tuber in 56 per cent of the holdings surveyed in the District were above the mean level of 1.85.

The mean weevil population in the District ranged from 49 to 352 per ten plants. The minimum level of population (49) was noted in one of the holdings in Trittala while the population in the other holding of the village was 83. Fifty three per cent of the holdings had the weevil population above the mean level of 189.06 per ten plants.

The percentage of crown infestation in Trichur District ranged from 20.70 to 33.33. The minimum incidence (20.70 per cent) in the District was observed in the second holding of Dasamangalam village, while in the other holding of that village the incidence was the maximum (33.33) in the District. Fifty per cent of the holdings in the District showed incidence above the mean level of 27.52 per cent.

The damage grade indices of crown in the District ranged from 1.0 to 1.8. The lowest level of index (1.0) was observed in the first and second holdings of Pilakadu and Dasamangalam villages respectively. The damage grade indices in the other holdings in the above villages were 1.6 and 1.8 respectively. One half the number of holdings surveyed in the District had the DGI above the mean level of 1.35.

The per cent of tuber infestation in the District ranged from 26.23 to 30.77. The minimum level (26.23 per cent) was observed in the first holding of Pilakadu village while the other holding in the same village had a higher infestation level of 30.28 per cent. One half of the holdings in the District had the tuber infestations above the mean level of 28.70 per cent.

The tuber damage indices in the District ranged from 1.5 to 2.9. The lowest DGI was observed in the first holding in Dasamangalam village while the other holding of the village had the next lower index of 1.6. One fourth the number of holdings in the District had the tuber DGI above the mean level of 1.98.

The mean weevil population in the District ranged from 141 to 308 numbers per ten plants. The lowest level of weevil population (141) was observed in the second holding of Dasamangalam village while in the first holding of the village it was only 160. One fourth the number of holdings surveyed in the District had the weevil population above the mean level of 191.23 per ten plants.

In Trivandrum District the crown infestation ranged from 18.00 to 25.00 per cent. The lowest incidence of 18.00 per cent was observed in one of the holdings of Panangod village while the incidence in the other holding of the same village was as high as 22.14 per cent. Fifty per cent of the holdings in the District had incidence above mean level of 22.16 per cent.

The damage grade indices in the District ranged from 1.2 to 2.2. The lowest index (1.2) was observed in the second holding of Thiruvallom village, while in the other holding of the same village it was 1.3. One half the number of holdings surveyed in the District had the DGI above the mean level of 1.63.

The percentage of tuber infestation ranged from 16.25 to 22.80. The lowest level as well as the highest level of tuber infestation were observed in the two holdings of the same village (Panangod). The tuber infestation in both the holdings of Thiruvallom village was more or less similar (20.00 and 21.11 per cent respectively). One half the number of holdings surveyed in the District had the incidence above the mean level of 20.04 per cent.

The tuber damage grade indices in the District ranged from 1.2 to 1.6. The lowest level of DGI was noted in one of the holdings of Panangod as well as Thiruvallom villages, while the damage grade indices in the other holdings of these villages were 1.6 and 1.4 respectively. One half the number of holdings had tuber damage grade indices above the mean level of 1.35.

The weevil population was ranging from 113 to 144 per ten plants. The lowest level was noted in one of the holdings of Thiruvallom village, while it was as high as 135 in the other holding of the same village. One half the number of holdings surveyed in the District had the weevil population above the mean level of 128.70 per ten plants.

4.2.2. Influence of soil types and cultural practices on the incidence of *C. formicarius*

The holdings in the surveyed areas in Malappuram and Palghat Districts had alluvial, red loam and laterite types of soil and in Kasaragod District the soils were of red loam and laterite types. Trichur and Trivandrum Districts had red loam and alluvial types of soil. The crop was being cultivated in all the Districts on ridges and furrows or on beds. In one third the number of holdings the harvest was done early (prior to 110 days after planting) while in the remaining holdings the harvest was significantly delayed (up to 130 days after planting). The cropping pattern was varying in the areas covered in the survey as shown in Table 4. The association of these varying factors with incidence of the *C. formicarius* was tested through x^2 - test and the results are presented in Table 5.

Table 5. Association of soil types and cultural practices on the incidence of C. *formicarius* in uplands of Kerala

Soil type and cultural practices	% of holding	Mean weevil infestation per holding: Crown, % based on number	Crown, DGI	Tuber, % based on weight	Tuber, DGI	Weevil population per 10 plants
Soil type						
Alluvial	40.00	23.58	1.47	19.60	1.55	150.50
Red loam	27.50	34.88	1.72	32.24	1.98	209.23
Laterite	32.50	30.41	1.55	26.13	1.85	198.31
x^2 (P=0.05)		19.20**	4.22 NS	23.27**	4.42 NS	4.55 NS
Method of planting						
Beds	27.50	28.63	1.61	27.08	1.80	179.59
Ridges	72.50	29.11	1.55	24.48	1.75	183.21
x^2 (P=0.05)		0.30 NS	2.99 NS	0.11 NS	0.13 NS	0.41 NS
Time of harvest						
Early	35.00	21.49	1.42	17.55	1.32	117.75
Late	65.00	33.01	1.64	29.32	2.00	216.92
x^2 (P=0.05)		26.24**	5.64**	26.71**	16.46**	15.33**
Crop rotation						
SP-F	22.50	23.11	1.64	17.79	1.58	155.40
SP-F-C-F	77.50	30.68	1.53	34.91	1.78	190.00
x^2 (P=0.05)		4.77**	0.10 NS	5.79**	0.9 NS	3.09 NS
Upland vs Lowland						
Lowland	37.50	19.93	1.04	11.47	0.78	50.79
Upland	62.50	28.98	1.57	25.20	1.76	182.21
x^2 (P=0.05)		37.50**	41.02**	89.01**	107.35**	99.66**

* Significant at 5%
** Significant at 1%
NS Nonsignificant

DGI Damage grade index
SP-F Sweet potato-Fallow (one year)
SP-F-C@-F Sweet potato-Fallow-Crop@-Fallow (two year)

@ Rice/Tapioca/Horsegram

The percentage of crown infestation was not seen significantly influenced by the method of planting. But soil type, time of harvest and crop rotation practices had significant influence. The percentage was lowest in alluvial soil (23.58 per cent) and highest in red loam soils (34.88 per cent) and the laterite soil came in between (30.41). In late harvested crop crown infestation was 33.01 per cent while in the early harvested crop it was 21.49 per cent only. The crop rotation, sweet potato - fallow, showed lesser crown infestation (23.11 per cent) while in the sweet potato - fallow - crop - fallow, it was significantly higher (30.68).

The damage grade indices of crown did not vary significantly in relation to soil type, method of planting and crop rotation practised. In the early harvest the crown DGI was significantly less (1.42) than in the late harvest (1.64).

The percentage of tuber infestation was not seen significantly influenced by method of planting whereas it was significantly influenced by the soil type, time of harvest and crop rotation practised. The percentage of tuber infestation was least in alluvial soil (19.60) and it was followed by laterite (26.13) and red loam (32.24). The percentage of tuber infestation was significantly low in early harvest (17.55) than in the late harvest (29.32). The crop rotation sweet potato - fallow showed a higher percentage of tuber infestation (34.91) than in sweet potato - fallow - crop - fallow sequence (17.79 per cent).

The damage grade indices of tuber was not found significantly influenced by soil type, method of planting and crop rotation practices. Late harvest caused a significantly higher tuber DGI (2.00) than the early harvest (1.32).

Similarly the mean weevil population on the crop was not significantly influenced by soil type, method of planting and crop rotation practices. However it was found influenced by time of harvest significantly. Crop harvested late had significantly highest weevil population (216.92 per ten plants) than the crop harvested early (117.75 per ten plants).

4.2.3. Natural enemies of *C. formicarius*

The parasitoids - *Rhaconotus* sp. and *Bracon* sp. and the predator - *Drapetis* sp. were recorded on the grubs of *C.formicarius* in the vines. The mean number of the parasitoids and the predator per ten plants are presented in Table 4. The mean numbers of parasitoids in Kasaragod, Malappuram, Palghat, Trichur and Trivandrum Districts were 8.3, 16.8, 23.2, 22.0 and 16.3 respectively and the ranges of the parasitoid population were 4 - 27, 12 - 26, 4 - 57, 14 - 38 and 4 - 27 respectively. The mean populations of the predator in the above Districts were 1.9, 5.8, 8.2, 12.8 and 3.3 respectively and the ranges of the predator populations were 1 - 9, 2 - 20, 8 - 24, 8 - 18 and 4 - 9 respectively.

4.2.4. Influence of upland and lowland cultivation on the incidence of C. formicarius

The variations in the incidence of C. formicarius in the two situations were tested through x^2 test (Table 5). The percentages of crown infestation, damage grade indices of crown, percentage of tuber infestation, damage grade indices of tuber and the weevil population per ten plants were significantly low in lowland (19.93, 1.04, 11.47, 0.78 and 50.79 respectively) than in upland (28.98, 1.57, 25.20, 1.76 and 182.21 respectively).

4.2.5. Yield loss caused by C. formicarius in different Districts of Kerala

The districtwise yield, yield of marketable tubers and the loss caused by C. formicarius in terms of percentage of infested tubers on weight basis and on value basis, estimated from the data collected in the survey are shown in Table 5a.

At a modest price of Rs. 1000/- per tonne, the State suffered a loss of Rs. 96 lakhs per annum. Palghat District with production of 17,575 tonnes of tuber and with the highest per cent tuber damage suffered the highest loss Rs. 53.77 lakhs. Though the percentage of tuber damage in Trichur District was high (28.7) the loss caused by the pest was only Rs. 4.18 lakhs as the production in the District was 1458 tonnes only. Kasaragod and Malappuram Districts with the production of 10486 and 11564 tonnes of tuber, suffered a loss around Rs. 19 lakhs. Trivandrum with an area almost similar to that of Trichur showed a loss of Rs. 2 lakhs

Table 5a. Yield loss caused by *C. formicarius* to sweet potato grown in different Districts of Kerala

Districts and area in ha		Mean yield of tuber ha^{-1}	Tuber yield in tonnes	Mean per cent damage on tuber (wt.basis)	Damaged tuber in tonnes	Marketable tuber in tonnes	Loss in thousand rupees @	Percentage to total loss
Kasaragod	955	10.98*	10486	18.23*	1912	8574	1912	19.91
Malappuram	1180	9.80*	11564	16.09*	1861	9703	1861	19.38
Palghat	1850	9.50	17575	29.38	5164	12411	5164	53.77
Trichur	135	10.80	1458	28.70	418	1040	418	4.35
Quilon	40	10.10	404	10.30	42	362	42	0.44
Trivandrum	140	10.08*	14.11	14.67*	207	1204	207	2.16

@ The cost of sweet potato tubers was calculated @ Rs. 1000/- per tonne

* Upland and lowland combined

only and the percentage loss was very low (14.70 per cent). Quilon with the least area under the crop recorded the lowest level of pest incidence and the least loss of Rs. 0.4 lakh.

4.3. Alternate hosts and harbouring plants

Ipomoea purpuria and *I. biloba* were the alternate hosts recorded in all the Districts. In addition *I. hispida* was found in Trivandrum, Quilon and Kasaragod Districts while *I. paundurata* was prevalent in Malappuram and Palghat Districts.

Being the more common alternate host of *C. formicarius* the suitability of *I. purpuria* and *I. biloba* for the multiplication of the insect was studied in comparison with the normal host, sweet potato. The related data are presented in Table 6. The mean egg period ranged from 7 to 8 days only. The larval period was longer in *I. biloba* (52.8 days) and it was closely followed by the larval duration in *I. purpuria* (45.8 days). In sweet potato the larval duration was 18 days only. The pupal period also was longer in the alternate hosts (10.8 to 10.9 days) than in sweet potato (7.0 days). The total life cycle in the alternate host (64.8 to 71.4 days) was double than that observed in sweet potato (32.4 days). The longevities of adults reared on *I. biloba* were 88.0 and 93.0 days for male and female respectively and for those obtained from *I. purpuria* the longevities were 96.3 and 99.6 for male and female respectively. The longevities of male and female *C. formicarius* reared on sweet potato were 93.6 and 112.0 days respectively.

Table 6. Biology of *C. formicarius* on alternate hosts and harbouring plants observed in the tracts covered under the survey of *C. formicarius*

Name of plant	Mean duration of (days)			Mean total life cycle (days)	Longevity (days)	
	Egg	Larva	Pupa		Male	Female
Alternate host:						
Ipomoea biloba	7.8 (7-9)	52.8 (45-58)	10.8 (9-13)	71.4 (61-80)	88.0 (63-112)	93.0 (69-114)
I. purpuria	8.1 (6-9)	45.8 (41-54)	10.9 (10-14)	64.8 (57.77)	96.3 (69-119)	99.6 (72-123)
Harbouring plants:						
Amaranthus viridis	-	-	-	-	33.3 (21-49)	45.0 (33-54)
Vigna sinensis	-	-	-	-	31.5 (25-45)	41.8 (27-58)
Original host:						
Sweet potato *I. batatas*	7.2 (6-9)	18.0 (16-26)	7.2 (6-10)	32.4 (28.45)	93.6 (80-98)	112.0 (96-130)

Figures in the parentheses are range

The harbouring plants observed in the survey were *Amaranthus viridis* L. and *Vigna sinensis* L. The longevity of adult weevils on these plants was very low when compared to the longevity on original host and alternate hosts (Table 6). The longevities were more or less the same on *A. viridis* and *V. sinensis* (33.3 and 31.5 days for males and 45.0 and 41.8 days for females on former and latter respectively).

4.4. Relative resistance of different varieties/cultivars of sweet potato to *C. formicarius*

The results of the field experiments on this aspect are presented in Table 7 and Fig. 4.

The percentages of crown infested by the pest were not included in the Table since hundred per cent incidence was observed in all the entries. The intensity of crown infestation, as revealed by the damage grade indices did not manifest wide variations though there was statistically significant differences among the forty entries in the experiment. Damage grade indices in seven entries viz., Selopia, H 268, 76 OP 217, 76 OP 219, H 620, X 5 and Nedinjilchuvala ranged from 2.1 to 2.9 while the damage grade indices of the remaining 33 entries ranged from 3.0 to 3.8.

With reference to the tuber infestation the percentage was significantly low in Selopia (9.8) while those of the remaining varieties ranged from 21.5 to 60.1. The tuber DGI was also lowest in Selopia (1.3) while in the remaining 39 entries the indices

Table 7. Incidence of *C. formicarius* on different varieties of sweet potato, yield (mean of three seasons) and phenotypic characters of the varieties

Varieties (Hybrids/ local cultivars)	Crown damage grade index	Mean infestation on tubers: Per cent based on weight of infested tubers	Mean infestation on tubers: Damage grade index	Mean infestation on tubers: Number of adults emerged 30 days after harvest per kg of infested tubers	Yield $kg/4.5m^2$	Phenotypic characters of varieties: Vine pigmentation	Tuber skin pigmentation	Tuber flesh colour	Tuber shape	Leaf lobe	Latex	Depth of tuber formation	Resistance rating
Seloria	2.2(1.490)	9.8(18.23)	1.3(1.126)	48.2(1.683)	5.27	PG	Re	O	Sp	En	H	17.0	MR***
H 268	2.9(1.712)	21.5(27.61)	2.4(1.539)	110.9(2.045)	5.38	G	Re	Y	El	D	H	16.9	MR***
76 OP 217	2.1(1.436)	23.1(28.72)	2.1(1.447)	120.5(2.081)	5.77	G	Y	Y	Ro	En	H	16.7	MR**
76 OP 219	2.4(1.536)	29.0(32.61)	2.4(1.537)	145.9(2.164)	4.28	G	Re	Y	Sp	M	H	16.9	MR**
H 620	2.8(1.678)	23.6(29.06)	2.3(1.504)	114.0(2.057)	3.72	G	Re	Y	El	M	H	16.6	MR***
H 633	3.2(1.789)	33.4(35.25)	2.9(1.689)	201.4(2.304)	4.22	G	Re	W	Sp	M	L	11.7	LS
X 5	2.9(1.710)	31.8(34.30)	2.9(1.703)	219.8(2.342)	4.68	G	W	W	Ro	En	L	12.6	LS
C 43	3.1(1.746)	41.8(40.29)	3.0(1.717)	192.3(2.284)	3.37	G	W	W	Ro	Sl	L	12.4	HS
Kalmegh	3.1(1.769)	27.8(31.76)	2.7(1.630)	167.9(2.225)	3.03	PG	Re	Y	El	En	H	15.2	LR**
IB 440	3.3(1.803)	30.8(33.66)	3.0(1.736)	199.1(2.299)	3.28	G	Y	Y	El	M	H	11.3	LS
H 2743	3.0(1.741)	33.6(35.40)	2.8(1.661)	171.8(2.235)	4.12	G	Re	Y	Sp	Sl	L	12.0	LS
Maruthipooven	3.1(1.773)	23.4(28.94)	2.6(1.598)	132.1(2.121)	3.68	G	Re	O	El	M	H	14.4	MR***
Kanhangad	3.0(1.722)	28.6(32.30)	2.9(1.696)	215.8(2.334)	6.05	G	Re	Y	El	D	H	11.9	LS
Muttavella	3.0(1.739)	33.0(35.08)	2.5(1.582)	149.6(2.175)	5.18	G	W	Y	Ro	E	L	12.6	LR**
X 4	3.4(1.834)	46.0(42.73)	3.6(1.884)	313.3(2.496)	2.95	G	W	W	Ro	Sl	L	9.8	MS
X 24	3.3(1.802)	39.5(38.94)	3.2(1.787)	263.6(2.421)	3.13	PG	Re	W	Sp	Sl	L	10.4	HS
V 35	3.5(1.875)	39.0(38.67)	3.0(1.740)	250.0(2.398)	2.83	G	Y	Y	Ro	Sl	L	11.0	S
C 71	3.5(1.866)	46.6(43.02)	3.0(1.741)	192.3(2.284)	2.73	G	Re	W	Sp	M	L	11.4	MS
75 OP 1	3.8(1.936)	50.4(45.21)	3.5(1.865)	289.1(2.461)	2.23	G	Re	Y	Sp	D	L	9.0	MS
75 OP 5	3.2(1.788)	46.8(43.14)	2.9(1.686)	179.0(2.253)	2.48	G	Re	Y	El	M	L	12.6	MS
75 OP 57	3.5(1.868)	27.6(31.72)	3.1(1.759)	213.2(2.329)	2.90	G	Re	W	Sp	M	H	15.4	S
H 506	3.4(1.834)	60.1(50.80)	3.9(1.969)	424.5(2.638)	3.30	G	Y	W	Ro	E	L	9.4	MS
CO 1	3.7(1.925)	46.5(42.98)	3.7(1.911)	336.5(2.527)	2.70	PG	Re	W	Sp	M	L	8.7	MS
CO 2	3.3(1.830)	50.3(45.17)	3.3(1.823)	259.4(2.414)	2.38	G	Re	W	Sp	M	L	10.1	MS
CO 3	3.1(1.761)	38.0(38.04)	3.2(1.782)	239.9(2.380)	4.70	G	Re	Y	El	D	L	10.9	S
IB 700	3.6(1.900)	48.5(44.14)	3.5(1.865)	318.4(2.503)	3.10	G	Re	Y	Sp	Sl	L	9.4	MS
H 4126	3.4(1.856)	50.5(45.26)	3.3(1.806)	327.3(2.515)	3.82	G	W	W	Ro	Sl	L	9.6	S
H 4021	3.4(1.839)	32.2(34.59)	3.1(1.767)	247.2(2.393)	3.87	G	Re	Y	Sp	M	L	10.7	S
S 30	3.2(1.777)	47.3(43.47)	3.6(1.894)	382.8(2.583)	3.15	P	W	Y	Ro	E	L	9.4	MS
Chedivella	3.3(1.814)	33.0(35.08)	3.3(1.806)	306.2(2.486)	6.22	G	Re	Y	El	D	L	8.6	MS
Ethenvella	3.5(1.866)	51.6(45.90)	4.0(1.991)	429.5(2.633)	5.78	G	W	Y	El	Sl	L	12.5	MS
Anacomban	3.5(1.873)	54.5(47.56)	3.9(1.974)	388.2(2.589)	3.28	G	Y	Y	El	Sl	L	8.9	MS
Kadukkavella	3.7(1.922)	43.3(41.13)	3.7(1.926)	388.2(2.589)	2.60	G	Re	W	El	M	L	9.8	MS
Bhadrakalichuvala	3.4(1.852)	38.7(38.47)	3.4(1.834)	299.2(2.476)	3.83	G	Re	O	Sp	M	L	9.6	MS
Parinkamavinchuvala	3.2(1.775)	42.3(40.56)	3.4(1.846)	311.2(2.493)	3.58	P	W	Y	Sp	En	H	10.0	MS
Nedinjilchuvala	2.8(1.671)	28.3(32.15)	3.2(1.777)	280.5(2.448)	5.80	G	Re	Y	Sp	D	H	11.6	HS
Kaavivella	3.7(1.910)	43.9(41.47)	3.7(1.917)	369.0(2.567)	5.12	G	Y	W	Sp	M	L	9.4	MS
Poineervella	3.1(1.770)	38.2(38.20)	3.5(1.857)	298.5(2.475)	4.43	G	W	W	El	M	L	10.0	MS
Panineervella	3.3(1.816)	37.4(37.69)	3.5(1.863)	354.0(2.549)	3.80	G	W	W	Sp	M	L	9.0	MS
Kottaramchuvala	3.3(1.807)	38.5(38.36)	3.2(1.784)	264.2(2.422)	3.03	G	Re	W	Sp	En	L	10.9	HS
C.D. at 5%	(0.110)	(6.91)	(0.20)	(0.139)	1.36								

Figures in parentheses in the column are transformed values of $\sqrt{x}$, arc Sin $\sqrt{x}$ and log x for Damage grade index, per cent and number of adults respectively

PG = Pinkish green/purple green
G = Green
P = Purple

Re = Red
W = White
Y = Yellow

O = Orange
Ro = Round
Sp = Spindle

El = Elongate
En = Entire
Sl = Slight

M = Moderate
D = Deep
L = Low
H = High

MR = Moderately resistant
LR = Less resistant
LS = Less susceptible

S = Susceptible
HS = Highly susceptible
MS = Most susceptible

*** Consistent in three seasons
** Consistent in two seasons only

Table 7a Reaction of varieties to *C. formicarius* based on pooled data (mean of three seasons) and different criteria adopted for evaluation

Group based on $\bar{x}$ and SD	% tuber infestation	Tuber DGI	Number of adults emerged per kg of infected tuber
Moderately resistant (MR) Below $\bar{x}$ − 2SD	Selopia***, Maruthipooven***, H 268***, H 620***, 76 OP 217**, 76 OP 219**, Kalmegh, 75 OP 57, Nedinjilchuvala, Kanhangad	Selopia, Maruthipooven, H 268, H 620, 76 OP 217, 76 OP 219, Muttavella	Selopia, Maruthipooven, H 268, H 620, 76 OP 217, 76 OP 219, Kalmegh, Muttavella, H 2743, 75 OP 5
Less resistant (LR) Between $\bar{x}$ − 2SD and $\bar{x}$ − 1SD	IB 440, Muttavella**, H 633, X 5, H 4021	Kalmegh**, H 2743	IB 440, H 633, C 71, C 43
Less susceptible (LS) Between $\bar{x}$ − 1SD and $\bar{x}$	H 2743, Panineervella	75 OP 5, H 633, Kanhangad, X 5, C 43, IB 440, V 35, C 71	75 OP 57, Kanhangad, X 5
Susceptible (S) Between $\bar{x}$ and $\bar{x}$ + 1 SD	CO 3, V 35, Poineervella, Chedivella, Kottaranchuvala, Bhadrakalichuvala, X 24	CO 3, Chedivella, X 24, H 4126, H 4021, Nedinjilchuvala, 75 OP 57, Kottaranchuvala	CO 3, V 35, H 4021
Highly susceptible (HS) Between $\bar{x}$ + 1SD and $\bar{x}$ + 2SD	C 43, Parinkamavinchuvala, Kadukkavella, Kaavivella	CO 2, Bhadrakalichuvala, Parinkamavinchuvala, Poineer vella, IB 700, OP 1, X 4, Panineervella	CO 2, X 24, Kottaranchuvala, Nedinjilchuvala
Most susceptible (MS) Above $\bar{x}$ + 2SD	Anacomban, Ethenvella, CO 1, S 30, H 506, OP 1, CO 2, H 4126, IB 700, X 4, 75 OP 5, C 71	Anacomban, Ethenvella, CO 1, S 30, H 506, Kadukkavella, Kaavivella	Anacomban, Ethenvella, CO 1, S 30, H 506, OP 1, H 4126, IB 700, X 4, Poineervella, Bhadrakalichuvala, Chedivella, Parinkamavinchuvala, Panineervella, Kadukkavella, Kaavivella
	$\bar{x}$ = 37.75 SD = 2.45	$\bar{x}$ = 1.715 SD = 0.07	$\bar{x}$ = 2.362 SD = 0.047

Reaction of the different varieties, moderately resistant and less resistant, in the different seasons and under different criteria

Season	Group	% tuber infestation	Tuber DGI	Number of adults emerged per kg of infected tuber
First season	MR	Selopia, Maruthipooven, H 268, H 620, 76 OP 217, 76 OP 219, Kalmegh, 75 OP 57, Kanhangad, CO 3, X 5, Nedinjilchuvala	Selopia, Maruthipooven, H 268, H 620, 76 OP 217, 76 OP 219, Kalmegh, 75 OP 57, Muttavella	Selopia, Maruthipooven, H 268, H 620, 76 OP 217, 76 OP 219, Kalmegh, 75 OP 57, Muttavella, 75 OP 5, IB 440, C 71
	LR	Muttavella, IB 440, H 633, Panineervella, H 4021	X 24, C 71, CO 3	X 24, H 2743, CO 3, X 5
		$\bar{x}$ = 38.49 SD = 2.13	$\bar{x}$ = 1.795 SD = 0.043	$\bar{x}$ = 2.378 SD = 0.043
Second season	MR	Selopia, Maruthipooven, H 268, H 620, Nedinjilchuvala	Selopia, Maruthipooven, H 268, H 620, Kalmegh, IB 440, 75 OP 5, C 43, 75 OP 217, 76 OP 219	Selopia, Maruthipooven, H 268, H 620, 75 OP 5, C 43
	LR	76 OP 217, IB 440, H 2743	Muttavella, X 5, H 4021, Kanhangad	76 OP 217, IB 440, 76 OP 219
		$\bar{x}$ = 35.79 SD = 2.99	$\bar{x}$ = 1.798 SD = 0.044	$\bar{x}$ = 2.327 SD = 0.053
Third season	MR	Selopia, Maruthipooven, H 268, H 620, 76 OP 217, 76 OP 219, Muttavella, V 35, H 2743	Selopia, Maruthipooven, H 268, H 620, 76 OP 217, 76 OP 219, Muttavella, 75 OP 5, H 633, Kalmegh, H 2743, Kanhangad	Selopia, Maruthipooven, H 268, H 620, 76 OP 217, 76 OP 219, Muttavella, H 633, Kalmegh, H 2743
	LR	H 633, Kalmegh	X 5, Chedivella	—
		$\bar{x}$ = 35.96 SD = 2.13	$\bar{x}$ = 1.662 SD 0.032	$\bar{x}$ = 2.311 SD = 0.032

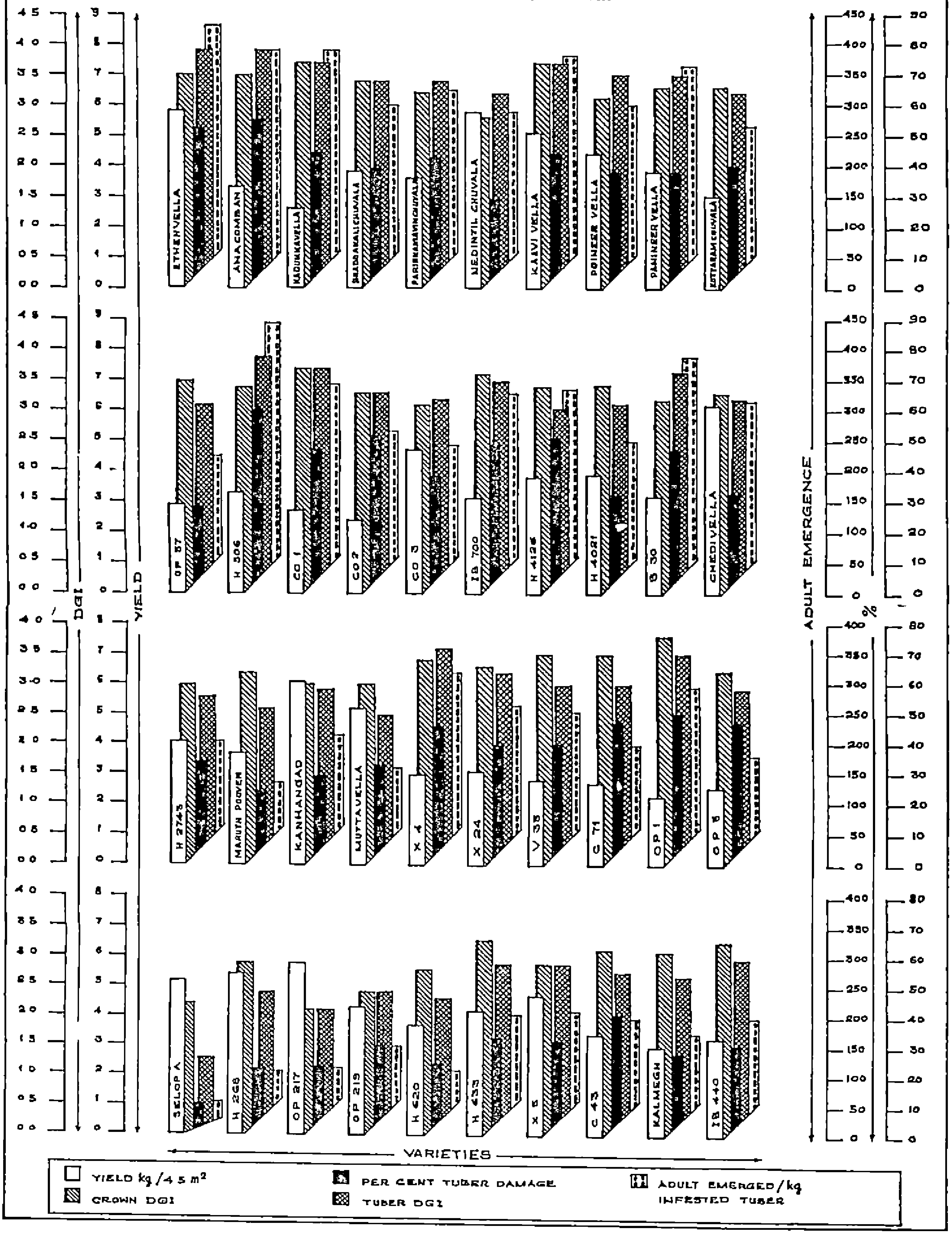
Underlined varieties are moderately resistant / less resistant under different criteria in the same season

*** Consistent in three seasons ** Consistent in two seasons only ranged from 2.1 to 4.0. The number of weevils obtained from one kg of the harvested tubers in each entry, stored for one month, also was very low in Selopia (48.2) while the range in the rest of the entries was from 110.9 to 434.5.

Though the percentage of tuber infestation, damage grade indices and numbers of weevils obtained from stored tubers were quite high in all the varieties/cultivars, there were wide variations in the data and hence the relative resistance of the forty entries to the pest was assessed. The grouping of the varieties based on relative resistance is shown in Table 7a.

In rating the entries the damage grade indices of the crown were not taken into consideration since the variation was comparatively less on this criterion. Based on the pooled analysis of the data obtained in all the three criteria adopted for evaluation, Selopia, Maruthipooven, H 268, H 620, 76 OP 217 and 76 OP 219 were classified as moderately resistant to C.formicarius. Kalmegh was also included in the group on the basis of percentage of tuber infestation and the number of adults emerged from stored tubers. But based on tuber DGI it came in the 'less resistant' group. Similarly Muttavella was rated as 'moderately resistant' cultivar based on the damage grade index of tuber and number of adults obtained from stored tubers. But it had to be rated as 'less resistant' on the basis of the percentage of the weight of infested tubers. Nedinjilchuvala rated as 'moderately resistant' on the basis of percentage of tuber infestation, was found to be

FIG 4 MEAN INCIDENCE OF *Cylas formicarius* ON DIFFERENT VARIETIES OF SWEET POTATO AND YIELD



in the 'susceptible' group based on tuber DGI and in the 'highly susceptible' group based on the number of adults emerging from stored tubers. The hybrid H 2743 found as 'moderately resistant' on the basis of the number of adults obtained from stored tubers was classified as 'less susceptible' on the basis of percentage of tuber infestation and as 'less resistant' based on tuber DGI. The variety 75 OP 5 was rated as 'moderately resistant' based on the number of adults obtained from stored tubers whereas its rating on percentage of infestation basis was 'most susceptible' and on tuber damage grade index it was classified in the 'less susceptible' group.

The number of varieties/cultivars included in 'moderately resistant', 'less resistant', 'less susceptible', 'susceptible', 'highly susceptible' and 'most susceptible' groups on the basis of the percentage of tuber infestation in pooled data were 10, 5, 2, 7, 4 and 12 respectively, based on the tuber damage grade indices 7, 2, 8, 8, 8 and 7 respectively and on the basis of the number of adults obtained from the stored tubers 10, 4, 3, 3, 4 and 16 respectively.

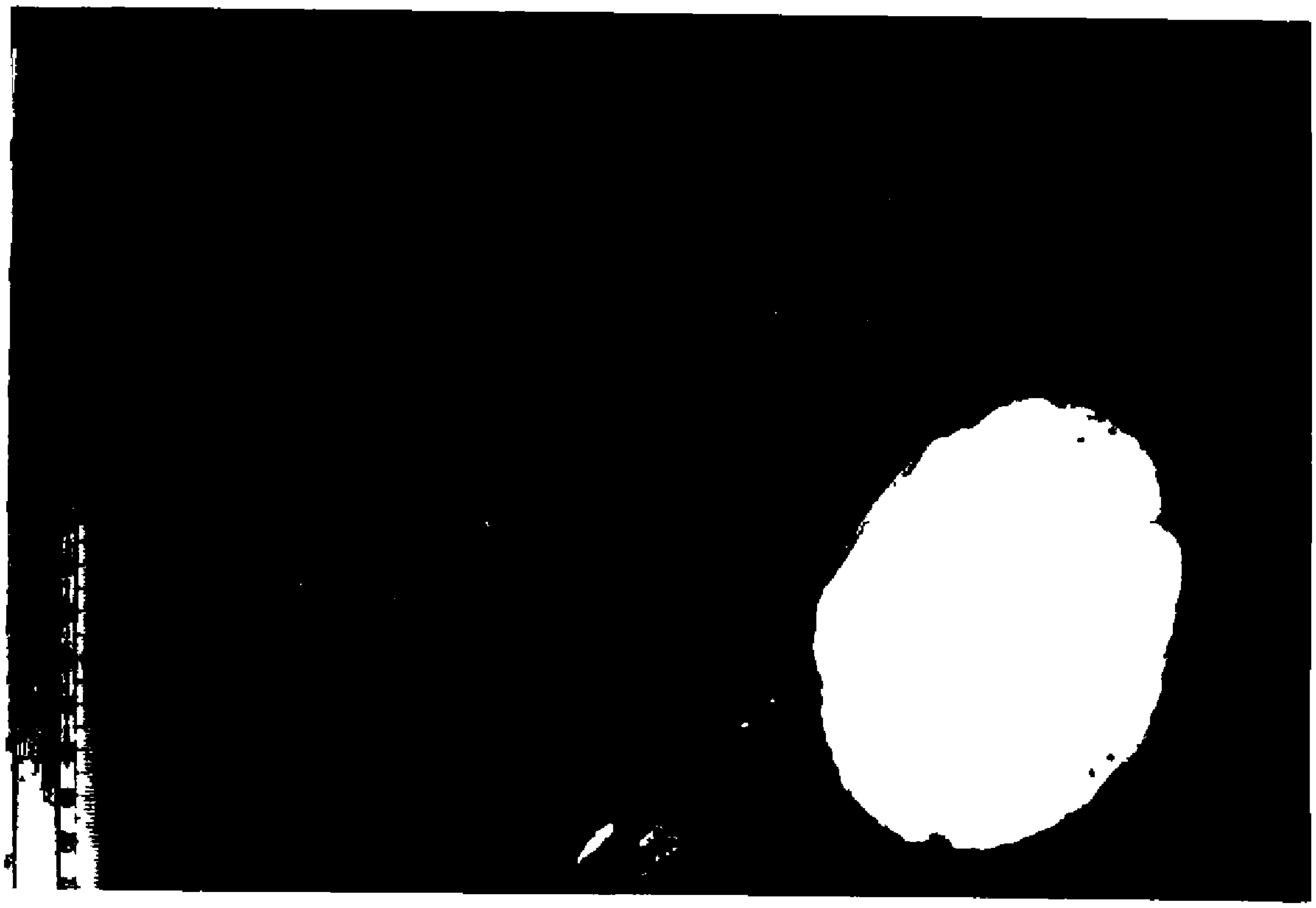
The data on the incidence of <u>C. formicarius</u> on the different entries of sweet potato in three different seasons are presented in the Appendix I. The varieties/cultivars were grouped in six categories based on the data obtained for each season separately. The 'moderately resistant' and 'less resistant' categories obtained in the three seasons are presented in Table 7a. Among six varieties

Plate IV

Moderately resistant cultivars

A - Selopia

B - Maruthipooven



grouped as 'moderately resistant' ones based on pooled data, under all the three criteria adopted, only four varieties viz., Selopia, Maruthipooven, H 268 and H 620 remained consistently so in all the three seasons. The entries 76 OP 217 and 76 OP 219 which were ranked as 'moderately resistant' in the pooled analysis, came in the same category in the first and third seasons. In the second season 76 OP 217 came in the 'less resistant' group based on percentage of tuber infestation and on the basis of adult emergence. On the basis of tuber DGI it came as 'moderately resistant'. The entry 76 OP 219 was in the 'less susceptible', 'moderately resistant' and 'less resistant' groups based on the percentage of tuber infestation, tuber DGI and adult emergence, respectively.

Muttavella which was ranked as 'less resistant' in the pooled analysis came in the same category during the first season and came as 'moderately resistant' during the third season. During the second season it fell out of both the categories. Kalmegh rated as 'less resistant' in the pooled analysis came in the same category during the third season and as 'moderately resistant' in the first season. This cultivar also fell out of both the categories during the second season. Hence these cultivars were rated as 'less resistant' based on consistent results in two out of three seasons.

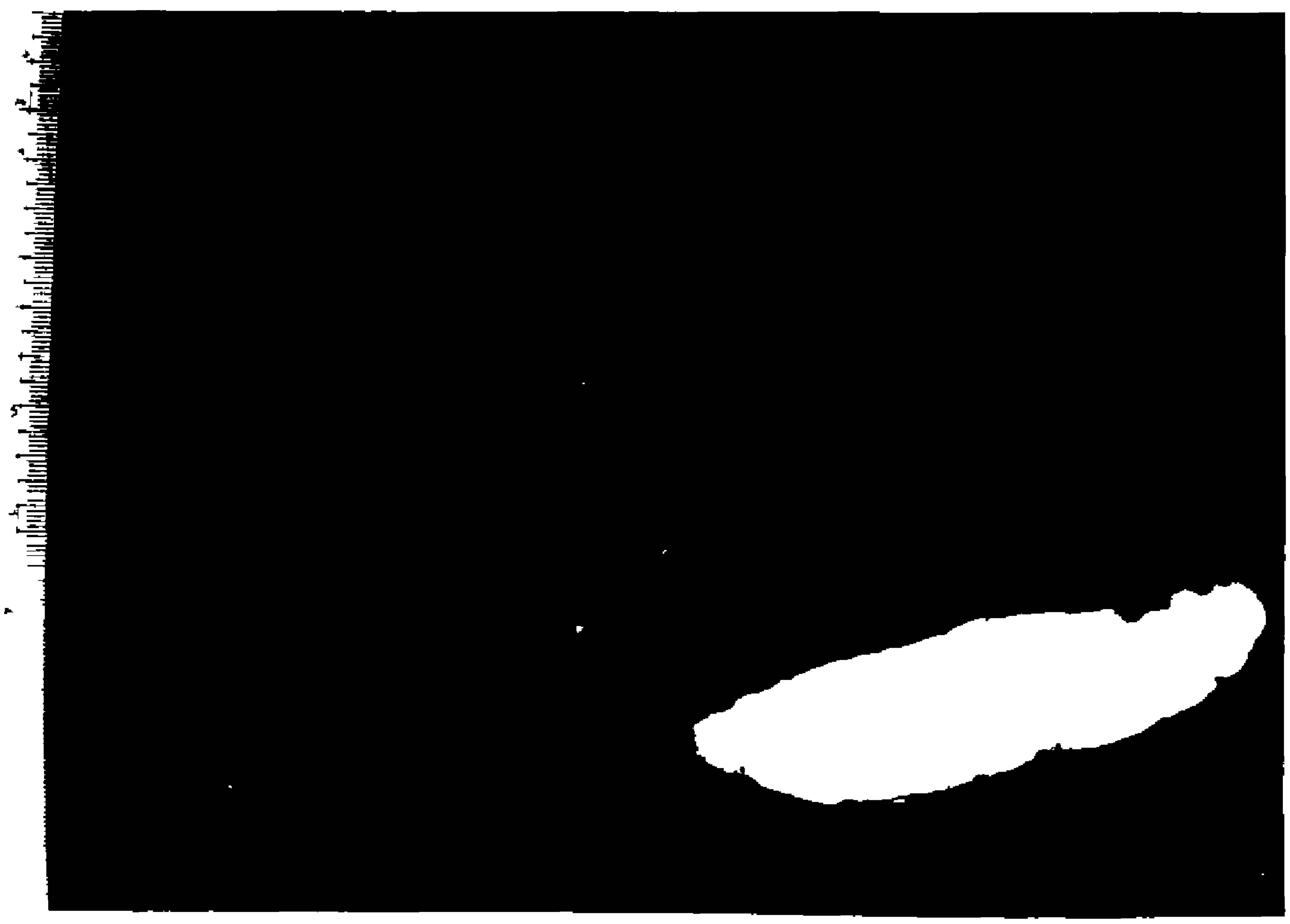
Based on the C.D. values of the pooled data (Table 7) Selopia was significantly superior to all other entries in the experiment and under all criteria followed for the assessment of relative

Plate V

Moderately resistant varieties

A - H 268

B - H 620



resistance. Based on percentage of tuber infestation the entries H 268, 76 OP 217, Maruthipooven, H 620, Kalmegh and 76 OP 219 came on par. Muttavella was inferior to H 268 but was on par with the other varieties in the above group. Based on the tuber damage grade indices the above seven entries came on par in the following descending order: 76 OP 217, H 620, H 268, 76 OP 219, Muttavella, Maruthipooven and Kalmegh. With reference to the number of adult weevils obtained from stored tubers H 268, H 620, 76 OP 217, Maruthipooven, 76 OP 219 and Muttavella came on par. Kalmegh was significantly inferior to H 268, H 620 and 76 OP 217. On mean yield basis the varieties could be ranked in the following descending order: 76 OP 217, H 268, Selopia, Muttavella, 76 OP 219, H 620, Maruthipooven and Kalmegh.

The salient morphological characters of the cultivars/ varieties included in 'moderately' and 'less' resistant categories under different criteria adopted for evaluation of resistance and showing consistency in consecutive seasons are shown in Plates IV to VI.

4.4.2. Mechanism of resistance

4.4.2.1. Physical factors

The phenotypic characters of different entries evaluated for resistance to *C. formicarius* showed significant variations and hence the influence of these characters on the resistance to *C. formicarius* was studied statistically. The results of the analysis are presented in Table 8.

Plate VI

Less resistant variety

76 OP 217

The purple, purple green and green pigmentation of the vines did not influence the levels of resistance significantly, under any of the criteria adopted for evaluation.

The tuber skin pigmentation also did not show any significant relation with the crown damage grade indices or with the percentage of infested tubers. But this factor was significantly associated with the variations in the tuber damage grade indices of the different entries. The maximum intensity of damage was seen in white skinned entries (3.29) and it was followed by yellow skinned (3.23) and red skinned (2.93) entries. The same trend was observed in the association between skin colour and number of adults emerged from stored tubers and it was 284.80, 263.40 and 206.34 respectively for white, yellow and red skinned entries.

The flesh colour of the tubers was not associated with the crown damage grade indices significantly. But this character was seen significantly associated with the incidence of C. formicarius on tubers. The percentage of infested tubers was highest in white fleshed entries (42.10) and was least in orange fleshed ones (22.88 per cent) and yellow fleshed entries (36.29) came between the two. The same ranking was observed with reference to the tuber damage grade indices and also with reference to the number of adults emerged from stored tubers. The tuber DGI was maximum in white fleshed entries (3.32) while in orange and yellow fleshed ones the DGI were 2.31 and 2.99 respectively. The number of adult emerging was maximum in white fleshed ones (279.90) while it was

Table 8. Association of different phenotypic characters of different varieties of sweet potato with the incidence of *C. formicarius*

Phenotypic characters	Number of entries	Crown DGI	Mean weevil infestation on tuber		
			% based on weight infested	DGI	Number of adults emerged 30 days after harvest per kg of infested
Vine pigmentation					
Purple	2	3.38(1.838)	44.80(42.01)	3.50(1.870)	345.10(2.538)
Purple green	4	3.05(1.747)	30.06(33.25)	2.55(1.597)	160.70(2.206)
Green	34	3.19(1.787)	38.04(38.08)	3.10(1.760)	237.00(2.375)
F (P=0.05)		(0.45)NS	(1.28)NS	(2.20)NS	(2.32)NS
Tuber skin pigmentation					
Red	24	3.18(1.783)	34.71(36.10)	2.93(1.712)	206.34(2.315)
Yellow	6	3.20(1.789)	41.57(40.15)	3.23(1.797)	263.40(2.429)
White	10	3.20(1.789)	41.92(40.35)	3.29(1.814)	284.80(2.455)
F (P=0.05)		(0.01)NS	(2.066)NS	(8.05)**	(5.24)*
Flesh colour					
Orange	3	2.91(1.705)	22.88(28.57)	2.31(1.519)	123.88(2.093)
Yellow	21	3.11(1.762)	36.29(37.04)	2.99(1.730)	221.09(2.345)
White	16	3.35(1.830)	42.10(40.46)	3.32(1.821)	279.90(2.447)
F (P=0.05)		(2.74)NS	(4.32)*	(5.63)*	(9.42)**
Tuber shape					
Round	9	3.08(1.756)	41.19(39.92)	3.06(1.749)	246.00(2.391)
Spindle	18	3.23(1.797)	37.14(37.55)	3.07(1.753)	234.80(2.371)
Elongate	13	3.20(1.789)	35.52(36.58)	3.06(1.748)	221.20(2.345)
F (P=0.05)		(0.28)NS	(1.41)NS	(2.64)NS	(0.3)NS
Leaf lobing					
Entire	9	2.90(1.704)	34.03(35.69)	2.77(1.665)	196.58(2.294)
Slight	9	3.36(1.833)	44.95(42.10)	3.33(1.825)	281.20(2.449)
Moderate	16	3.28(1.810)	36.75(37.32)	3.09(1.759)	230.14(2.362)
Deep	6	3.13(1.768)	33.88(35.60)	3.04(1.744)	228.52(2.359)
F (P=0.05)		(2.81)NS	(2.01)NS	(1.63)NS	(1.145)NS
Latex in tuber					
Low	28	3.34(1.828)	42.77(40.84)	3.29(1.815)	274.85(2.439)
High	12	2.84(1.686)	25.91(30.60)	2.56(1.600)	154.85(2.190)
F (P=0.05)		(20.97)**	(42.63)**	(22.11)**	(21.24)**
Depth of tuber formation					
r		-0.738**	-0.781**	-0.67**	-0.856**

Figures in parentheses in the column are transformed values of $\sqrt{x}$, arc Sin $\sqrt{x}$ and log x for Damage grade index (DGI), per cent infestation and adult emergence respectively

*Significant at 5% **Significant at 1% NS Nonsignificant

F-tests were calculated on the basis of unequal replications minimum in orange fleshed ones (123.88). The yellow fleshed ones came inbetween the two (221.09).

Round, spindle or elongate tubers obtained from different entries in the experiment were not significantly associated with the extent and intensity of the pest damage. Entire, slight lobing, moderate lobing or deep lobing nature of the leaves also was not significantly associated with the levels of the pest incidence.

Pest attack in varieties/cultivars having higher latex content was significantly lower under all the four criteria adopted for the assessment of results. The mean DGI of crown, percentage of tuber infestation, DGI of tuber and number of adults emerged in entries with higher latex content being 2.84, 25.91, 2.56, 154.85 respectively and with lower latex content being 3.34, 42.77, 3.29 and 274.85 respectively.

The depth of tubers in the soil showed a highly significant negative correlation with the extent and intensity of *C.formicarius* incidence under all the four criteria adopted for evaluation.

4.4.2.2. Biochemical factors

One entry from the moderately resistant group (Selopia), one from less resistant group (76 OP 217), one from less susceptible group (Kanhangad) and two from most susceptible group (Ethenvella, Anacomban) were included in the studies. The different chemical components of the tubers were estimated and the results are presented in Table 9.

Table 9. Influence of chemical constituents in different varieties/cultivars of sweet potato on the development of *C. formicarius*

Varieties	Moisture %	Dry matter %	Sugar %	Starch %	Total phenols mg/g	OD phenols mg/g	Carotenoids IU	No. of weevils obtained from 1 kg roots inoculated and kept for 30days
Selopia	72.9	27.1	1.85	24.2	48.2	25.1	3373 (3.528)	38.8 (1.589)
76 OP 217	67.4	32.6	2.15	28.8	44.0	22.1	908 (2.958)	88.7 (1.948)
Kanhangad	66.8	33.2	3.06	26.6	63.9	22.5	1227 (3.089)	135.0 (2.130)
Ethenvella	65.2	34.8	2.40	27.1	49.0	18.5	1172 (3.069)	252.2 (2.402)
Anacomban	66.3	33.7	2.41	26.1	63.2	20.5	1384 (3.141)	242.2 (2.384)
C.D. at 5 per cent	5.1	5.1	NS	NS	NS	2.2	(0.436)	(0.252)

Figures in parentheses are transformed values of log x

NS Nonsignificant

The moisture content of 76 OP 217, Kanhangad local, Ethenvella and Anacomban were on par (65.2 to 67.4 per cent) and was significantly lower than that of Selopia (72.9 per cent). Dry matter content also showed the same trend. With reference to sugar, starch and total phenols significant variations were lacking. OD phenol content of Selopia (25.1 mg/g) was significantly higher than those of the remaining entries. The minimum level of OD phenols was observed in Ethenvella (18.5) and it was on par with Anacomban (20.5), 76 OP 217 (22.1) and Kanhangad local (22.5). The carotene content was highest in Selopia (3373 IU) and it was on par with that of Anacomban (1384). The latter was on par with Ethenvella, Kanhangad local and 76 OP 217.

4.4.2.3. <u>Antibiosis</u>

The number of weevils obtained from one kg of inoculated roots stored for 30 days showed significant variations among the five varieties/cultivars evaluated. The least number (38.8) obtained was from Selopia and it was significantly lower than the number obtained from other entries. Selopia was followed by 76 OP 217 (88.7) and the latter was on par with Kanhangad local (135.0). Ethenvella and Anacomban were on par and the number of weevils obtained from these cultivars was significantly higher than those obtained from the other three entries.

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

4.5.1. Population of *C. formicarius*

The data relating to the two field experiments conducted on this aspect were pooled and statistically analysed. The results are presented in Table 10 and Fig. 5 and 6.

4.5.1.1. Incidence on/in the crown

The adult population on the crown region and on the foliage started building up from 28 DAP (0.63 per 10 plants), but it remained without significant increase up to 70 DAP. A sharp increase in the adults was observed during the 77th DAP (10.54 per 10 plants) and then it remained without significant change up to the harvest (105 DAP).

Eggs were first observed on the crown on the 42nd day (8.9 per 10 plants), and the mean numbers recorded in subsequent observations showed an increase and the number reached the peak (36.11 eggs per 10 plants) on 70th DAP. Then the number declined but eggs were present on the crown even up to the time of harvest.

The larvae were first observed in the crown at 49 DAP (7.12 per 10 plants) and the number showed gradual increase in the subsequent observations and it reached the peak (36.25 per 10 plants) at 77 DAP. Then it declined gradually and reached a very low level of 2.09 larvae per 10 plants at 105 DAP.

Table 10. Incidence of *C. formicarius* at different growth stages of sweet potato grown in field (mean of 2 seasons)

Period of observation DAP	Infestation on crown		Tuber damage		Number of adults emerged from 1 kg infested tubers	Population (10 plants)							
						crown				tuber			
	%	DGI	%	DGI		Egg	Larva	Pupa	Adult+	Egg	Larva	Pupa	Adult
7	0.0 (0.0)	0.0 (1.0)	0.0 (0.0)	0.0 (1.0)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)
14	0.0 (0.0)	0.0 (1.0)	0.0 (0.0)	0.0 (1.0)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0 301)	0 0 (0 301)	0.0 (0.301)
21	0.0 (0.0)	0.0 (1.0)	0.0 (0.0)	0.0 (1.0)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0 301)
28	3.81 (11.25)	0.3 (1.13)	0.0 (0.0)	0.0 (1.0)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.63 (0.420)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0 301)
35	14.34 (22.25)	0.3 (1.13)	0.0 (0.0)	0.0 (1.0)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	2.74 (0.676)	0.0 (0.301)	0.0 (0.301)	0.0 (0 301)	0 0 (0.301)
42	35.88 (36.80)	0.85 (1.360)	0.0 (0.0)	0.0 (1.0)	0.0 (0.301)	8.90 (1.037)	0.0 (0.301)	0.0 (0.301)	3.61 (0.749)	0.0 (0.301)	0.0 (0.301)	0 0 (0 301)	0 0 (0 301)
49	44.41 (41.79)	1.15 (1.465)	0.0 (0.0)	0.0 (1.0)	0.0 (0.301)	13.99 (1.201)	7.12 (0.960)	0.0 (0.301)	2.90 (0.690)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)	0 0 (0.301)
56	47.10 (43.34)	1.38 (1.541)	5.47 (13.53)	0.35 (1.162)	2.47 (0.650)	20.70 (1.356)	10.91 (1.111)	0.0 (0.301)	3.03 (0.702)	4.97 (0.843)	0.0 (0.301)	0.0 (0.301)	0.0 (0.301)
63	63.41 (52.78)	1.70 (1.641)	20.75 (27.10)	0.88 (1.368)	15.67 (1.247)	33.00 (1.543)	16.11 (1.258)	4.71 (0.827)	1.13 (0.496)	19.58 (1.330)	4.05 (0.782)	0.0 (0.301)	0.0 (0 301)
70	74.65 (59.77)	2.08 (1.751)	23.76 (29.18)	1.18 (1.475)	38.36 (1.606	36.11 (1.581)	26.42 (1.422)	15.02 (1.231)	2.09 (0.612)	31.04 (1.519)	12.06 (1.148)	0.0 (0.301)	0 0 (0.301)
77	83 52 (66.06)	2.65 (1.910)	32.26 (34.61)	1.81 (1.676)	86.10 (1.945)	24.50 (1.423)	36.25 (1.559)	19.18 (1.326)	10.59 (1.100)	45.42 (1.676)	23.64 (1.409)	0.74 (0.437)	0.0 (0.301)
84	67.87 (63.62)	3.08 (2.020)	35.00 (36.23)	2.34 (1.828)	114.14 (2.065)	13.85 (1.200)	16.07 (1.257)	1 .63 (1.194)	10.00 (1.079)	83.90 (1.934)	36.11 (1.581)	15.00 (1.230)	0.0 (0.301)
91	80.00 (63.44)	3.47 (2.115)	44.20 (41.67)	3.20 (2.050)	141.00 (2.155)	5.52 (0.876)	15.30 (1.238)	17.28 (1.285)	11.55 (1.132)	103.20 (2.022)	66.55 (1.836)	26.58 (1.456)	9.07 (1.0[illegible])
98	91.23 (72.78)	4.08 (2.253)	46.95 (43.25)	3.60 (2.145)	165.88 (2.225)	2.34 (0.657)	6.63 (0.936)	10.82 (1.108)	16.41 (1.265)	61.83 (1.805)	90.04 (1.964)	56.08 (1.764)	19.88 (1.340)
105	90.41 (71.96)	4.08 (2.253)	52.20 (46.25)	4.25 (2.291)	228.14 (2.362)	0.38 (0.376)	2.09 (0.612)	9 .83 (1.073)	6.97 (0.953)	40.85 (1.632)	89.00 (1.959)	82.72 (1.928)	47.32 (1.693)
C.D.at 5%	(19.30)	(0.647)	(11.82)	(0.204)	(0.281)	(0.545)	(0.665)	(0.178)	(0.501)	(0.606)	(0.574)	(0.[illegible]	(0.124)

Figures in parentheses in the column are arc Sin $\sqrt{x}$, $\sqrt{x+1}$ and log (x + 2) values for per cent, DGI and number of adult emergence and population respectively

DAP Days after planting   DGI Damage grade index   + on crown and foliage

The pupae were first observed at 63 DAP (4.71 per 10 plants) and the maximum number was noted at 77 DAP (19.18 pupae per 10 plants). Then it declined and the numbers recorded in subsequent observations remained on par till the harvest (105 DAP).

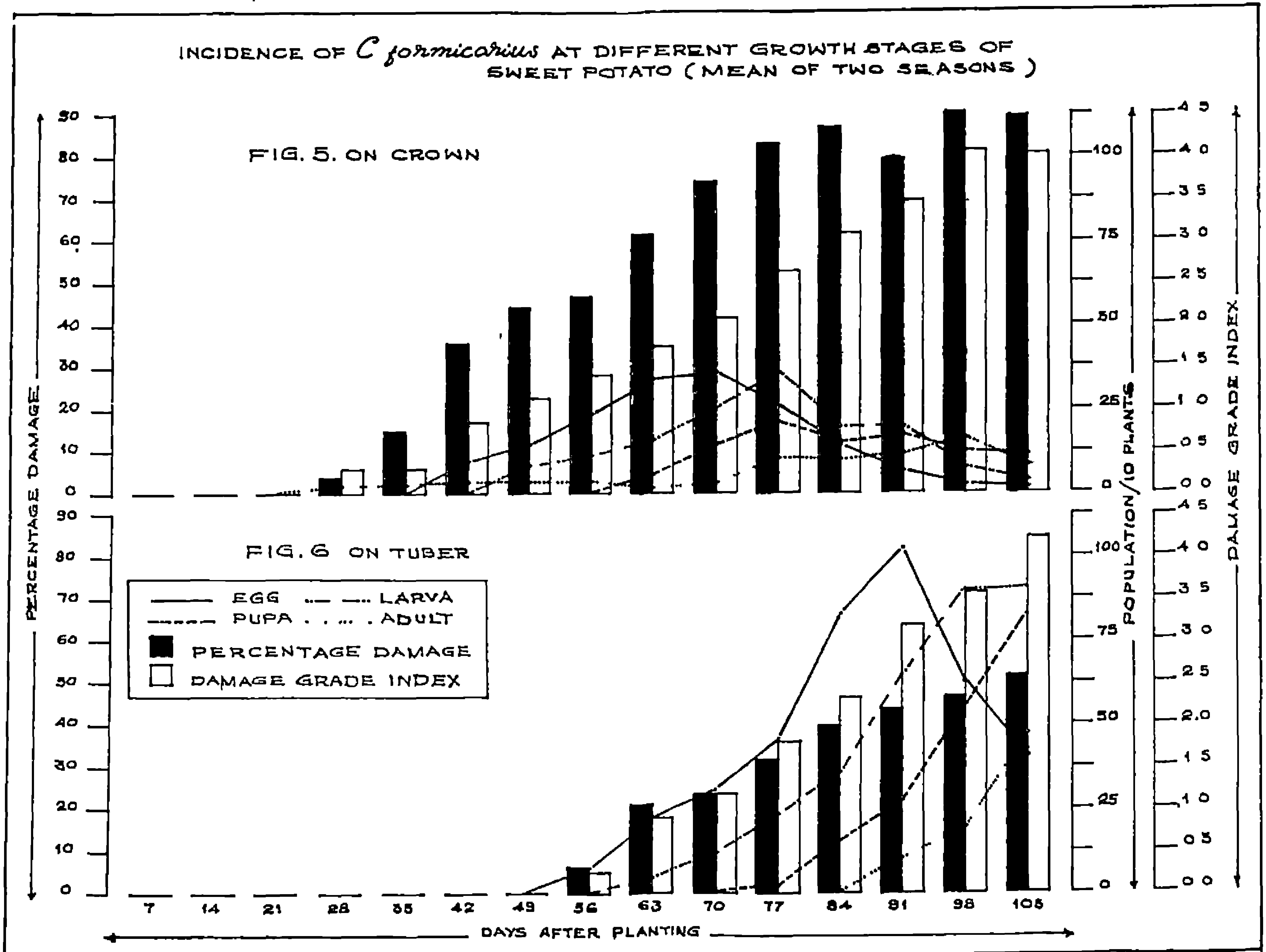
4.5.1.2. Incidence on/in tubers

The eggs were not observed on the absorbing or tuberous roots up to 49 DAP. The eggs were first observed on tubers on the 56th DAP and the mean number was 4.97 per 10 plants. In subsequent observations the number showed a steady increase and it reached the peak (103.20 eggs per 10 plants) at 91 DAP. Then the number declined. But even at the time of harvest significant number of eggs (40.85 per 10 plants) were observed on tubers.

The larvae inside the tubers were first observed at 63 DAP (4.05 per 10 plants) and it reached the peak of 90.04 per 10 plants at 98 DAP and the larval population found at the time of harvest (105 DAP) remained on par with the peak level.

The pupae were first noted at 77 DAP (0.74 per 10 plants) and in subsequent observations the number was steadily increasing and even at the harvest it had not reached the peak. The mean number of pupae found at harvest was 82.72 per 10 plants.

The life cycle of C. formicarius was seen completed inside the tubers at the late stage of the crop and the adults were first observed at 91 DAP only (9.07 numbers in the tubers from 10 plants). In the subsequent two observations there was significant increase in the number of adults found in the tubers. But as in the case of


INCIDENCE OF C formicarius AT DIFFERENT GROWTH STAGES OF SWEET POTATO (MEAN OF TWO SEASONS)
FIG. 5. ON CROWN
FIG. 6 ON TUBER
EGG
LARVA
PUPA
ADULT
PERCENTAGE DAMAGE
DAMAGE GRADE INDEX
PERCENTAGE DAMAGE
POPULATION/10 PLANTS
DAMAGE GRADE INDEX
DAYS AFTER PLANTING
7
14
21
28
35
42
49
56
63
70
77
84
91
98
105

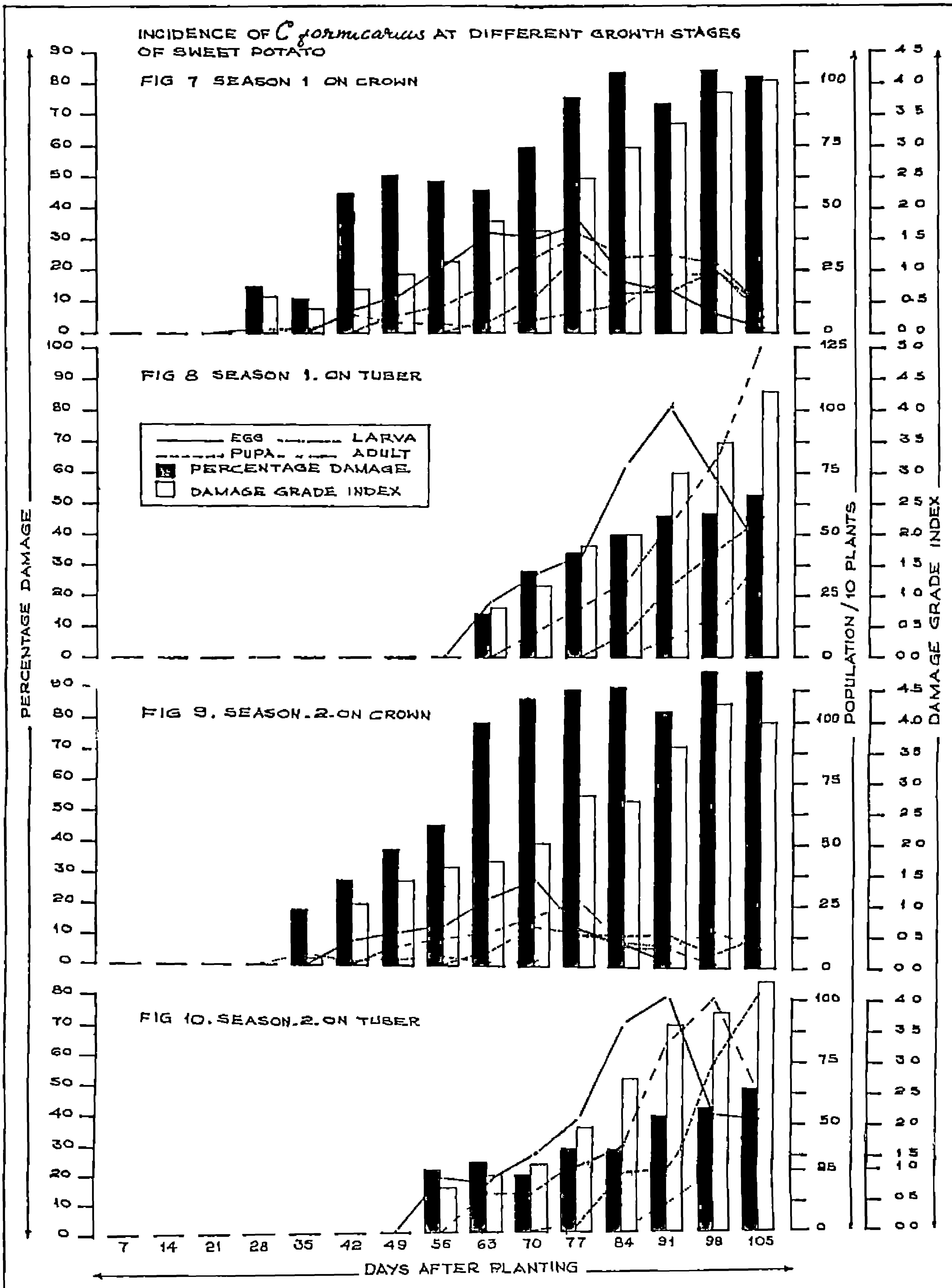
pupae here also the peak was not reached even at the time of harvest. The maximum number of adults was observed at 105 DAP (47.32).

4.5.2. Extent and intensity of damage caused by the pest

The damage noted at different growth stages of the crop was in broad agreement with the destructive life stages of the pest observed (Table 10 and Fig. 5 and 6). The crown infestation commenced at 28 DAP (3.81 per cent), when the adult population started settling on the crop. Concurrent with the larval emergence the percentage of infested crowns also showed an increase. The incidence reached the peak of 87.87 per cent at 84 DAP. The percentage of crown infestation observed from 63rd to 105th DAP were on par (74.65 to 90.41).

The intensity of crown damage which was first noted at 28 DAP (0.30) showed a steady increase in the subsequent observations and reached the peak (4.08) at 98 DAP. It remained at the same level in the last two observations at 98 and 105 DAP. The DGI of crown observed from 63rd DAP to 105th DAP were on par (1.70 to 4.08).

The tuber damage was first noted at 56 DAP, the mean percentage of the weight of infested tubers being 5.47 and it showed a steady increase in subsequent observations. The infestation reached the highest level of 52.20 per cent in the last observation made at 105 DAP only. The percentages of tuber damage observed between 77 DAP and 105 DAP were on par (32.26 to 52.20).


INCIDENCE OF C. formicarius AT DIFFERENT GROWTH STAGES OF SWEET POTATO
FIG 7 SEASON 1 ON CROWN
FIG 8 SEASON 1. ON TUBER
FIG 9. SEASON.2.ON CROWN
FIG 10. SEASON.2.ON TUBER
EGG
LARVA
PUPA
ADULT
PERCENTAGE DAMAGE
DAMAGE GRADE INDEX
PERCENTAGE DAMAGE
POPULATION / 10 PLANTS
DAMAGE GRADE INDEX
DAYS AFTER PLANTING

The tuber damage grade indices as well as the number of adults emerging from infested tubers kept in store showed an increasing trend till harvest, commencing from 56 DAP. The tuber DGI and the number of adults obtained from tubers collected and stored at 56 DAP were 0.35 and 2.47 respectively and at the time of harvest (105 DAP) they were 4.25 and 228.14 respectively.

The data pertaining to the two seasons during which the experiment was conducted are presented in the Appendix II and Fig. 7 to 10. The results showed that the sequence of occurrence of the life stages of the pest and the damage were remarkably similar in the two seasons. The pest population as well as the levels of damage in the crown and tubers during the first season were slightly higher than those of the second season.

4.6. Effect of reridging on the incidence of *C. formicarius*

The data relating to the extent and intensity of damage caused to the crown and tubers of sweet potato by *C. formicarius* in relation to the reridging done at ten day intervals from planting for two seasons and their pooled values as well as the results of statistical analysis of the data are presented in Table 11.

The percentage of crown infestation was omitted from the Table since all the crowns were seen infested. The damage grade indices of crown observed during two seasons as well as the pooled data did not vary significantly.

Table 11. Effect of reridging on the incidence of *C. formicarius* on sweet potato grown in field

Reridging done on (DAP)	Crown DGI			Percentage of infested tubers by weight			Tuber DGI			Number of adult weevil emerged from 1 kg of infested tuber stored for 30 days		
	S-1	S-2	Mean	S-1	S-2	Mean	S-1	S-2	Mean	S-1	S-2	Mean
T_1 30	3.50 (1.871)	3.10 (1.760)	3.30 (1.816)	51.00 (45.58)	30.70 (3[illegible].65)	40.67 (39.62)	3.75 (1.936)	3.90 (1.974)	3.83 (1.955)	288.4 (2.460)	286.5 (2.457)	287.8 (2.[illegible]59)
T_2 30, 40	3.55 (1.884)	3.60 (1.897)	3.58 (1.891)	40.00 (39.18)	32.90 (34.99)	36.45 (37.09)	3.65 (1.911)	4.15 (2.034)	3.90 (1 973)	186.6 (2.271)	271.5 (2.434)	225.4 (2.353)
T_3 30, 40, 50	3.70 (1.923)	3.20 (1.789)	3.45 (1.856)	47.25 (43.42)	35.50 (36.38)	41.14 (39.90)	3.45 (1.857)	3.95 (1.984)	3.70 (1.921)	154.5 (2.189)	297.2 (2.473)	214.3 (2.331)
T_4 30, 40, 50, 60	3.30 (1.810)	3.80 (1.949)	3.55 (1.880)	38.45 (38.30)	39.48 (38.93)	38.98 (38.62)	3.10 (1.761)	3.25 (1.803)	3.18 (1.781)	107.9 (2.033)	114.6 (2.059)	111.2 (2.046)
T_5 30, 40, 50, 60, 70	3.30 (1.816)	3.35 (1.830)	3.33 (1.823)	34.80 (36.10)	30.00 (33.18)	32.40 (34.64)	3.[illegible] (1.732)	2.95 (1.717)	2.98 (1.725)	97.5 (1.989)	134.0 (2.127)	114.3 (2.058)
T_6 30, 40, 50, 60, 70, 80	3.40 (1.843)	3.20 (1.788)	3.30 (1.816)	28.10 (31.99)	20.40 (26.81)	24.10 (29.40)	2.70 (1.642)	2.90 (1.703)	2.80 (1.673)	68.40 (1.835)	107.2 (2.030)	85.7 (1.933)
T_7 30, 40, 50, 60, 70, 80, 90	3.30 (1.816)	3.55 (1.880)	3.43 (1.848)	21.20 (27.38)	14.10 (22.01)	17.50 (24.70)	2.85 (1.688)	2.85 (1.688)	2.85 (1.688)	71.5 (1.854)	77.1 (1.887)	74.3 (1.871)
T_8 40, 50, 60, 70, 80, 90	3.50 (1.869)	3.10 (1.761)	3.30 (1.815)	28.65 (32.35)	12.30 (20.49)	19.77 (26.42)	2.75 (1.658)	2.85 (1.688)	2.80 (1 673)	75.9 (1.880)	127.0 (2.104)	98.2 (1.992)
T_9 50, 60, 70, 80, 90	3.70 (1.923)	3.50 (1.869)	3.60 (1.896)	29.45 (32.87)	19.10 (25.92)	24.10 (29.40)	2.60 (1.611)	2.90 (1.703)	2.75 (1.657)	73.8 (1.868)	106.7 (2.028)	88.7 (1.948)
T_{10} 60, 70, 80, 90	3.70 (1.923)	3.75 (1.934)	3.73 (1.929)	31.00 (33.81)	17.30 (24.55)	23.80 (29.18)	3.50 (1.871)	3.60 (1.896)	3.55 (1.883)	72.5 (1.860)	150.7 (2.178)	104.5 (2.019)
T_{11} 70, 80, 90	3.80 (1.949)	3.90 (1.974)	3.85 (1.962)	41.20 (39.91)	26.70 (31.04)	33.69 (35.48)	3.75 (1.936)	3.95 (1.987)	3.85 (1.962)	150.3 (2.177)	267.3 (2.427)	200.4 (2.302)
T_{12} 80, 9[illegible]	3.30 (1.816)	3.50 (1.870)	3.40 (1.843)	41.00 (39.81)	34.90 (36.21)	37.85 (37.97)	3.90 (1.975)	4.00 ([illegible] 000)	3.95 (1.988)	172.2 (2.236)	289.1 (2.461)	223.4 (2.349)
T_{13} 90	3.45 (1.857)	4.00 (1.999)	3.73 (1.928)	42.65 (40.77)	37.90 (38.00)	40.28 (39.39)	3.95 (1.987)	[illegible].85 (1.961)	3.90 (1.974)	214.3 (2.331)	286.5 (2.457)	247.7 (2.394)
T_{14} Control (without reridging)	3.60 (1.897)	4.10 (2.025)	3.85 (1.961)	49.05 (44.46)	53.40 (46.96)	51.23 (45.71)	3.90 (1.975)	4.35 (2.085)	4.13 (2.030)	260.0 (2.415)	340.5 (2.532)	297.9 (2.474)
C.D. at 5 per cent	NS	NS	NS	(7.49)	(7.69)	(7.20)	(0.083)	(0.204)	(0.134)	(0.196)	(0.197)	(0.318)

Figures in parentheses in the column are $\sqrt{x}$, arc Sin $\sqrt{x}$ and log x values for DGI, percentage and number of adult emergence respectively

S-1 First season S-2 Second season NS Nonsignificant DGI Damage grade index

The percentage of infested tubers in different treatments (in the pooled data) showed reduction compared to the control. The percentage of infested tubers in control (51.23) came on par with the treatments T_1, T_3, T_4 and T_{13} (39.62, 39.90, 38.62 and 39.39 per cent respectively). The maximum reduction in percentage of tuber infestation was in T_7 (17.50 per cent) and it was on par with T_6, T_8, T_9 and T_{10} (24.10, 19.77, 24.10 and 23.80 per cent respectively).

With reference to the mean DGI of tubers T_1, T_2, T_3, T_{11}, T_{12} and T_{13} (DGI 3.83 - 3.95) came on par with the control (4.13). The maximum reduction was observed in T_9 (DGI 2.75) and it came on par with T_4, T_5, T_6, T_7 and T_8 (DGI 2.80 - 3.18).

The number of adults emerged from stored tubers was maximum in the control (297.9) and this came on par with T_1, T_2, T_3, T_{11}, T_{12} and T_{13}. The lowest number was obtained from T_7 (74.3 adults). T_4, T_5, T_6, T_8, T_9 and T_{10} (111.2, 114.3, 85.7, 98.2, 88.7 and 104.5 adults respectively) were on par with T_7.

The percentage of tuber infestation during the first season in T_1, T_2, T_3, T_4, T_{11}, T_{12} and T_{13} came on par with that of the control. During the second season the infestation in the control was significantly higher than those in treatments. There was an overall agreement with reference to the best treatment (T_7) and the treatments on par with the same, in both the seasons and in the pooled data. Regarding the tuber DGI and the number of adult emergence from stored tubers, the data obtained from the two seasons and the pooled values did not show remarkable variations.

4.7. Effect of organic amendments on the incidence of *C. formicarius*

The results of the two field experiments and the pooled data as well as the results of statistical analysis are presented in Table 12. There was 100 per cent infestation of crown in all treatments and hence the percentage of crown infestation is not shown in the Table. The data relating to DGI of crowns did not show significant variations either in the two experiments or in pooled data.

The lowest infestation of tuber (27.75 per cent) was observed in the plots treated with *Eupatorium* and it was followed by peruvalam (33.30 per cent), lemongrass (37.77 per cent) and punna (44.33 per cent), the differences among the above treatments being statistically insignificant. In the control plots the tuber infestation was quite high (61.67 per cent) and the treatment with punna, neem, pongam, erukku and kattavanakku came on par with the control.

With reference to mean DGI of tuber, *Eupatorium* (2.36) and peruvalam (2.58) were found to be the effective treatments and they were on par. All other treatments came on par with the control (3.67).

Based on the number of weevils obtained from the stored tubers, *Eupatorium* (164.44) and peruvalam (200.45) were on par. All other treatments were on par and significantly superior to the control (413).

Table 12. Effect of organic amendments on the incidence of C. formicarius on sweet potato

Treatments (leaves @ 3 t ha^{-1})	Crown DGI			Percentage of weight of tubers infested			Tuber DGI			Number of adult weevils emerged from 1 kg of infested tuber stored for 30 days		
	S-1	S-2	Mean	S-1	S-2	Mean	S-1	S-2	Mean	S-1	S-2	Mean
Neem (*Azadirachta indica*)	2.67 (1.634)	3.40 (1.844)	3.02 (1.739)	45.73	51.79	48.76	3.13 (1.768)	3.33 (1.825)	3.23 (1.797)	327.3 (2.515)	264.2 (2.422)	294.44 (2.469)
Pongam (*Pongamia glabra*)	2.87 (1.695)	3.44 (1.855)	3.15 (1.775)	41.70	62.51	52.10	2.93 (1.713)	3.48 (1.865)	3.20 (1.789)	240.4 (2.381)	274.8 (2.439)	257.00 (2.410)
Eupatorium odoratum	3.13 (1.770)	3.37 (1.836)	3.25 (1.803)	30.67	24.83	27.75	2.53 (1.591)	2.20 (1.483)	2.36 (1.537)	158.1 (2.199)	171.0 (2.233)	164.44 (2.216)
Peruvalam (*Clerodendron infortunatum*)	3.08 (1.755)	3.24 (1.800)	3.16 (1.778)	34.60	32.00	33.30	2.73 (1.653)	2.43 (1.559)	2.58 (1.606)	206.5 (2.315)	194.1 (2.288)	200.45 (2.302)
Lemongrass (*Cymbopogon flexuosus*)	3.40 (1.845)	3.37 (1.836)	3.39 (1.841)	44.27	31.27	37.77	3.27 (1.807)	2.90 (1.703)	3.08 (1.755)	266.1 (2.425)	271.6 (2.434)	269.15 (2.430)
Punna (*Calophyllum inophyllum*)	3.08 (1.754)	3.53 (1.880)	3.30 (1.817)	34.60	54.07	44.33	2.83 (1.683)	3.47 (1.863)	3.14 (1.773)	324.3 (2.511)	261.8 (2.418)	291.74 (2.465)
Erukku (*Calotropis gigantea*)	2.67 (1.634)	3.50 (1.871)	3.07 (1.753)	47.03	55.03	51.03	3.20 (1.788)	3.51 (1.873)	3.36 (1.831)	285.1 (2.455)	250.6 (2.399)	267.30 (2.427)
Kataavanukku (*Jatropha glandulifera*)	3.07 (1.752)	3.57 (1.890)	3.32 (1.821)	39.33	56.53	47.93	3.00 (1.731)	3.60 (1.897)	3.29 (1.814)	291.7 (2.465)	275.4 (2.440)	283.14 (2.452)
Control	3.20 (1.789)	3.50 (1.872)	3.35 (1.831)	57.23	66.10	61.67	3.53 (1.880)	3.82 (1.954)	3.67 (1.917)	400.9 (2.603)	425.6 (2.629)	413.05 (2.616)
C.D. at 5 per cent	NS	NS	NS	6.61	9.04	19.21	(0.107)	(0.105)	(0.190)	(0.108)	(0.117)	(0.126)

Figures in parentheses in the column are $\sqrt{x}$ and log x values for DGI and number of adult emergence respectively

S-1 First season S-2 Second season NS Nonsignificant DGI Damage grade index

The data in Table 12 revealed that the performance of the various treatments in the two seasons were broadly agreeing. *Eupatorium* and peruvalam were the first and second among the treatments in ranking based on efficacy. With reference to the percentage of tuber infestation peruvalam came on par with punna and erukku in the first season. In the second season it came on par with lemongrass while punna and erukku came significantly inferior. Based on DGI, peruvalam came on par with punna, pongam and kattavanakku during the first season. In the second season treatments other than *Eupatorium* were not on par with peruvalam. Based on the number of weevil obtained from stored tubers *Eupatorium* which was on par with peruvalam under other criteria was significantly superior in the first season. But in the second season these were on par.

4.8. Effect of organic cakes and wood ash on sweet potato weevil incidence

The data obtained from the field experiments in two seasons and the pooled values along with the results of the statistical analysis are presented in Table 13. Since all the crown were infested the percentage of crown infestation was not presented in the Table. The extent and intensity of crown damage observed in various treatments did not vary significantly.

Based on the percentage weight of infested tubers (pooled data), all treatments (except wood ash 1000 kg ha^{-1} applied at 30 DAP) were significantly superior to the control. The

Table 13 The effect of organic cakes and wood ash on sweet potato weevil incidence

Treatments (kg/ha)	Crown DGI			Percentage of infected tuber by weight			Tuber DGI			Number of weevils emerged from 1 kg of infested tuber stored for 30 days		
	S-1	S-2	Mean	S-1	S-2	Mean	S-1	S-2	Mean	S-1	S-2	Mean
applied at 30 DAP												
Neem cake 500	3 3(1 817)	4 2(2 045)	3 73(1 931)	61 54	59 80	60.67	3 7(1 924)	3 9(1 975)	3 80(1 949)	425 6(2 629)	477 5(2 679)	450 8(2 654)
, 1000	2 8(1 673)	3 2(1 789)	3 00(1 731)	55 56	57 25	56 41	3 3(1 817)	3.6(1 897)	3 45(1 857)	347 5(2 541)	429 5(2 633)	386 4(2 587)
1500	3 0(1 732)	3 9(1 975)	3 45(1 854)	61.20	58 64	59.92	3 3(1 817)	3 6(1 897)	3 45(1 857)	381 4(2 558)	422 7(2 626)	390 8(2 592)
Punna cake 500	3.2(1 789)	3 6(1 897)	3.40(1 843)	51 69	50 00	50.85	3 3(1 817)	3 5(1 871)	3 40(1 844)	389 0(2 590)	415 0(2 618)	401 8(2 604)
, ,, 1000	3 5(1 871)	3 3(1 817)	3 40(1 844)	61 29	62 24	61.77	3 7(1 924)	3 2(1 789)	3 45(1 856)	66,.3(2.823)	385 5(2 586)	401 8(2 604)
, , 1500	2 8(1 673)	3.4(1 844)	3.10(1 759)	59.32	59.56	59.44	3 1(1 767)	3 2(1.789)	3.15(1 775)	284 0(2 453)	387 3(2 588)	331 9(2 521)
Mahwa cake 500	4 0(2.000)	3 2 1 789)	3 60(1 895)	57 14	57 06	57.10	3 3(1 817)	3 5(1 871)	3 40(1 844)	313 3(2 496)	338 0(2 529)	325 1(2 512)
, , 1000	3 5(1 871)	3 2(1 789)	3 35(1 830)	50.00	49 00	49 50	3 3(1 817)	3 4(1 844)	3 35(1 830)	334 2(2 524)	389 9(2 591)	360 6(2 557)
,, , 1500	3 5(1 871)	3 3(1 817)	3.40(1 844)	35 71	36 36	36 04	2 8(1.673)	2 6(1 613)	2 70(1 643)	191.0(2 281)	216 3(2 335)	203 2(2 308)
Wood ash 1000	3 5(1 871)	3 2(1.789)	3 25(1 803)	64 77	63 03	63 90	3 4(1 844)	3 7(1 924)	3 55(1 883)	368 1(2 566)	489 8(2 690)	424 6(2 628)
, ,, 2000	3 6(1 897)	3 5(1 871)	3 55(1 884)	51 32	52 13	51 73	3 8(1 949)	3 3(1 817)	3 55(1 883)	445 7(2 649)	390 0(2 591)	416 9(2 620)
, , 3000	3 2(1 789)	3 0(1 732)	3 10(1 761)	54 93	54 10	54 52	3 0(1 732)	3 0(1 732)	3 00(1 732)	299 2(2 476)	340 4(2 532)	310 2(2 504)
applied at 50 DAP												
Neem cake 500	3 6(1 897)	3 9(1 975)	3 75(1 936)	51 49	42 86	47.18	3 0(1 732)	3 1(1 761)	3 05(1 746)	274 8(2 439)	370 7(2 569)	319 2(2 504)
, 1000	3 0(1 732)	3 0(1 732)	3 00(1 732)	50 50	48 54	49 52	3 2(1 789)	3 0(1 732)	3 10(1 761)	297 2(2 473)	314 8(2 498)	306 2(2 486)
, , 1500	3 2(1 789)	3 2(1 789)	3 20(1 789)	34 78	32 20	33 49	2 8(1 673)	2 9(1 703)	2 85(1 688)	214 8(2 332)	299 2(2 476)	252 0(2 403)
Punna cake 500	3 0(1 732)	3 2(1 789)	3 10(1 761)	52 63	51 92	52 28	3 7(1 924)	3 6(1 897)	3 65(1 911)	448 7(2 652)	420 7(2 624)	434 5(2 638)
,, , 1000	3 5(1 871)	3 0(1 732)	3 25(1 802)	52 00	53 17	52 59	3 2(1 789)	3 0(1 732)	3 10(1 761)	316.2(2 500)	334 2(2 524)	325 1(2 512)
,, , 1500	3 8(1 949)	3 2(1 789)	3 50(1 869)	60.41	60 10	60 26	3 4(1 844)	3 3(1 817)	3 35(1 830)	317 7(2 502)	396 3(2 598)	354 8(2 550)
Mahwa cake 500	3 4(1 844)	3 6(1 897)	3 50(1 871)	47 06	47 62	47 34	3 4(1 844)	3 3(1 817)	3 35(1 830)	383 7(2 584)	386 4(2 587)	385 5(2 586)
, 1000	3. (1.761)	3 2(1 789)	3 15(1 775)	31 71	34 48	36 10	2 5(1 581)	2 6(1 613)	2 55(1 597)	19,. 0(2 290)	191 9(2 283)	193 5(2 287)
, ,, 1500	3 3 1 817)	3 0(1 732)	3 15(1 775)	27.27	29 17	28 22	2 2(1 483)	2.4(1 549)	2 30(1 516)	171 0 2 233)	187 0(2 272)	178 6(2 252)
Wood ash 1000	3 4(1 844)	3 0(1 732)	3 20(1 788)	60 00	59 52	59 76	3 8(1 949)	3 6(1 897)	3.70(1 923)	449 3(2 653)	424 6(2 628)	437 5(2 641)
, ,, 2000	3 0(1 732)	3 1(1 761)	3 05(1 747)	50 00	53 06	51.53	3 6(1 897)	3 6(1 897)	3 60(1 897)	407 4(2 610)	426 6(2 630)	416 9(2 620)
,, , 3000	3 0(1 732)	3 0(1.732)	3 00(1 732)	47.06	48 00	47.53	3 5(1 871)	3 8(1 949)	3 65(1 910)	405 5(2 608)	473 2(2 675)	437 5(2 641)
Control	4 0(2 000)	3 2(1.789)	3 60(1.895)	70 97	69 23	70 10	3 9(1 975)	4.0(2 000)	3 95(1 987)	487 5(2 688)	534 6(2 728)	510 5(2.708)
C D at 5%	NS	NS	NS	7.31	7.65	7.42	(0 096)	(0 081)	(0 093)	(0 098)	(0 130)	(0 102)

Figures in parentheses in the column are $\sqrt{x}$ and log x values for Damage grade index (DGI) and number of weevils respectively

S-1 First season S-2 Second season NS Nonsignificant percentage in the control was 70.10 while in the treatments it ranged from 28.22 to 63.90. Mahwa cake @ 1500 kg ha^{-1} showed the minimum infestation (28.22 per cent) and it was followed by neem cake @ 1500 kg ha^{-1} (33.49 per cent) both applied at 50 DAP, there being no significant difference between the two. The latter was on par with mahwa cake @ 1500 kg ha^{-1} applied at 30 DAP (36.04 per cent) and mahwa cake @ 1000 kg ha^{-1} applied at 50 DAP (36.10 per cent) respectively. All the above four treatments were significantly superior to the remaining treatments.

With reference to the tuber DGI also, mahwa cake @ 1500 kg ha^{-1} applied at 50 DAP was the best with 2.30 DGI and it was followed by mahwa cake 1000 kg ha^{-1} applied at 50 DAP (2.55 DGI), there being no significant difference between the two. The latter was on par with mahwa @ 1500 kg ha^{-1} applied at 30 DAP and neem cake @ 1500 kg ha^{-1} applied at 50 DAP. The control plot (3.95 DGI) was on par with wood ash treated plots (all the three doses applied at 50 DAP) and neem cake @ 500 kg ha^{-1} applied at 30 DAP.

The number of weevils emerged from tubers kept in store was also the least in plots treated with mahwa cake @ 1500 kg ha^{-1} (178.6 adults) and it came on par with mahwa cake 1000 kg ha^{-1} (193.5) both applied at 50 DAP and mahwa cake at 1500 kg ha^{-1} (203.2) applied at 30 DAP. There was no significant difference among the above treatments. The maximum number of adults emerged was observed in the control (510.5) and it was on par with all

Table 14. Evaluation of different materials as attractant to the adults of C. *formicarius* in the laboratory

Treatments	Mean number of adults attracted in 24 hours
Whole sweet potato tubers 200g	63.9 (8.056)
Fresh sweet potato cut tubers 200g	76.2 (8.787)
Fresh sweet potato tubers crushed 200g	58.3 (7.699)
Vinegar alone 25ml	0.0 (1.000)
Yeast 4g in 25ml water	0.0 (1.000)
Jaggery 10g	0.6 (1.247)
Vinegar 25ml + yeast 4g	0.0 (1.000)
Vinegar 25ml + jaggery 10g	0.9 (1.366)
Vinegar 25ml + jaggery 10g + yeast 4g	0.6 (1.247)
Crushed tubers 200g + vinegar 25ml	1.4 (1.548)
Crushed tubers 200g + yeast 4g	2.5 (1.860)
Crushed tubers 200g + jaggery 10g	36.7 (6.139)
Crushed tubers 200g + yeast 4g + vinegar 25ml	6.1 (2.660)
Crushed tubers 200g + yeast 4g + vinegar 25ml + jaggery 10g	52.5 (7.317)
Fermented cocoa pulp alone 200g	21.1 (4.699)
Fermented cocoa pulp 200g + vinegar 25ml	0.0 (1.000)
Fermented cocoa pulp 200g + yeast 4g	0.0 (1.000)
Fermented cocoa pulp 200g + jaggery 10g	3.1 (2.014)
Fermented cocoa pulp 200g + vinegar 25ml + yeast 4g	1.1 (1.463)
Fermented cocoa pulp 200g + vinegar 25ml + yeast 4g + jaggery 10g	25.8 (5.179)
Fresh toddy 25ml	0.0 (1.000)
Fresh toddy 25ml + vinegar 25ml	0.0 (1.000)
Fresh toddy 25ml + yeast 4g	0.0 (1.000)
Fresh toddy 25ml + jaggery 10g	0.0 (1.000)
Fresh toddy 25ml + vinegar 25ml + yeast 4g	0.0 (1.000)
Fresh toddy 25ml + vinegar 25ml + yeast 4g + jaggery 10g	0.6 (1.247)
Fresh vines of *Ipomoea* sp. (Alternate hosts) 200g	38.5 (6.282)
Fresh vines of sweet potato 200g	39.3 (6.349)
C.D. at 5 per cent	(0.969)

Figures in parentheses are $\sqrt{x+1}$ values three doses of wood ash applied at 50 DAP and @ 1000 and 2000 kg ha^{-1} applied at 30 DAP, neem cake @ 500 kg ha^{-1} applied at 30 DAP and punna cake @ 500 kg ha^{-1} applied at 50 DAP.

The four treatments viz., mahwa cake @ 1500 kg ha^{-1}, mahwa cake 1000 kg ha^{-1} applied at 50 DAP, neem cake 1500 kg ha^{-1} applied at 50 DAP and mahwa cake @ 1500 kg ha^{-1} applied at 30 DAP which were ranked as the more effective treatments in the pooled data were maintaining the same ranking in both the seasons and under the different criteria adopted for the assessment of results.

4.9. Standardisation of techniques for trapping adults of *C. formicarius* in the field

4.9.1. Evaluation of different materials for attracting the adult weevils

The data relating to the experiment and the results of the statistical analysis of the same are presented in Table 14.

The maximum number of weevils (76.2) was attracted by fresh cut tubers of sweet potato. The treatment was followed by whole tubers (63.9), and the difference between the two was insignificant. Fresh crushed sweet potato tubers (58.3) and crushed tubers + yeast + vinegar + jaggery (52.5) were the second effective lot and they were on par among themselves. Fresh vines of *Ipomoea purpuria*, sweet potato vines and crushed tubers mixed with jaggery attracted 38.5, 39.3 and 36.7 numbers of weevils

Table 15. Activity of *C. formicarius* adults in field

Trapping done during	Number of adults trapped	
6.00 - 7.00 hours	6.9	(2.814)
8.00 - 9.00 ,,	0.9	(1.390)
10.00 - 11.00 ,,	0.0	(1.000)
12.00 - 13.00 ,,	0.5	(1.207)
14.00 - 15.00 ,,	0.7	(1.287)
16.00 - 17.00 ,,	17.7	(4.323)
18.00 - 19.00 ,,	24.5	(5.047)
20.00 - 21.00 ,,	20.2	(4.607)
22.00 - 23.00 ,,	8.9	(3.147)
24.00 - 1.00 ,,	5.5	(2.540)
2.00 - 3.00 ,,	5.5	(2.552)
4.00 - 5.00 ,,	4.6	(2.369)
C.D. at 5 per cent		(0.572)

Figures in parentheses are $\sqrt{x + 1}$ values respectively in 24 hours. There was no significant difference among these treatments. Fermented cocoa pulp with vinegar, jaggery and yeast attracted 25.8 weevils in 24 hours while fermented cocoa pulp alone attracted 21.1 weevils. The remaining treatments in the experiment were either having negligible levels of attraction or no attraction.

4.9.2. Activity of adults of *C. formicarius* in the field

The data relating to the experiment conducted for assessing the peak activity of the adults and the results of the statistical analysis of the data are presented in Table 15.

The data clearly showed that the activity of the beetle remained high from 16.00 to 22.00 h. The first two hours catch (17.7) was significantly lower than the catch obtained from 18.00 to 20.00 h (24.5) and the latter was on par with the number trapped during 20.00 and 21.00 h (20.2). During 22.00 and 23.00 h, the catch declined significantly (8.9). The activity of the beetle from 24.00 to 08.00 was rather low and the bihourly catch during the period ranged from 4.6 to 6.9 only. During the 08.00 and 09.00 h the catch reached to a negligible level of 0.9 and during 10.00 and 11.00 h there was no beetle activity and was shown by the total absence of weevils in the trap.

4.9.2.1. Assessment of the optimum frequency for removing weevils from traps set in field for the control of *C.formicarius*

The data relating to the experiment and the statistical analysis of the same are presented in Table 16.

Table 16. Assessment of the optimum frequency for collecting adult weevils from traps set in field for the control of <u>C. formicarius</u>

Period of collection		Mean number of weevils collected
16.00 - 17.00 hours	16.3(4.037)	
18.00 - 19.00 ,,	23.9(4.889)	
20.00 - 21.00 ,,	22.1(4.701)	
22.00 - 23.00 ,,	4.0(2.213)	
24.00 - 1.00 ,,	3.3(1.817)	
2.00 - 3.00 ,,	3.4(1.843)	
4.00 - 5.00 ,,	5.6(2.366)	
C.D. at 5%	(0.310)	
Total for 16.00 - 5.00 bihourly intervals		79.5(8.918)
Total for 16.00 - 5.00 hours		72.4(8.510)
Total for 16.00 - 21.00 hours		69.9(8.360)
		NS

NS Nonsignificant

Figures in parentheses are transformed values of $\sqrt{x}$

Total number of adults collected from 16.00 to 06.00 h was 79.5, when the beetles attracted to the traps were being removed at bihourly intervals. When the traps were set at 16.00 h and the beetles attracted were removed in a single lot at the end of 05.00 h, the total number obtained was 72.4. The number of weevils obtained at the end of 21.00 h from the traps set at 16.00 h was 69.9. The number of beetles collected in the above three schedules did not differ statistically.

4.9.3. Assessment of the effect of the size of sweet potato tubers (cut and whole) used as bait material and the optimum frequency of changing the bait for collecting the adults of *C. formicarius*

The results of the experiments and the statistical analysis of the data are presented in Table 17.

Tubers of 9 and 6 cm diameter came on par and were significantly superior to the tubers of 3 cm diameter in the observations recorded at various intervals as well as in the mean values.

The mean number of adults collected in traps provided with the whole tubers and the tubers cut lengthwise or crosswise showed that the latter were attracting significantly higher number of beetles. In general the catch between the lengthwise and crosswise cut tubers of 9 and 6 cm diameter, did not vary significantly as observed at 24 h and in the cut tubers maintained with daily changing in all the observations recorded up to 120 h.

Table 17. Standardisation of sweet potato tubers to be used in traps for controlling adults of *C. formicarius* in field

Sweet potato tubers	Size cm / Type	Number of adults collected at intervals of																	
		24 h			48 h			72 h			96 h			120 h			Mean		
		9	6	3	9	6	3	9	6	3	9	6	3	9	6	3	9	6	3
Whole tuber unchanged	–	43.8 (6.692)	41.6 (6.526)	18.8 (4.446)	37.8 (6.228)	36.8 (6.147)	10.8 (3.428)	17.6 (4.311)	17.8 (4.332)	9.6 (3.251)	11.8 (3.571)	10.8 (3.425)	0.1 (1.028)	4.6 (2.355)	4.2 (2.279)	0.0 (1.000)	20.4 (4.631)	19.6 (4.542)	5.9 (2.630)
Whole tuber changed	–	45.0 (6.782)	42.8 (6.617)	19.0 (4.472)	44.8 (6.767)	43.8 (6.692)	7.4 (4.289)	47.2 (6.943)	45.8 (6.840)	18.4 (4.404)	45.6 (6.826)	43.8 (6.692)	16.8 (4.215)	44.0 (6.718)	42.4 (6.588)	18.8 (4.446)	45.3 (6.808)	43.7 (6.682)	1 1 (4.365)
Tubers cut unchanged	L	62.4 (7.962)	60.4 (7.836)	31.6 (5.709)	41.4 (6.511)	39.8 (6.386)	15.4 (4.049)	18.4 (4.404)	16.0 (4.117)	3.6 (2.129)	2.8 (1.951)	2.6 (1.915)	0.0 (1.000)	0.0 (1.000)	0.0 (1.000)	0.0 (1.000)	18.1 (4.366)	16.7 (4.210)	6.7 (2.777)
	C	55.2 (7.497)	54.2 (7.443)	26.0 (5.196)	27.4 (5.328)	25.6 (5.156)	9.6 (3.251)	14.9 (3.993)	13.0 (3.742)	3.5 (2.116)	3.0 (2.000)	2.4 (1.833)	0.0 (1.000)	0.0 (1.000)	0.0 (1.000)	0.0 (1.000)	1[illegible].7 ([illegible])	12.2 (3.635)	5.4 (2.522)
Tubers cut changed daily	L	63.8 (8.049)	61.0 (7.874)	30.6 (5.620)	65.0 (8.124)	63.2 (8.013)	29.0 (5.477)	63.0 (8.001)	60.8 (7.861)	27.6 (5.347)	64.1 (8.099)	61.0 (7.874)	30.8 (5.637)	62.2 (7.950)	61.2 (7.887)	27.8 (5.365)	63.4 (8.026)	61.4 (7.902)	29.1 (5.489)
	C	54.0 (7.416)	53.6 (7.389)	22.6 (4.857)	55.6 (7.523)	55.0 (7.483)	20.6 (4.646)	56.0 (7.550)	55.8 (7.536)	28.6 (5.440)	54.6 (7.456)	52.8 (7.334)	18.8 (4.446)	55.2 (7.497)	55.0 (7.482)	17.8 (4.332)	55.1 (7.488)	54.4 (7.444)	21.5 (4.744)
Tubers cut cut surface chipped daily	L	64.8 (8.111)	62.2 (7.950)	29.6 (5.531)	51.6 (7.252)	50.4 (7.169)	17.4 (4.289)	42.2 (6.573)	40.6 (6.449)	9.8 (3.280)	11.6 (3.546)	10.8 (3.428)	0.0 (1.000)	3.5 (2.129)	3.0 (2.000)	0.0 (1.000)	29.5 (5.522)	28.1 (5.39[illegible])	8.2 (3.032)
	C	57.4 (7.642)	54.6 (7.456)	20.6 (4.646)	45.6 (6.826)	40.8 (6.464)	13.6 (3.818)	35.8 (6.065)	34.8 (5.982)	9.8 (3.278)	8.6 (3.121)	8.6 (3.093)	0.0 (1.000)	1.6 (1.619)	0.8 (1.342)	0.0 (1.000)	24.5 (5.05[illegible])	22.7 (4.8[illegible]7)	6.6 (2.718)
C.D. at 5%			(0.606)			(0.720)			(0.590)			(0.509)			(0.760)			(1.540)	

Figures in parentheses are $\sqrt{x+1}$ values   L Cut lengthwise   C Cut crosswise

C.D. at 5 per cent between intervals (0.703)

In the case of whole tubers of 9 and 6 cm diameter the catch between 24 and 48 h did not vary significantly, but in the case of 3 cm diameter tubers there was a significant drop in the catch during the period. In the case of lengthwise and crosswise cut tubers the mean number collected at 48 h was significantly lower than the number collected at 24 h. In the whole as well as in the cut tubers the weevils collected at 72 h were far lower than the previous catches and the catches at 96 and 120 h were very low. This trend was more pronounced in the case of tubers of 3 cm diameter.

Even when the cut tubers were chipped daily, the catches at 48 h were significantly lower than those observed at 24 h. At 72 h though there was reduction in the catch, it was not as remarkable as the reduction observed in the whole and cut tubers kept unchanged. But at 96 h, the chipping had little effect on the attraction of adults and it was similar to that of the whole tuber kept unchanged at 96 h.

The mean number of weevils collected in different treatments over a period of 120 h was remarkably higher in traps in which the tubers were changed daily. This effect was more conspicuously observed in the case of cut tubers than in the whole tubers. But between lengthwise and crosswise cut there was no significant difference. The mean values in all the treatments also revealed that 3 cm diameter tubers were less effective than 6 and 9 cm diameter tubers.

Table 18. Effect of varying quantities of sweet potato tubers in trapping adults of <u>C.</u> <u>formicarius</u> in field

Quantities of tuber used (g)	No. of adults collected during 18.00 to 6.00 hours					
	R_1	R_2	R_3	R_4	R_5	mean
25	12	9	7	6	5	7.6 (2.759)
50	19	11	13	17	18	15.4 (3.929)
100	63	54	45	48	60	53.8 (7.334)
200	67	60	58	38	45	53.1 (7.284)
300	45	36	60	48	57	47.1 (6.864)
	C.D. at 5 per cent					(0.808)

Table 19. Effect of placing traps at varying distances in collecting adults of <u>C.</u> <u>formicarius</u> in field

Distances among traps (m)	No. of adults trapped during 18.00 to 6.00 hours					
	R_1	R_2	R_3	R_4	R_5	mean
3	54	50	46	63	66	55.5 (7.453)
5	57	58	65	54	69	60.5 (7.777)
10	33	31	27	38	25	30.6 (5.535)
15	12	15	18	13	9	13.2 (3.637)
	C.D. at 5 per cent					(0.637)

Figures in parentheses are $\sqrt{x}$ values

4.9.4. Assessment of the optimum quantity of sweet potato tuber to be used in the traps set for collecting adults of *C. formicarius* in the field

The data relating to the experiment and the results of the statistical analysis of the same are presented in Table 18.

The mean numbers of weevils collected in the traps using varying quantities of sweet potato tubers of 6 cm diameter showed significant variations. The maximum catch was with 100 g quantity (53.8) and it was followed by 200 g (53.1) and 300 g (47.1), there being no significant variations among the treatments. The collections with 25 and 50 g of tubers were significantly lower (7.6 and 15.4 respectively) than in the rest of the treatments.

4.9.5. Effect of placing traps at varying distances in collecting adults of *C. formicarius* in the field

The data relating to the experiment and the results of the statistical analysis of the same are presented in Table 19.

The mean numbers of weevils collected in traps placed at different distances showed significant variations. The maximum number of weevils was collected in traps kept five metres apart (60.5) and it was closely followed by the traps kept three metres apart, there being no significant difference between the two. The higher distance of 10 and 15 m among the traps caused considerable drop in the number of weevils collected. The mean numbers obtained in these traps were 30.6 and 13.2 respectively.

4.9.6. Fixing optimum intervals for trapping adults of *C. formicarius* for controlling the damage

The data relating to the field experiment and the results of statistical analysis of the same are presented in Table 20.

The maximum reduction in the percentages of crown infestation was observed in plots from which the weevils were trapped out at three day intervals (18.13 per cent). It was closely followed by the infestation in the plots in which trapping was done at seven and ten day intervals (18.25 and 20.23 per cent respectively). The above three treatments were on par and significantly superior to the trapping done at 15 day intervals and to the control. The plots treated with fenthion 0.05 per cent recorded the lowest crown infestation at 4.54 per cent. This was significantly superior to all other treatments. Infestation in control (56.87 per cent) was significantly higher than any of the other treatments in the experiment.

Based on the DGI of crown trapping done at 3 day intervals (DGI 1.83) was very effective. It was followed by the trappings at 7 and 10 day intervals (1.97 and 2.0 respectively). All the above treatments were on par and significantly superior to control (3.98). Trapping at 15 day intervals was the least effective (2.30). The plots treated with fenthion showed the least crown DGI of 1.30 and this was on par with the damage in plots where the trapping of weevils was done at 3 and 7 day intervals.

Table 20. Effect of varying frequencies of trapping the adults of *C. formicarius* on the extent of damage done by the pest

Trappings done between 50 and 80 DAP at intervals of	Infestation of crown		Infestation of tuber		No. of adults emerged from 1 kg infested tuber stored for 30 days	Yield/4.8 m^2 (kg)		Total number of adults trapped
	%	DGI	% of infested tuber by weight	DGI		Marketable	Total	
3 days	18.13 (25.20)	1.83 (1.351)	16.67 (24.10)	1.60 (1.265)	24.1 (1.382)	4.00	4.80	246
7 days	18.25 (25.29)	1.97 (1.404)	16.70 (24.12)	1.61 (1.269)	27.2 (1.434)	4.05	4.85	210
10 days	20.23 (26.73)	2.00 (1.415)	18.20 (25.25)	1.65 (1.285)	30.5 (1.485)	4.10	5.00	216
15 days	30.00 (33.21)	2.30 (1.518)	26.05 (30.69)	2.09 (1.446)	95.5 (1.980)	3.50	4.70	153
Fenthion 0.05%	4.54 (12.30)	1.30 (1.140)	4.50 (12.24)	1.08 (1.039)	11.5 (1.060)	5.25	5.50	-
Control	56.87 (48.95)	3.98 (1.995)	47.6 (43.62)	3.83 (1.957)	274.2 (2.438)	2.20	4.20	-
C.D. at 5%	(2.58)	(0.265)	(5.25)	(0.140)	(0.330)	0.40	0.435	

Figures in parentheses in the column are arc Sin $\sqrt{x}$, $\sqrt{x}$ and log x for percentages, DGI and number of adult emergence respectively

DGI Damage grade index

The percentage of tuber infestation observed in plots from which weevils were trapped out at 3, 7 and 10 day intervals were 16.67, 16.70 and 18.20 respectively. The infestation was high in trapping done at 15 day intervals (26.05 per cent) and the control (47.60). Plots treated with fenthion had 4.5 per cent tuber infestation only.

Tuber damage index (1.08) was least in fenthion treated plots and it was followed by the plots in which trappings were done at 3 days (1.60), 7 days (1.61), 10 days (1.65) and 15 days (2.09) intervals and control plots (3.83).

Based on the number of weevils obtained from stored tubers fenthion (11.5) was the best and it was on par with the treatment in which trappings were done at 3 day intervals (24.1). It was followed by trappings done at 7 days (27.2) and 10 days (30.5), there being no significant difference among the treatments. Trapping at 15 day intervals (95.5) was significantly inferior to the above treatments but was significantly superior to the control (274.2).

The marketable tubers obtained in various treatments showed that the trapping of weevils at intervals 3, 7 and 10 days were on par (4.00, 4.05 and 4.1 kg per 4.8 m^2 respectively). These were significantly superior to the yield from the control plots (2.2 kg) and that of the plots in which the adults were trapped at 15 day intervals (3.50 kg). The quantity of tuber obtained from the plots treated with fenthion was the highest (5.25 kg). It was significantly superior to all the treatments including control.

The total numbers of weevils collected by trapping at intervals of 3, 7, 10 and 15 days were 246, 210, 216 and 153 respectively.

4.10. Chemical control of *C. formicarius*

4.10.1. Relative efficacy of different insecticides applied to soil for the control of *C. formicarius*

The data relating to the experiment and the results of the statistical analysis of the same are presented in Table 21.

Quinalphos, fenthion, endosulfan, monocrotophos and fenitrothion (0.05 per cent emulsion) were found to be on par with reference to the DGI of the crown, 1.48, 1.44, 1.42, 1.50 and 1.39 respectively. All the above treatments were superior to the control (DGI 3.72) and also to the granular formulations of phorate (DGI 1.96) and carbofuran (DGI 1.96) applied at 1.5 kg ai ha^{-1}. The phorate and carbofuran were on par and significantly superior to the control.

The percentages of infested tubers in various treatments (3.1 to 17.6 per cent) were significantly lower than that of the control (84.9 per cent). The least incidence was in endosulfan treated plots (3.1 per cent). It was followed by fenthion (3.3 per cent), fenitrothion (3.6) and monocrotophos (8.3), there being no significant differences among the treatments. Monocrotophos was on par with quinalphos (17.2 per cent), phorate (17.6) and carbofuran (15.4).

Table 21. Relative efficacy of different insecticides for the control of *C. formicarius* and the residues of insecticides in tubers at harvest

Treatments		Crown DGI	% of the weight of infested tubers	Tuber DGI	No. of adults emerged from 1 kg infested tuber stored for 30 days	Marketable tuber 4.8 m^2 (kg)	Residue
Quinalphos	0.05%	1.48(1.215)	17.2(24.35)	1.66(1.288)	19.9(1.299)	4.21	ND
Fenthion	,,	1.44(1.199)	3.3(10.53)	1.22(1.103)	7.1(0.852)	5.47	ND
Endosulfan	,,	1.42(1.190)	3.1(10.15)	1.20(1.095)	7.0(0.848)	5.37	ND
Monocrotophos	,,	1.50(1.225)	8.3(16.60)	1.30(1.140)	10.0(0.999)	4.80	ND
Fenitrothion	,,	1.39(1.180)	3.6(10.90)	1.92(1.385)	8.0(0.901)	5.40	ND
Phorate	1.5 kg ai ha^{-1}	1.96(1.399)	17.6(24.81)	1.98(1.407)	24.2(1.384)	4.20	ND
Carbofuran	1.5 ,,	1.96(1.401)	15.4(23.14)	1.93(1.389)	19.0(1.278)	4.20	ND
Control		3.72(1.930)	84.9(67.18)	3.10(1.762)	264.9(2.423)	1.20	ND
C.D. at 5 per cent		(0.127)	(12.33)	(0.225)	(0.142)	1.12	

Figures in parentheses are transformed values of $\sqrt{x}$, arc Sin $\sqrt{x}$ and log x for DGI, Based on DGI of tubers also the lowest incidence was observed in endosulfan treated plots (DGI 1.20). Fenthion (1.22), monocrotophos (1.30) and quinalphos (1.66) came on par among themselves and with endosulfan. Quinalphos was on par with phorate (1.98) and carbofuran (1.83). All the treatments were superior to the control (DGI 3.10).

The number of adults obtained from tubers collected from endosulfan treated plots and stored was the least (7.0). Endosulfan (7.0), fenthion (7.1) and fenitrothion (8.0) came on par. Monocrotophos (10.0) was significantly inferior to the above treatments. Carbofuran (19.0), quinalphos (19.9) and phorate (24.2) were superior to the control (264.9) but significantly inferior to endosulfan, fenthion and fenitrothion.

Based on the quantity of marketable tubers obtained (per plot of 4.8 m^2) in various treatments, fenthion (5.47 kg) endosulfan (5.37) and fenitrothion (5.40) came on par and significantly superior to the rest of the treatments. The yield obtained from the control plots (1.20) was the lowest and significantly less than those of the insecticide treated plots. Residues of none of the insecticides could be detected in the tubers collected at the time of harvest.

4.10.1.1. Effect of insecticides used as soil drench for the control of *C. formicarius* on the population of soil microflora

The data collected on this aspect along with the results of statistical analysis are presented in Table 22.

Table 22. Effect of insecticides used as soil drench for the control of C. formicarius on the population of soil microflora

Insecticides	Mean number of colonies obtained per one gram dry soil											
	Actinomycetes				Bacteria*				Fungi*			
	50 DAP	52 DAP	80 DAP	82 DAP	50 DAP	52 DAP	80 DAP	82 DAP	50 DAP	52 DAP	80 DAP	82 DAP
Quinalphos 0.05% applied at 50 and 80 DAP	2.50 (1.87)	2.39 (1.84)	1.53 (1.59)	1.21 (1.48)	17.23 (4.27)	13.67 (3.83)	6.67 (2.77)	4.15 (2.27)	28.1 (5.30)	50.4 (7.10)	8.6 (2.94)	10.0 (3.17)
Fenthion 0.05% applied at 50 and 80 DAP	2 53 (1.88)	1.69 (1.64)	2.53 (1.88)	0.97 (1.40)	13.67 (3.83)	16.06 (4.13)	11.04 (3.47)	8.18 (3.03)	59.3 (7.70)	32.5 (5.70)	18.8 (4.34)	16.0 (4.00)
Endosulfan 0.05% applied at 50 and 80 DAP	2.53 (1.88)	0.75 (1.32)	1.20 (1.48)	2.06 (1.75)	14.44 (3.93)	12.47 (3.67)	5.60 (2.57)	9.43 (3.23)	79.2 (8.90)	27.4 (5.23)	34.0 (5.83)	16.8 (4.10)
Monocrotophos 0.05% applied at 50 and 80 DAP	0.85 (1.36)	0.69 (1.31)	3.84 (2.20)	2.33 (1.82)	6.13 (2.67)	10.76 (3.43)	13.67 (3.83)	7.00 (2.83)	26.0 (5.10)	33.5 (5.79)	7.3 (2.71)	11.5 (3.39)
Fenitrothion 0.05% applied at 50 and 80 DAP	1.04 (1.43)	0.70 (1.30)	2.76 (1.91)	2.25 (1.80)	18.36 (4.40)	12.91 (3.73)	12.91 (3.73)	12.47 (3.67)	29.2 (5.40)	19.3 (4.39)	21.2 (4.60)	7.7 (2.77)
Phorate 1.5 kg ai ha^{-1} applied at 50 DAP	1.89 (1.70)	1.05 (1.43)	1.47 (1.57)	2.50 (1.87)	9.43 (3.23)	19.52 (4.53)	9.04 (3.17)	10.56 (3.40)	49.0 (7.00)	56.3 (7.50)	16.2 (4.02)	12.5 (3.54)
Carbofuran 1.5kg ai ha^{-1} applied at 50 DAP	2.10 (1.76)	2.42 (1.85)	3.33 (2.08)	1.75 (1.66)	2.13 (1.77)	11.74 (3.57)	9.24 (3.20)	2.00 (1.73)	19.4 (4.40)	44.6 (6.68)	10.9 (3.30)	10.5 (3.24)
Control	0.54 (1.24)	0.85 (1.36)	0.82 (1.35)	0.69 (1.30)	3.97 (2.23)	4.42 (2.33)	14.44 (3.93)	5.25 (2.50)	38.4 (6.20)	9.6 (3.10)	4.0 (2.00)	11.8 (3.43)
C.D. at 5%	NS	NS	NS	0.34		NS	NS	NS	-	NS	NS	NS

Figures in parentheses are $\sqrt{x+1}$ values for actinomycetes and bacteria and $\sqrt{x}$ values for fungi

NS Nonsignificant

* Mean values are adjusted to the pretreatment mean values in 50 DAP through ANACOVA

The mean number of colonies of actinomycetes obtained per gram of dry soil did not show significant variations prior to the treatments (50 DAP) and two days after the treatments (52 DAP). The persistent effect as shown at 80 DAP also failed to show any significant variation. The data obtained two days after second application (at 82 DAP) showed significant variation. The populations in all treatments except quinalphos and fenthion were significantly higher than that of the control. The immediate effect of the treatments observed in the data collected at 50 and 52 DAP as well as 80 and 82 DAP showed that quinalphos, fenthion, endosulfan, monocrotophos and fenitrothion had a slight suppressing effect on the actinomycetes population. Except in quinalphos this suppressing effect was seen rectified within a period of 30 days after treatment (50 and 80 DAP), whereas in the case of quinalphos the decreasing trend of population was maintained throughout. In the case of phorate also, there was an initial suppression and the population showed a recovery in subsequent observation. In the case of carbofuran there was a slight increase in the population immediately after treatment at 50 DAP and this trend was maintained up to 30 days after treatment (i.e. 80 DAP). But in the observation made at 82 DAP the population showed a negative trend.

The immediate effect of fenthion, endosulfan and monocrotophos on the population of bacteria, as observed two days after the two insecticidal treatments at 50 and 80 DAP showed a very erratic trend though slight reduction could be noted in quinalphos and fenitrothion. In the case of phorate and carbofuran treated plots also the trend of the bacterial population was erratic. Control plots also had a fluctuating bacterial population during the period of the experiment. The analysis of covariance of data failed to reveal significant difference among treatments.

The fungal population declined in the plots treated with fenthion, endosulfan and fenitrothion while there was an increase in the plots treated with quinalphos and monocrotophos. The granular application of phorate and carbofuran caused an initial boosting and later a decline in fungal population. The fungal population in the control plots also was fluctuating and there were no significant variations in the data.

4.10.2. Effect of soil drenching with insecticides at different growth stages of sweet potato for the control of *C. formicarius*

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 23.

When endosulfan 0.05 per cent emulsion was drenched around the base of the plants once at 50, 65 or 80 DAP, the treatment at 65 DAP was found to be significantly superior to the other two treatments, based on all the five criteria adopted for evaluation. The percentage of crown infestation, DGI of crown, percentage of tuber damage (on weight basis), DGI of tuber and number of adults emerged from stored tubers relating to the treatment on 65th DAP were 15.4, 2.1, 90.6, 1.1 and 21.1 respectively. Treatment done at 65 DAP came on par with the treatment in which two drenchings were given on 50 and 65 DAP, under all the criteria adopted for evaluation. The drenchings at 50 + 80 DAP, 50 + 65 + 80 DAP and 60 + 90 DAP were on par and superior to the drenching on 65th DAP alone. All the treatments were significantly superior to the control in which the percentage of crown infestation, DGI of crown, percentage of tuber damage, DGI of tuber and the number of adults emerged from tubers kept in store were 75.8, 3.6 58.7, 4.0 and 448.7 respectively. Endosulfan, fenthion and fenitrothion (0.05 per cent emulsion) were equally effective.

The yields of marketable tubers obtained from the plots treated at 65 DAP or at 50 + 65 DAP were on par but significantly less than the yields obtained from plots treated at 50 + 80 DAP, 50 + 65 + 80 DAP or 60 + 90 DAP, there being no significant differences among the latter group of treatments.

With reference to the tobacco decoction (1.0 per cent), the treatments given on 65th DAP came on par with all the treatments in which two or three drenchings were given, under all the criteria adopted for the evaluation of insect damage, except the number of adults emerged from the tubers kept in store. The number of weevils emerged from stored tubers was significantly lower when drenched at 50 + 80, 50 + 65 + 80 or 60 + 90 DAP than the other treatments.

The yield obtained from the plots treated with tobacco decoction on 65th DAP came on par with drenching at 50 + 65 DAP. The yields in plots treated at 50 + 80 DAP, 50 + 65 + 80 DAP and 60 + 90 DAP were on par and significantly superior to the former two treatments.

Table 23. Efficacy of drenching the soil around sweet potato vines with insecticides at different intervals after planting in controlling C. *formicarius*

Treatments		Infestation on crown		Tuber damage		Number of adult weevil emerged from 1kg infested tuber stored for 30 days	Marketable tuber per $4.8\ m^2$ (kg)
		%	DGI	% of infested tuber by weight	DGI		
Endosulfan 0.05% at -							
50	DAP	39.2(38.77)	2.6(1.598)	33.2(35.20)	2.6(1.624)	129.1(2.111)	3.87
65	,,	15.4(23.10)	2.1(1.445)	10.6(19.00)	1.1(1.058)	21.1(1.324)	4.33
80	,,	20.7(27.07)	2.4(1.560)	25.0(30.00)	2.8(1.669)	129.4(2.112)	3.90
50+65	,,	15.1(22.87)	2.0(1.431)	10.8(19.20)	1.2(1.086)	26.0(1.415)	4.27
50+80	,,	9.6(18.03)	1.1(1.032)	4.0(11.50)	1.0(1.011)	8.5(0.929)	4.98
50+65+80	,,	9.1(17.60)	1.1(1.026)	4.8(12.70)	1.0(1.015)	9.1(0.960)	4.90
60+90	,,	9.5(17.97)	1.2(1.093)	4.0(11.50)	1.0(1.010)	8.8(0.944)	4.86
Fenthion 0.05% at -							
50	DAP	32.5(34.77)	2.5(1.574)	35.2(36.40)	2.7(1.641)	127.1(2.104)	4.00
65	,,	16.2(23.70)	2.1(1.436)	9.5(17.90)	1.1(1.046)	22.1(1.344)	4.25
80	,,	29.8(33.07)	2.5(1.574)	29.7(33.00)	2.8(1.680)	126.8(2.103)	4.05
50+65	,,	17.0(24.35)	2.0(1.422)	10.1(18.50)	2.0(1.407)	24.5(1.353)	4.15
50+80	,,	10.8(19.20)	1.2(1.092)	4.1(11.70)	1.0(1.018)	8.5(0.930)	4.90
50+65+80	,,	10.3(18.70)	1.2(1.092)	4.3(12.00)	1.0(1.016)	8.7(0.940)	4.85
60+90		9.8(18.23)	1.2(1.092)	4.4(12.10)	1.0(1.015)	8.9(0.950)	4.95
Fenitrothion 0.05% at -							
50	DAP	32.0(34.43)	2.6(1.626)	31.3(34.00)	2.8(1.677)	120.5(2.081)	3.75
65	,,	13.5(21.53)	2.1(1.453)	10.3(18.70)	1.3(1.129)	13.7(1.138)	4.25
80	,,	23.4(28.90)	2.5(1.588)	21.0(27.30)	2.7(1.638)	55.5(1.744)	4.05
50+65	,,	18.2(25.27)	2.0(1.421)	10.5(18.90)	1.3(1.126)	22.5(1.352)	4.40
50+80	,,	9.5(17.97)	1.0(1.022)	4.8(12.60)	1.0(1.022)	8.5(0.928)	4.90
50+65+80	,,	10.8(19.20)	1.1(1.066)	4.3(11.90)	1.0(1.020)	9.0(0.956)	4.85
60+90	,,	10.5(18.90)	1.2(1.092)	4.3(11.80)	1.0(1.015)	9.1(0.958)	4.85
Tobacco decoction 1.0% at -							
50	DAP	36.0(36.87)	2.7(1.652)	30.6(33.60)	2.9(1.697)	150.0(2.176)	3.85
65	,,	13.8(21.77)	1.8(1.332)	10.5(18.90)	1.2(1.073)	22.3(1.349)	4.00
80	,,	26.0(30.67)	2.4(1.547)	27.8(31.80)	2.7(1.656)	123.3(2.091)	3.85
50+65	,,	13.1(21.73)	1.9(1.391)	10.0(18.40)	1.2(1.072)	22.3(1.349)	4.25
50+80	,,	14.5(22.37)	1.5(1.222)	6.6(14.90)	1.2(1.073)	13.6(1.135)	4.90
50+65+80	,,	14.0(21.97)	1.5(1.220)	6.7(15.00)	1.1(1.070)	13.7(1.138)	4.90
60+90	,,	12.6(20.80)	1.6(1.265)	6.4(14.70)	1.2(1.074)	13.6(1.134)	4.85
Control		75.8(60.50)	3.6(1.897)	58.7(50.00)	4.0(1.996)	448.7(2.652)	2.60
C.D. at 5%		(2.590)	(0.345)	(5.900)	(0.042)	(0.171)	0.43

Figures in parentheses in the column are transformed values of arc Sin $\sqrt{x}$, $\sqrt{x}$ and log x for percentage, damage grade index (DGI) and number of adult emergence respectively

DAP Days after planting

4.10.2.1. Persistent toxicity of various insecticides, applied in soil for the control of *C. formicarius* to the adults of the pest

The per cent mortality of the weevils when exposed to soil (collected from treated field at weekly intervals) in the laboratory and the results of statistical analysis of the data are presented in Table 24.

The data showed that the mortality obtained in samples collected on the first day from plots treated with the three synthetic insecticides ranged from 88.2 to 92.3 per cent and were on par, while corresponding samples from plots treated with tobacco decoction gave mortalities ranging from 73.3 to 76.0 per cent only showing that it was significantly inferior to the above synthetic insecticides. The mortalities observed in samples collected from endosulfan, fenthion and fenitrothion treated plots (one application only) at seventh day after treatment were on par (81.3 and 84.1 per cent). The mortalities obtained in samples collected at 14, 21 and 28 days after treatment indicated that the three insecticides had the same persistent toxicity to the adults of *C. formicarius*. On 14th day the mortality ranged from 75.2 to 78.7 per cent in the above treatments and during the 21st day the mortalities dropped to the range of 66.9 to 69.4 per cent and during the 28th day it dropped to the range of 42.4 to 51.2 per cent. The three insecticides were on par on 28th day after treatment also. During the 35th day after treatment the mortalities fell

Table 24. Persistent toxicity of various insecticides, used for drenching the soil in sweet potato field to the adults of C. *formicarius*

Treatments		Corrected per cent mortality of C. *formicarius* exposed to soils collected at intervals of (days after drenching)								
		1	7	14	21	28	35	42	49	56
Endosulfan 0.05% at										
50	DAP	88.2(69.9)	81.3(64.4)	77.2(61.5)	68.9(56.1)	50.3(45.2)	18.0(25.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)
65	,,	89.4(71.0)	84.1(66.5)	77.2(61.5)	69.4(56.4)	51.2(45.7)	20.2(26.7)	0.0(0.0)	-	-
80	,,	92.2(73.8)	82.7(65.4)	77.2(61.5)	66.9(54.9)	50.0(45.0)	-	-	-	-
50+65	,,	88.2(69.9)	82.7(65.4)	77.4(61.6)	90.7(72.3)	82.7(65.4)	74.7(59.8)	66.6(54.7)	37.2(37.6)	0.0(0.0)
50+80	,,	92.3(73.9)	86.7(68.6)	80.0(63.4)	70.2(56.9)	51.2(45.7)	90.7(72.3)	85.4(67.5)	78.7(62.5)	66.6(54.7)
50+65+80	,,	92.3(73.9)	86.7(68.6)	77.2(61.5)	90.7(72.3)	79.4(63.0)	90.7(72.3)	86.7(68.6)	82.7(65.4)	66.6(54.7)
60+90	,,	92.3(73.9)	86.7(68.6)	81.3(64.4)	71.9(58.0)	52.1(46.2)	92.0(73.6)	82.7(65.4)	76.6(61.1)	-
Fenthion 0.05% at										
50	DAP	88.2(69.9)	82.7(65.4)	78.7(62.5)	68.7(56.0)	42.4(40.6)	19.6(26.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)
65	,,	88.2(69.9)	82.7(65.4)	75.9(60.6)	67.6(55.3)	43.9(41.5)	17.3(24.6)	0.0(0.0)	-	-
80	,,	89.9(71.5)	84.1(66.5)	75.2(60.1)	68.7(56.0)	45.0(42.1)	-	-	-	-
50+65	,,	89.4(71.0)	82.7(65.4)	77.4(61.6)	90.7(72.3)	84.0(66.4)	68.1(55.6)	53.3(46.9)	26.7(31.1)	0.0(0.0)
50+80	,,	90.8(72.3)	85.5(67.6)	77.4(61.6)	70.7(57.2)	45.8(42.6)	88.0(69.7)	82.7(65.4)	77.4(61.6)	66.6(54.7)
50+65+80	,,	91.3(72.8)	85.5(67.6)	77.4(61.6)	89.4(71.0)	78.7(62.5)	89.4(71.0)	82.7(65.4)	77.4(61.6)	66.6(54.7)
60+90	,,	92.3(73.9)	87.0(68.9)	78.7(62.5)	74.7(59.8)	43.0(41.0)	88.0(69.7)	81.3(64.4)	76.5(61.0)	-
Fenitrothion 0.05% at										
50	DAP	88.2(69.9)	81.3(64.4)	77.4(61.6)	68.7(56.0)	46.0(42.7)	14.3(22.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)
65	,,	88.2(69.9)	82.8(65.5)	76.2(80.8)	69.4(56.4)	47.0(43.3)	14.6(22.5)	0.0(0.0)	-	-
80	,,	88.2(69.9)	82.3(65.1)	77.4(61.6)	68.7(56.0)	47.9(43.8)	-	-	-	-
50+65	,,	89.6(71.2)	84.1(66.5)	78.2(62.2)	89.4(71.0)	81.3(64.4)	71.9(58.0)	55.9(48.4)	17.2(24.5)	0.0(0.0)
50+80	,,	92.3(73.9)	85.3(67.5)	81.3(64.4)	74.7(59.8)	47.7(43.7)	90.7(72.3)	85.5(67.6)	76.6(61.1)	66.0(54.3)
50+65+80	,,	92.3(73.9)	84.0(66.4)	80.0(63.4)	90.7(72.3)	80.0(63.4)	91.2(72.7)	82.7(65.4)	78.7(62.5)	66.8(54.8)
60+90	,,	89.6(71.2)	85.5(67.6)	80.0(63.5)	73.3(58.9)	46.3(42.9)	92.0(73.6)	85.4(67.5)	76.6(61.1)	-
Tobacco decoction 1% at										
50	DAP	74.7(59.8)	70.2(56.9)	63.6(52.9)	10.6(19.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
65	,,	75.9(60.6)	70.7(57.2)	65.3(53.9)	13.0(21.1)	0.0(0.0)	0.0(0.0)	0.0(0.0)	-	-
80	,,	76.0(60.7)	71.9(58.0)	62.6(52.3)	12.4(20.6)	0.0(0.0)	-	-	-	-
50+65	,,	76.0(60.7)	70.2(56.9)	63.6(52.9)	73.5(59.0)	69.1(56.2)	14.3(22.2)	0.0(0.0)	0.0(0.0)	0.0(0.0)
50+80	,,	74.7(59.8)	70.7(57.2)	66.6(54.7)	11.4(19.7)	0.0(0.0)	74.7(59.8)	70.2(56.9)	56.1(48.5)	35.9(36.8)
50+65+80	,,	73.3(58.9)	70.7(57.2)	61.3(51.5)	78.5(62.4)	71.9(58.0)	76.0(60.7)	70.7(57.2)	60.1(50.8)	37.2(37.6)
60+90	,,	76.0(60.7)	70.3(57.0)	62.6(52.3)	10.2(18.6)	0.0(0.0)	76.0(60.7)	71.9(58.0)	57.3(49.2)	-
C.D. at 5 per cent		(3.9)	(5.6)	(4.0)	(5.2)	(4.9)	(3.6)	(2.2)	(3.1)	(2.4)

Figures in parentheses are arc Sin $\sqrt{x}$ values — Crop harvested below 20 per cent and thus the treatments became ineffective then. The data showed that the persistent toxicity of endosulfan, fenthion and fenitrothion were the same and the insecticides remained effective up to a period of four weeks after treatment. The mortalities in samples collected from plots treated with tobacco decoction showed that the efficacy of the treatment persisted for a period of two weeks only. In the third week the mortality dropped to the range of 10.6 to 13 per cent.

The persistent toxicity of the pesticides was not influenced by the stage of the crop. The mortalities of the weevil in soil collected at each interval from plots having 50, 65 and 80 day old plants were on par. The growth stage of the crop did not influence the persistent effect of tobacco decoction.

The mortalities of the weevil observed in samples collected from plots at weekly intervals after a single drenching or the last application in treatments with repeated drenching (50 + 65, 50 + 80 and 50 + 65 + 80) showed that the synthetic insecticides remained effective for four weeks and the tobacco decoction for two weeks, in both the cases. It showed that there was no cumulative effect observed in the successive application of the pesticide.

4.11. Integrated control of *C. formicarius*

4.11.1. For a less susceptible cultivar (Kanhangad local)

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 25 and Fig. 11.

The percentage of crown infestations in various treatments ranged from 9.26 to 17.43 and the results were on par and hence the treatments were significantly superior to the control (farmers' practice) which had 64.10 per cent crown infestation. The crown damage grade indices in the treatments also showed a similar trend. The DGI in the treatments ranged from 1.20 to 1.30 while in control it was as high as 3.01.

The percentage of tuber infestation (by weight) was lowest (2.27) in plots where cultural methods of control combined with chemical treatment were adopted and it was superior to all other treatments. In plots where chemical treatment alone was given, the tuber infestation was 6.29 per cent and in plots in which the cultural methods alone was practised the percentage of tuber damage was 9.60. The tuber damage in the control was very high (36.00 per cent). The damage grade indices of tuber also showed the same trend. The lowest index (0.47) was observed in plots under the cultural methods of control combined with chemical treatment and it was significantly superior to all other treatments. The above treatment was followed by chemical control alone (0.74) and cultural methods alone (0.85), the difference between the two being statistically significant. The tuber DGI in the control (3.28) was significantly higher than the remaining treatments. The number of adults emerged from stored tubers in the different treatments also showed the same trend. The minimum number (6.2) was recorded in tubers collected from the plots in which cultural methods of control and chemical treatment were given. It was

Table 25. Integrated control of *Cylas formicarius* on a less susceptible cultivar of sweet potato (Kanhangad local)

Treatments	Infestation on crown %	Infestation on crown DGI	Tuber damage % of infested tuber by weight	Tuber damage DGI	No. of adult emerged from 1 kg infested tuber stored for 30 days
Cultural methods alone	17.43 (24.68)	1.30 (1.139)	9.60 (18.05)	0.85 (0.921)	21.6 (1.334)
Cultural methods and chemical control combined	9.26 (17.72)	1.20 (1.095)	2.27 (8.66)	0.47 (0.688)	6.2 (0.790)
Chemical control alone	10.43 (18.84)	1.25 (1.116)	6.29 (14.52)	0.74 (0.862)	16.1 (1.206)
Farmers' practice (without any plant protection measures)	64.10 (53.19)	3.01 (1.736)	36.00 (36.86)	3.28 (1.812)	285.1 (2.455)
C.D. at 5 per cent	(7.04)	(0.110)	(5.32)	(0.098)	(0.071)

Treatments	Mean yield from plots (4.8m^2) Total tubers (kg)	Mean yield from plots (4.8m^2) Good tubers (kg)	Good tuber yield t/ha	Additional yield over control t/ha (Rs.)	Cost of treatment/ha (Rs.)	Gross income over control	Net addl. income	Cost benefit ratio
Cultural methods alone	7.550	6.825	14.2	6.9	1650	6900	5250	1 : 3.2
Cultural methods and chemical control combined	7.900	7.710	16.0	8.7	1900	8700	6800	1 : 3.6
Chemical control alone	7.200	6.750	14.0	6.7	2200	6700	4500	1 : 2.0
Farmers' practice (without any plant protection measures)	5.500	3.520	7.3	-	-	-	-	-
C.D. at 5 per cent	1.350	0.442	-	-	-	-	-	-

Treatments	Percentage of parasitization in the aerial vines	Total adult trapping - DAP 50	60	70	80	Total
Cultural methods alone	27.41 (31.57)	158	167	109	60	494
Cultural methods and chemical control combined	25.15 (30.10)	181	164	90	52	487
Chemical control alone	19.58 (26.26)	-	-	-	-	-
Farmers' practice (without any plant protection measures)	29.40 (32.84)	-	-	-	-	-
C.D. at 5 per cent	(5.16)	-	-	-	-	-

Figures in parentheses are transformed values of arc Sin $\sqrt{x}$, $\sqrt{x}$ and log x for percentage, DGI and number of adults emerged respectively

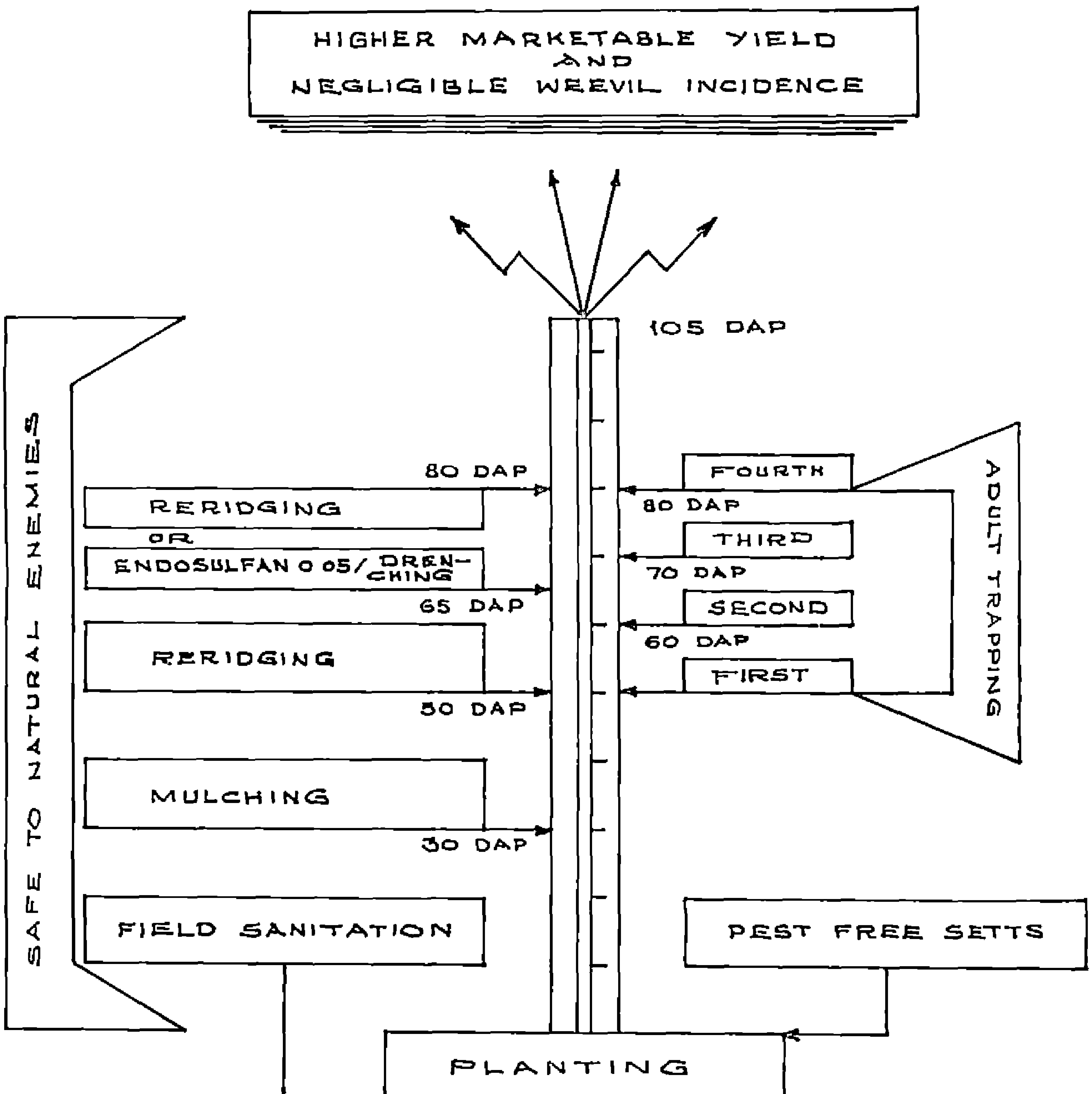
DAP Days after planting DGI Damage grade index followed by chemical treatment alone (16.1) and cultural methods alone (21.6) and the difference between the two being statistically significant. The number of adults emerged from stored tubers from the control plots was 285.1 and it was significantly higher than the remaining treatments.

The total yield was significantly lower in the control plot (5.5 kg per 4.8 m^2) while in the treatments it ranged from 7.2 to 7.9 and these were on par. There were significant difference among the yield of good tubers in treatments. The highest yield of good tubers (7.71 kg/4.8 m^2) was obtained from plots maintained under cultural methods of control combined with chemical treatment and was superior to cultural control alone or chemical control alone, the latter two being on par. The yield of good tubers obtained in the control plots was 3.52 kg only.

The occurrence of parasitoids was least (19.58 per cent) in plots protected with chemicals alone but it was also on par with the percentages in other treatments. The highest parasitization (29.40 per cent) was observed in plots maintained under farmers' practice.

The maximum net additional income obtained over the control was Rs. 6800/- which was obtained from the plots protected with a combination of cultural and chemical methods of control. The cost-benefit ratio of the treatment was 1 : 3.6. On the basis of net additional income and cost-benefit ratio the above treatment was followed by the treatments cultural control alone and chemical control alone.

FIG. 11.



INTEGRATED CONTROL OF SWEET POTATO WEEVIL *C formicarius*

4.11.2. <u>Integrated control of *C. formicarius* using a moderately resistant cultivar (Selopia)</u>

The data relating to the experiment and the results of statistical analysis of the same are presented in Table 26.

The percentage of crown infestation and DGI of crown were lower in treatments (4.30 to 6.08 and 1.12 to 1.20 respectively) than those in the control (17.3 and 2.13 respectively).

The percentage of tuber infestation and the tuber damage index were 10.13 and 1.21 respectively in the control. In treatments the percentage of infestation ranged from 2.08 to 2.17 and the tuber DGI ranged from 0.45 to 0.69 only. The number of adult weevils obtained from stored tubers was highest in the control (68.1) and it was followed in the descending order by chemically protected plots (10.1), plots protected by cultural methods alone (9.9) and plots protected by cultural and chemical methods of control (3.6). Based on the percentage of tuber damage all treatments were on par and significantly superior to the control. Based on the other criteria cultural control combined with chemica control was significantly superior to the other two treatments which were again on par between themselves.

The total yield and yield of good tubers were significantly higher in treatments than in the control. The additional yield of good tubers obtained over the control was in the range of 2.1 to 2.5 t ha^{-1} only. There was no significant difference in the percentage of parasitization observed in different treatments and the control, it was in the range of 10.38 to 14.57 only.

Table 26. Integrated control of *Cylas formicarius* on a moderately resistant cultivar of sweet potato (Selopia)

Treatments	Infestation on crown		Tuber damage		No. of adult emerged from 1 kg infested tuber stored for 30 days
	%	DGI	% of infested tuber by weight	DGI	
Cultural methods alone	6.08 (14.28)	1.20 (1.095)	2.17 (8.48)	0.69 (0.831)	9.9 (0.996)
Cultural methods and chemical control combined	4.30 (11.97)	1.12 (1.058)	2.08 (8.30)	0.45 (0.671)	3.6 (0.552)
Chemical control alone	5.40 (13.42)	1.15 (1.072)	2.17 (8.48)	0.64 (0.800)	10.1 (1.006)
Farmers' practice alone (control)	17.30 (24.58)	2.13 (1.459)	10.13 (18.56)	1.21 (1.100)	68.1 (1.833)
C.D. at 5 per cent	(4.89)	(0.187)	(1.70)	(0.082)	(0.091)

Treatments	Mean yield from plots (4.8m^2)		Good tuber yield t/ha	Additional yield over control t/ha (Rs.)	Cost of treatment/ha (Rs.)	Gross income over control	Net addl income	Cost benefit ratio
	Total tubers (kg)	Good tubers (kg)						
Cultural methods alone	5.50	5.38	11.2	2.3	1650	2300	650	1 : 0.4
Cultural methods and chemical control combined	5.60	5.49	11.4	2.5	1900	2500	600	1 : 0.3
Chemical control alone	5.40	5.28	11.0	2.1	2200	2100	-100	-
Farmers' practice alone (control)	4.08	4.30	8.9	-	-	-	-	-
C.D. at 5 per cent	0.91	1.17	-	-	-	-	-	-

Treatments	Percentage of parasitisation on the aerial vines	Total adult trapping - DAP				
		50	60	70	80	Total
Cultural methods alone	14.57 (22.44)	121	67	53	39	280
Cultural methods and chemical control combined	11.83 (20.12)	136	60	54	45	295
Chemical control alone	10.38 (18.80)	-	-	-	-	-
Farmers' practice alone (control)	13.15 (21.26)	-	-	-	-	-
C.D. at 5 per cent	NS	-	-	-	-	-

Figures in parentheses are transformed values of arc Sin $\sqrt{x}$, $\sqrt{x}$ and log x for percentage, DGI and number of adults emerged respectively

DAP Days after planting NS Nonsignificant DGI Damage grade index

The gross income over the control (farmers' practice) was highest (Rs. 2500/-) from plots protected with cultural methods of control combined with chemical treatment. But the net additional income from this treatment was Rs. 600/- only. The gross income over the control and net additional income were Rs. 2300/- and Rs. 650/- respectively from plots treated with cultural methods alone and Rs. 2100/- and Rs. (-)100/- in the case of plots protected with chemical control only. The cost-benefit ratios relating to the treatments ranged from 1 : 0.3 to 1 : 0.4 only.

4.12. Assessment of the reliability of different criteria adopted in various experiments for evaluation of *C. formicarius* incidence

The coefficient of variations (CV) in the data collected in different experiments under the different criteria adopted for evaluating the severity of damage caused by *C. formicarius* are presented in Table 27.

The CV of crown incidence in terms of percentage of crown infestation was available only in the six of the eleven experiments. In the rest of the experiments the percentage of crown infestation was not included as there was hundred per cent infestation. Among the six cases, the CV values for the percentage of crown infestation were less in three experiments while in the remaining experiments the CV values of damage grade indices

Table 27. Coefficient of variation for different criteria adopted in various experiments for assessing the severity of damage caused by C. formicarius

Survey/Experiments	Criteria adopted for evaluation				
	% crown infestation	DGI of crown	% tuber infestation	DGI of tuber	No.of adults emerged from infested tubers stored for 30 days (kg^{-1})
Survey - lowland	44.31	39.49	34.40	15.91	15.57@
Survey - upland	38.99	66.35	31.91	19.23	25.28@
Screening of varieties/cultivars for resistance to the pest	-	3.70	9.19	3.23	2.60
Incidence of the pest at different growth stages of the crop	13.18	3.18	11.08	8.07	3.76
Effect of reridging on the pest incidence	-	4.13	10.09	3.87	4.13
Effect of organic amendments on the pest incidence	-	4.28	10.18	3.17	2.71
Control of the pest with organic cakes and wood ash	-	4.34	6.98	2.41	1.72
Relative efficacy of different insecticides for the control of the pest	-	5.43	30.02	9.72	6.46
Assessment of optimum frequency of soil drenching with insecticides at different intervals for the control of the pest	6.20	15.59	17.00	1.94	7.39
Integrated control using less susceptible cultivar Kanhangad local	18.35	6.45	20.34	6.80	3.66
Integrated control using moderately resistant cultivar Selopia	22.72	28.25	11.57	7.15	6.18

- 100% incidence   DGI Damage grade index

@ Weevil population for 10 plants

were less. Thus two criteria were not showing consistency in different experiments.

With reference to the three criteria adopted for the assessment of tuber damage, the CV values relating to the percentage of tuber infestation were far higher than the CV values relating to the other two criteria. With reference to the damage grade indices of tubers and number of adults emerged from stored infested tubers the CV values were very close in five experiments and in four experiments the CV values were higher in the data relating to the damage grade indices.

DISCUSSION

5. DISCUSSION

5.1. Survey on the occurrence of *C. formicarius* in Kerala

Sweet potato is largely grown in Kasaragod and Malappuram Districts in the northern region of the State, Palghat and Trichur in the central region and Quilon and Trivandrum in the southern region. The area under this crop in the remaining Districts of the State is very negligible. The above regions have been identified as three distinct agro-climatic zones of the State for the implementation of the National Agricultural Research Projects.

The crop is raised as a purely rainfed one in the upland regions of Palghat and Trichur Districts and as an irrigated crop in the lowlands of Quilon District. In Kasaragod, Malappuram and Trivandrum Districts both upland and low/wetland cultivations are available.

The soil types in the above Districts show wide variations, include alluvial, black loam, red loam or laterite groups. The planting is done on beds or ridges and in some places on mounds too. The harvesting is done early, 105 to 110 days in some locations while in other places it is up to 130 days after planting. Normally the crop of four months duration is cultivated only once in an year and in a few places it is cultivated once in two years. In very few places two crops of sweet potato were grown annually. In the many areas of Trichur and Palghat Districts the land is left fallow after one crop of sweet potato while in the other Districts crops like rice, tapioca, tobacco or horsegram are grown in rotation.

The above wide variations in the agro-ecosystem of the crop prompted the detailed survey in the present investigation with a view to identify the areas where the pest has not gained entry so far and also to estimate the extent and intensity of the damage done by the pest in the widely distributed areas under the crop. The extent and intensity of damage done by the pest were assessed in terms of the percentages of vines and roots damaged, damage grade indices of crown and tubers, and the number of weevils observed in/on the foliage and in tubers per 10 plants. The results obtained under the different criteria often show significant variations and the superiority of the treatments was judged on the basis of the overall agreement. In the survey of the insect pest normally only one or two of these criteria are adopted. In the present investigations the survey was carried out under all the five criteria. The entire area available under the crop has been covered in the survey and the samples have been drawn adopting purposive and stratified random sampling technique. This facilitated a reliable estimation of the yield loss caused by the pest in Kerala. Such a survey on C. formicarius is being done for the first time and this is the first survey done on the incidence of the pest in Kerala.

The detailed studies showed that the insect has got established in all the agro-climatic zones of the State as a major constraint in the production of the crop. The pest was seen in varying intensities in all the locations covered in the survey except in one place in Trivandrum District (Kottukal village) where the crop was completely free from the pest. This was the only one location in which a moderately resistant cultivar, Selopia, was seen cultivated. In all the other locations covered in the survey Kanhangad local was being cultivated. However in the second location in Kottukal village where Kanhangad local was cultivated there was a high incidence of C. formicarius. It showed that the resistance of the variety (Selopia) had significantly contributed to the single instance of pest free location noted in the survey. It also indicated the high potential of the use of resistant varieties for containing the pest.

Another remarkable observation in the survey is the contrast in the intensity of pest incidence in upland and low land cultivations (Tables 2 and 4 and Figs. 2 and 3). While the insect is not seen as a serious problem in lowland, under all the different criteria adopted for assessment, it has become a serious limiting factor in the productivity of the crop in the uplands of Kerala. The remarkable difference in the two situations is that the crop is grown with protected irrigation in lowlands while in uplands it is grown as a rainfed crop. The survey indicates that the cultivation of sweet potato with irrigation will reduce the damage from C. formicarius.

A scrutiny of the results obtained in the present survey in comparison with the already reported results relating to other sweet potato growing States in the country leads to some interesting observations. The percentages of crown infestation in Orissa, Bihar and West Bengal were reported as 56, 60 and 15 respectively, percentage of tuber as 33, 15 and 6 respectively and weevil populations per plant as 11, 8 and 4 respectively (Pillai and Prasad, 1983). The pest infestation in Kerala is on par with that of Orissa and Bihar where the crop is grown very extensively, to the tune of ten times than that of Kerala. The pest incidence in Kerala is higher than that of West Bengal. The congenial climate prevailing in the south throughout the year might have contributed significantly for the better establishment of the pest in Kerala. Data on the incidence of the pest in the other southern states of the country, based on field surveys, are lacking. The results reported from the experimental stations in Tamil Nadu and Karnataka indicate that the pest is quite serious in the above States also. The percentages of crown and tuber infestations reported went up to 70 and 40 respectively (Subramanian, 1959; Subramanian _et al_., 1977; Jayaramaiah, 1975a). However the continuous cultivation of the crop in experimental fields will contribute to the high build up of the weevil population, especially because the life stages of the pest continue to thrive in large numbers in the left over residues of the crop. This serves as a source of inoculum for the succeeding crop. The percentages of crown and tuber damage observed in the experimental plots laid out in the Agricultural College Farm for the present investigations also were far higher than the incidence observed in the survey.

Based on the mean values, under different criteria, for the different Districts (Tables 2 and 4) and from the statistical analysis of the data on the distribution of the locations covered in the survey in different ranges of incidence/damage (vide. Tables 2a and 4a) it was found that incidence of C. formicarius in the different Districts did not vary significantly, though under some criteria the intensity of incidence was a little less in the southern Districts. Thus the pest is seen established equally well in the different agro-climatic zones of the State and this clearly indicates the wide adaptability of the insect to the varying agro-climatic conditions.

The intensity of pest damage and population of the insect showed variations within each District and under the different criteria adopted for assessment of damage. As pointed out in the results, high or low levels of incidence was not observed in contiguous areas of any District. The incidence in one of the two holdings in some villages remained low, the second holding in the respective villages showed high incidence and consequently locations with similar intensity of infestation were seen distributed wide apart within the District. Thus areas with distinct levels of pest incidence could not be identified within any of the Districts covered in the survey.

Since the soil types and cultural practices within the Districts showed remarkable variations, the associations of these factors with the extent and intensity of damage caused by the pest and with population of the insect were evaluated. As shown in the results in lowlands maximum incidence of the pest was seen in black loam soils, it was followed by red loam and alluvial types of soil and in upland situations the red loam soil showed highest incidence and it was followed by laterite and alluvial soils. The higher clay content of the black loam and red loam soils induces higher cracking and this may render the tubers more accessible to the female weevils settling for egg laying and hence the quick build up of populations and higher level of damage observed. This observation is in agreement with some of the earlier findings also (Rabindranath, 1979; Eusebio, 1983).

Another important factor seen associated with higher crown and tuber damage and weevil population in the lowland as well as upland situations is delaying harvest beyond the maturation of the crop. Kemner (1924) and Pillai et al. (1987) also recommended the avoidance of delayed harvest for minimising weevil damage.

In lowland situations the normal practice observed is the growing of one crop of sweet potato rotated with rice or tobacco. In limited number of locations two crops of sweet potato were seen raised every year and percentage of infested tubers in such holdings were significantly higher. But under the other criteria adopted for the assessment of results, the differences were not statistically significant. In upland situations as shown in the results, one crop of sweet potato alone was being raised every year followed by fallowing and in some locations rice, tapioca or pest was seen in black loam soils, it was followed by red loam and alluvial types of soil and in upland situations the red loam soil showed highest incidence and it was followed by laterite and alluvial soils. The higher clay content of the black loam and red loam soils induces higher cracking and this may render the tubers more accessible to the female weevils settling for egg laying and hence the quick build up of populations and higher level of damage observed. This observation is in agreement with some of the earlier findings also (Rabindranath, 1979; Eusebio, 1983).

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As clearly seen in the results (Tables 2, 4 and 5) the upland crop was seen suffering heavily from the pest compared to the incidence in the lowland under all the criteria adopted for the assessment of results. The regular irrigation provided in the lowland, keeps the soil moist throughout and reduces the tendency for cracking during the bulking of roots and this in turn reduces the accessibility of the weevils settling for egg laying on tubers. The favourable effect of irrigation for reducing the weevil damage was reported by Trehan and Bagal (1957). Yu (1983) also reported that in soils with high water retention capacity, the sweet potato crop had low weevil damage.

5.1.1. Natural enemies of *C. formicarius*

The parasitoids *Rhaconotus* sp. and *Bracon* sp. and the predator *Drapetis* sp. observed in the survey were distributed in most of the holdings in lowland and upland situations. As in the case of pest, these natural enemies were more abundant in upland situations. But the population of the biocontrol agents did not show definite correlation with the weevil population. Though the above natural enemies were recorded in India by Rajamma (1980), no earlier report is available on the distribution of these natural enemies in Kerala. Reports on the successful utilization of parasites and predators for the control of the weevil are also lacking. Since they are found on the weevil grubs present in the vines of the plant, drastic reduction in the population in tubers through these agents is not feasible. From Cuba Castineiras *et al*. (1982) reported higher yields from fields having the incidence of a big headed ant predator - *Pheidole megacephala*.

5.2. Yield loss caused by *C. formicarius* in Kerala

The annual yield loss estimated in the present investigation was 9604 tonnes and the value of this at a very moderate price level would amount to Rs. 96.04 lakhs. Around 54 per cent of the loss is incurred by Palghat District and the loss suffered by Malappuram and Kasaragod Districts amount to 19.91 and 19.38 per cent respectively. The loss in the remaining Districts was 6.95 per cent of the total loss. This information highlights the need for concerted effort for controlling the pest in Palghat, Malappuram and Kasaragod Districts in the State.

5.3. Alternate hosts/harbouring plants of *C. formicarius*

Among 14 species of *Ipomoea* recorded as alternate hosts of *C. formicarius* from India (Subramanian, 1959; Jayaramaiah, 1975a; Pillai and Lal, 1976), four species viz. *I. purpuria*, *I. biloba*, *I. paundurata* and *I. hispida* were found during the survey in Kerala. The former two were noted in all the Districts surveyed and *I. hispida* was found in Trivandrum, Quilon and Kasaragod while *I. paundurata* was noted in Malappuram and Palghat Districts only. The wide prevalence of *I. purpuria* and *I. biloba* in Kerala prompted a detailed study on their suitability for the multiplication of the weevil and it was done under laboratory conditions. The pest is found to complete its life cycle successfully in the above hosts though the duration was double than that observed on sweet potato. The results showed that these alternate hosts serve an important role in maintaining the pest in the field throughout the year though the crop is available only for a short duration of 4-5 months in an year and hibernation is not common among insects under the weather conditions prevalent in South India.

The harbouring plants observed in the survey were *Amaranthus viridis* and *Vigna sinensis*. On these the weevils survived for a period of 30 - 45 days under laboratory conditions and probably under field conditions they can thrive more and thus contribute significantly to the survival of the pest during the off-season of the crop.

The observations on the alternate hosts and harbouring plants highlights the necessity for keeping the sweet potato fields and surroundings free from these plants to keep the population of the weevil under control. The importance of this field operation in the control of C. formicarius had been stressed by many earlier workers also (Reinhard, 1923; Wood, 1976; Talekar, 1983).

5.4. Screening of sweet potato varieties/cultivars for resistance to C. formicarius

Though effective measures for controlling C. formicarius using insecticides are available, the technology is seldom adopted by farmers. It is mainly because sweet potato is a crop raised on marginal lands unsuitable for growing more remunerative crops and the farmers keep the input cost at the minimum level. In this context availability of resistant varieties will go a long way in checking the depradations of C. formicarius in the field.

Though intensive researches in this line have been carried out in many centres in the world, very little effort has been made in India in this direction. Subramanian (1959) screened ten varieties in the field and concluded V 10 (Coimbatore selection) and B 4004 (obtained from U.S.A.) as less susceptible. Jayaramaiah (1975c) screened ten cultivars in a field experiment and observed that the local cultivars with hard crown and long stalked tubers were less susceptible. Pillai and Kamalam (1977) evaluated 127 genotypes at CTCRI and concluded that accessions with long necked tubers were less susceptible. The CTCRI varieties H 268, H 633

(Pillai and Nair, 1981), 75 OP 40, 75 OP 59, 76 OP 217 and 5 x 45 (Anon., 1983; Pillai *et al*., 1987) were reported as less susceptible in field than the local susceptible standards used. From Coimbatore Thamburaj *et al*. (1981) identified CO 2 and from Bihar Singh *et al*. (1982) reported RS 5 as less susceptible varieties of sweet potato. The above varieties are not being cultivated extensively in any of the sweet potato growing tracts in India. In Kerala also Kanhangad local is the cultivar that is being extensively grown by the farmers. In this context all varieties which could be obtained from the different centres of sweet potato research in India and the local cultivars which could be collected through an intensive survey in the State, were screened in the field in three successive seasons to identify the available resistant varieties/cultivar, if any.

As mentioned in the results the relative resistance in the varieties/cultivars was assessed in terms of percentage of tuber infestation, damage grade indices of tuber and the number of adult weevils emerging from infested tubers stored in the laboratory. The grouping of varieties was done on the basis of mean and standard deviation following the methods adopted by Talekar (1982a). Such an extensive screening of sweet potato varieties/cultivars, under varied criteria, had not been undertaken so far in India.

Based on the results of the pooled analysis of the data obtained in the three seasons, none of the entries was found immune to the incidence of the pest. The cultivar Selopia and

Maruthipooven and varieties H 268, H 620, 76 OP 217 and 76 OP 219 were classified as 'moderately resistant (MR) under all the criteria adopted for evaluation. Similarly Muttavella and Kalmegh were rated as 'less resistant' (LR). The varieties which fell in these two top groups (MR and LR) were tested for their consistency in performance in the three successive seasons.

The results revealed that Selopia, Maruthipooven, H 268 and H 620 could be ranked as 'moderately resistant'. 76 OP 217 and 76 OP 219 fell in the 'moderately resistant' group in two seasons and in the other season the variety 76 OP 217 came in the 'moderately resistant' group under tuber DGI criterion and in the 'less resistant' group under adult emergence and percentage of tuber infestation. The variety 76 OP 219, Muttavella and Kalmegh were in 'less resistant' group in two seasons but in one season both fell out of 'moderately resistant' and 'less resistant' categories. Thus based on the performance under different criteria of evaluation and for consistency in the three seasons the local cultivars Selopia and Maruthipooven and CTCRI varieties H 268, H 620 and 76 OP 217 were considered superior with reference to their relative resistance to the weevil.

Based on CD values (Table 7) Selopia was identified as significantly superior to all entries in the experiment under all the criteria adopted for the evaluation. H 268, H 620, Maruthipooven and 76 OP 217 were on par but inferior to Selopia. Among the above selected entries, the yields obtained from

76 OP 217, H 268 and Selopia were on par whereas the yields of H 620 and Maruthipooven were significantly inferior to the former entries. The yield obtained from Kanhangad local (a less susceptible cultivar), the most popular cultivar grown in Kerala, also was on par with 76 OP 217, H 268 and Selopia. The size and shape of tubers and pigmentation of tuber skin and flesh of the above varieties were within acceptable limits. The moisture content of the tubers in Selopia was on the higher side while dry matter, starch and sugar were on the lower side when compared with the cultivar Kanhangad local as well as the variety 76 OP 217. But the percentages of these components were within the limits of the composition of many high yielding lines evolved by AVRDC, Taiwan (Anon., 1982b). These varieties can hence be popularised in Kerala for limiting the pest incidence and for increasing yield.

Because of the variations in the levels of resistance shown by the different entries in the experiment and in their morphological and physiological attributes the association of these was statistically analysed. The tuber damage grade indices and number of adult weevils emerging from stored tubers were higher in white skinned tubers than in yellow or red skinned ones.

The flesh colour of tuber in different entries also showed an association with the incidence of the weevil. The percentage of tuber infestation, DGI of tuber and the number of adults emerged from stored infested tubers were more in the white fleshed entries than in yellow or orange fleshed ones.

The level of weevil resistance as shown in all the four criteria was associated with latex content of the tubers. Entries with higher latex content showed less weevil incidence. Pillai and Kamalam (1977) reported that the pest preferred varieties/accessions having low latex content.

The depth of tuber in the soil was negatively correlated with the incidence of pest under all the criteria. This had been identified as an important contributing factor to the resistance (escape mechanism) of sweet potato varieties by Cockerham and Harrison (1952), Anon. (1976), Burdeos and Gapasin (1980) and Villanueva (1981).

The results of the chemical analysis of different components of tubers, of moderately resistant, less resistant and susceptible entries in the experiment showed that no definite conclusion could be established between the varying levels of resistance and moisture, dry matter, starch, sugar, total phenol, OD phenol and carotenoid content of the tubers. Lack of such correlations were reported earlier by Anota and Odebiyi (1984). But a correlation of dry matter, starch and carotene content of sweet potato tubers with the resistance to C. formicarius had been reported by Cockerham and Deen (1947), Anon. (1976), Pillai and Kamalam (1977) and Hahn and Leuschner (1981, 1982).

The number of weevils obtained from the inoculated tubers clearly indicated the existence of antibiosis in the varieties selected as moderately or less resistant entries (Table 8).

The number of weevils obtained from the tubers was directly correlated with increasing levels of susceptibility. Antibiosis had already been pointed out as an important factor contributing to the resistance in sweet potato (Barlow and Rolston, 1981; Mullen et al., 1981; Hahn and Leushner, 1982; Proshold, 1986).

5.5. Incidence of *C. formicarius* at different growth stages of sweet potato in the field

The results obtained from the experiments conducted for two seasons indicated that the weevils settled on the crop from fourth week after planting only. The sequence of occurrence of the different life stages in the crown showed that in general the beetles completed one life cycle in the crown. The population of the life stages in the crown reached the peak between 70 to 77 DAP and subsequently it showed a declining trend though all life stages including eggs could be observed on the crown till harvest. The damage observed on the crown (percentage of crown infestation and damage grade indices) showed an increasing trend from 28 DAP to 98 DAP, but the data were on par from 63rd to 105th DAP. The adult population in the crown and foliage recorded a sharp rise from 70 DAP and it was increasing up to 98 DAP. This is parallel to the increasing trend noted in the number of eggs on the crown between 42 and 70 DAP indicating that the adults observed on the plants during the period were emerging from the immature stages developing in the crown.

The eggs were observed on the tubers from 56 DAP but there was a sharp rise from 70 DAP. This period coincides with period of emergence of the adults from the crown. The increase in the number of eggs in the roots from 70 DAP and simultaneous fall in the number of eggs on the crown showed that the weevils emerging from the crown were largely descending and settling on the roots for egg laying.

As in the case of crown, in the tuber also the weevils completed only one generation. The fully formed weevil was first noted inside the tubers on 86th DAP. The generation commencing with the eggs laid by the weevils will not get time to complete another generation prior to the harvest of the crop which is done normally between 105 and 110 DAP. Large number of immature stages were observed in tubers even at the time of harvest and it showed that the infestation is likely to continue in the tubers in store and in the crop residues left in the field after harvest. Coinciding with the occurrence of the life stages of the weevil in and on tubers the extent of damage done by the pest, as shown by the percentage of infestation, damage grade indices and the number of adult weevils obtained from stored infested tubers, also varied.

The overall indication is that the crown remained highly susceptible to the pest attack between 42 DAP and 70 DAP. Remoroza (1978) in Philippines also observed that crown remained susceptible from 42 DAP than at younger or older stages. In subsequent studies in Philippines the susceptible stage of the crown was adjudged between 56 and 77 DAP (Sanchez, 1981; Sanchez *et al.*, 1984).

Though the number of eggs on tubers reached high levels only after 70 DAP the occurrence commenced from 49 DAP. The initial lot might have been contributed by the weevils migrating from the adjacent fields and those laid after 70 DAP might be by the weevils emerging from the crown. Hence it will be desirable to protect the tubers around 50 DAP from the migrating weevils and around 70 DAP from the weevils emerging from crown. In Malaysia, Hua (1970) observed higher population of weevils on the crop from 50 DAP. Eusebio (1983) reported from Philippines that the infestation of roots commenced only from 44 DAP. These observations are in broad agreement with the present findings.

The life cycle of insects is known to be influenced considerably by the climatic factors and hence the above durations may show variations from place to place. But the data collected in the field experiments conducted during July-October '84 (rainy season) and January-April '85 (summer season) in the present investigations did not show remarkable variations. In this connection it may also be noted that the variations in the climatic factors during the two seasons were not so conspicuous (vide. Appendix IV) since normal rain was not received during the period of the experiments.

5.6. Effect of reridging on the incidence of C. formicarius

The results of the experiment showed that reridging as a cultural operation for the control of C. formicarius was effective since in many treatments, the incidence of the pest was significantly low when compared to that of control.

The highest reduction in the percentage of tuber infestation was observed in treatment 7 (T_7) and T_8, T_9 and T_{10} came on par with the same (pooled data). In treatments T_7, T_8, T_9 and T_{10} the reridgings were commenced at 30, 40, 50 and 60 DAP respectively and the reridging in all the treatments was terminated at 90 DAP. Parity in the efficacy of the above treatments showed that commencing the treatment at 60 DAP was as effective as the commencement of the treatments at 30, 40, or 50 DAP.

Among the treatments preceeding T_7, only T_6 came on par with it. In these two treatments reridgings were commenced at 30 DAP and the reridging was terminated at 80 DAP in T_6, while in T_7 it was at 90 DAP. The parity of the two treatments showed that reridging could be terminated at 80 DAP instead of 90 DAP in T_7 without losing the efficacy of treatment significantly. Thus commencement of reridging at 60 DAP and terminating the same at 80 DAP was found optimum for reducing the percentage of tuber infestation by C. formicarius. The results obtained in the first and second season experiments were in full agreement.

Assessment of the results in terms of the tuber damage grade indices following the procedure detailed in preceeding paragraph, showed that in the pooled data and for data obtained in second season the optimum period for reridging was between 50 and 60 DAP, while in the first season the corresponding period came between 50 and 80 DAP.

With reference to the numbers of weevils obtained from the infested tubers collected from treated plots, it was seen that the crop should be given reridging at 60 DAP (pooled data). In the first season experiment the optimum period was observed between 60 and 70 DAP and in the second season it was identified between 50 and 60 DAP. Taking the extreme limits of the optimum periods observed under the different criteria adopted for the assessment of results, reridgings done between 50 and 80 DAP was chosen as the best for the control of _C. formicarius_.

Though reridging was suggested as a method for controlling _C. formicarius_ by earlier workers (Passalow and Rossiter, 1962; Remoroza, 1978; Burdeos and Gapasin, 1980) the number of reridgings required and the optimum stage of the crop for the treatment had not been fixed so far. One reridging at 60 DAP was recommended from Nigeria (Anon., 1976) and two reridgings done at 28 and 42 DAP were found effective against the pest in Philippines (Pardales and Cerna, 1987).

The weevils gain access to the tubers through the numerous cracks developing in the soil at tuberization. The period between 50 and 80 DAP is the active phase of bulking of the roots. Prevalence of weevils in the field was also found at high levels from

56 to 91 DAP. The reridging done at the optimum intervals of 50 - 80 DAP would seal the soil cracks at the peak activity of the weevils and thus reduce the weevil damage to the tuber significantly. Though the technique does not give complete protection to the tubers, the extent of reduction in weevil damage was remarkably high. Obviously this method can be considered as a very promising component of an integrated pest management system.

5.7. Effect of organic amendments on the incidence of *C. formicarius*

The efficacy of *Eupatorium* and peruvalam applied at 5 t ha^{-1} at the time of planting was reported by Johnson *et al.* (1979) and Rajamma (1982). Since the incidence of the pest is crucial at the later stages of the crop, the application of the organic amendments at the time of planting may not remain very effective. In this context the effect of shifting the time of application to 30 DAP and reducing the dose to 3 t ha^{-1} was studied in the present experiment.

The results obtained from the two field experiments revealed that application of *Eupatorium*, peruvalam, lemongrass and punna reduced the percentage of tuber infestation when compared with the control as well as with other treatments. But under the different criteria adopted for evaluation and also from the results obtained in the two seasons, *Eupatorium* and peruvalam showed consistently superior performance. Hence the above treatments were chosen for containing the pest incidence in the field.

The inhibitory effect of the above organic amendments on the pest may be attributed to the enhancement of soil moisture caused by mulching (Smee, 1965; Anon., 1986a) and also the reduction in the soil cracking due to the treatment. In addition, the insecticidal repellent and hormonal effects attributed to the extracts of Eupatorium and peruvalam also might have contributed to the reduction in the pest incidence.

5.8. Use of organic cakes and wood ash for the control of sweet potato weevil (C. formicarius)

Johnson et al. (1979) reported that mahwa cake and punna cake applied at 2000 kg ha^{-1} at planting of sweet potato reduced the incidence of C. formicarius significantly. Pillai et al. (1981) and Rajamma (1982) tried the lower doses of some of the organic cakes and found them ineffective. In this context, field experiments were carried out to study the performance of neem cake, punna cake, mahwa cake and wood ash, each at three different levels to arrive at an economically viable and effective dosage for the control of sweet potato weevil. Possibility of enhancing the efficacy by delaying the time of application to 30 and 50 DAP was also assessed.

From the results already presented it may be concluded that the weevil population can be significantly controlled by adding mahwa cake and the treatment should be with minimum dose of 1000 kg ha^{-1} applied at 50 DAP. Neem cake applied at 1500 kg ha^{-1} at 50 DAP also came on par with the above treatment.

Wood ash which is commonly considered by the farmers as an inhibiting substance, was found ineffective for controlling the pest or for reducing the damage.

5.9. Standardisation of techniques for trapping sweet potato weevils in the field

Possibility of reducing damage caused by C. formicarius by trapping the adult weevils in the field using fresh cut tubers of sweet potato was pointed out long ago (Eddy, 1942; Cockerham and Deen, 1948). Recently in 1982 Bartolini also observed it as a promising method for controlling the pest. But basic informations required for the adoption of the idea as a definite method of control in field were lacking. Hence a series of experiments were included in the present investigations for standardising the techniques for the trapping of weevils in the field. Following are the conclusions drawn from the various experiments.

Sweet potato tubers, sweet potato vines and vines of Ipomoea purpuria were tried alone and in combination with vinegar, yeast and/or jaggery. Sweet potato tubers were found to be most attractive to the adults of C. formicarius and hence chosen as suitable bait to be used in traps.

Trapping of weevils from an infested sweet potato field at two hour intervals showed that the beetles were attracted to the trap in larger numbers between 16.00 and 22.00 h and the catch declined drastically between 22.00 and 08.00 h and was negligible between 08.00 and 16.00 h. Howard (1982) in his studies on the behaviour of the weevils observed that the males became active at night and the activity reached the peak at 21.00 h. Proshold (1983) observed that at night, males moved on to the plants, while females moved to the root for oviposition.

In evaluating the desirability of setting traps in the field at 16.00 h (beginning of weevil activity) and collecting and removing the beetles at bihourly intervals, at 22.00 h (end of peak activity) or at 06.00 h the next day showed that the numbers obtained in all the above methods were on par. The results showed that the beetles attracted to the tubers and settled on them, did not move away from the bait. Setting up the trap at 16.00 h and collecting and destroying the catch at 06.00 h the next day is convenient for adoption.

Baiting with sweet potato tubers of varying diameter, cut crosswise or lengthwise with and without daily changing showed that cut tubers of 6 cm diameter changed daily was ideal for maximising the catch of C. formicarius. The chipping of the cut surface did not restore the attractiveness of the tubers remarkably. This indicated the possibility of some aroma in fresh tubers which declined over a period of 24 to 48 h rendering the bait ineffective in the traps. If the trap is to be continuously used the bait has to be changed daily.

Experiments using varying quantities of the bait showed that tubers of 100 g lots were as effective as 200 or 300 g lots for attracting the weevils while 25 and 50 g lots were less effective.

When the traps were placed at 3, 5, 10 and 15 m spacing in field, the distances of 3 and 5 m came on par on the basis of the number of weevils trapped and hence the 5 m spacing was chosen as the best.

The effect of trapping the weevils done at intervals of 3, 7, 10 and 15 days between 50 and 80 DAP was studied in terms of the four criteria adopted in the earlier experiments. The results revealed that the trappings done at 10 day intervals were the optimum. Though this method alone did not completely control the damage done to the crop, there was a very conspicuous reduction in the intensity of damage as shown under the different criteria. The damage in plots maintained with insecticidal protection for comparison, however, had the maximum reduction in the extent of damage and it gave a significantly higher yield. Obviously trapping of adults done in combination with other methods of control would be ideal to check the pest incidence.

On the basis of the results obtained from the preceding experiments it is found that sweet potato tubers of 6 cm diameter cut to weigh 100 g, may be used as baits and the traps may be set 5 m apart in infested fields, four times at 10 day intervals from 50 DAP. The traps may be set up at 16.00 h and the weevils attracted to the bait may be collected and destroyed at 06.00 h the next day.

5.10. Chemical control of *C. formicarius*

The review of the publications on the chemical control of *C. formicarius* showed that a large number of chemicals, inorganic insecticides, chlorinated hydrocarbons, organophosphates, carbamates and synthetic pyrethroids have been recommended from time to time for the control of C. formicarius. Most of them were recommended for foliar application and in many cases repeated applications had to be adopted. This being prohibitively costly, the method got little adoption. For some time, the soil application of chlorinated hydrocarbons were being resorted to. But the long persistence of these chemicals in soil compelled the abandoning of the practice though it was often effective. In recent years granular insecticides like carbofuran and phorate were evaluated against the pest but being systemic, the results were not encouraging. Drenching the soil around the base of the vines with emulsions of some contact organophosphatic insecticides have been recently reported as an effective technology for controlling the pest (Rajamma, 1983). Field experiments for evaluating the efficacy of this methodology were included in the present investigations and the results of the experiments revealed that endosulfan, fenitrothion and fenthion were found superior and on par. These insecticides had already been recommended as foliar treatment for the control of C. formicarius by several workers (Butani and Verma, 1976; Waddil, 1982; Rolston, 1984; Sanchez et al., 1984; Rajamma and Pillai, 1985; Ray and Yazdani, 1985). The granular insecticides phorate and carbofuran were less effective. Lack of contact toxicity and less translocation of the toxicants to the tubers, where the insect breeds would have contributed to the poor performance of these insecticides. But soil treatment with phorate or carbofuran also had been recommended for controlling C. formicarius (Anon., 1974, 1978; Talekar, 1983). Granular insecticides are not seen widely recommended for the control of the pest.

The drenching of soil with the insecticides even at 90 DAP did not leave detectable residues in tubers at harvest and the finding revealed the safety of the method for large scale adoption.

The assessment of the population of actinomycetes, bacteria and fungi in the soil collected at two and thirty days after treatment with insecticides showed that the micro-organisms were not affected by endosulfan, fenitrothion, fenthion, monocrotophos and quinalphos @ 1667 l ha^{-1} of 0.05 per cent emulsions or phorate and carbofuran @ 1.5 kg ai ha^{-1}. The effect of insecticides on soil microflora reported earlier was also contradicting as elaborated under review of literature (vide. para 2.15.4).

Studies on the effect of soil drenching at different intervals after planting revealed that the treatments done at 50 and 80 DAP or 60 and 90 DAP or 50, 65 and 80 DAP were on par and it was followed by a single drenching at 65 DAP. Endosulfan, fenthion and fenitrothion and tobacco decoction were effective for the control of C. formicarius. Johnson et al. (1979) reported the efficacy of soil drenching at 30 and 60 DAP and Rajamma (1983) got good control of the pest by drenching at 50 and 70 DAP. But drenchings were not tried by the above authors at varying intervals as was done in the present investigations. The application at 30 DAP may not be purposeful since the incidence of the pest on tubers commence around 50 DAP only.

Bioassay of insecticide residues in soil drenched with endosulfan, fenthion and fenitrothion showed that the persistent toxicity was significantly high (over 52 per cent mortality) even at the fourth week after treatment while the persistent toxicity of tobacco decoction remained effective only for two weeks after treatment. The growth stages of the crop did not influence the persistent toxicity of the pesticide. Repeated treatment also did not give cumulative effect. The persistent toxicity of insecticides to *C. formicarius* was studied for the first time and the results revealed that frequent treatments at close intervals led to the mere wastage of insecticides.

5.11. Integrated control of *C. formicarius*

The following practices could be deduced for the control of *C. formicarius* based on the informations available in literature and on the conclusions drawn from the different experiments carried out in the present investigations.

4.11.1. Cultural methods of control

i) In the survey carried out in the sweet potato growing tracts of Kerala, it was observed that alternate hosts suitable for the multiplication of pest and harbouring plants giving shelter to them, during off seasons were available in plenty.

The population built up in the above plants served as a source of infestation for the new plantings. Hence all such plants should be removed from the fields and adjacent areas prior to planting.

ii) It is well known that the immature stages as well as adults of C. formicarius gain entry to new plantings through planting materials. To avoid this source of infestation plantings should always be done with tips of the vines on which the weevils seldom lay eggs.

iii) Application of Eupatorium or peruvalam leaves @ 3 t ha^{-1} at 30 DAP was found effective for reducing the weevil population, though the method did not give absolute control of the pest.

iv) The application of mahwa cake @ 1000 kg ha^{-1} at 50 DAP also reduced the pest incidence significantly but the lower dose of 500 kg ha^{-1} was ineffective. On cost basis, the treatment can be advantageously adopted by farmers at places where the material is cheap.

v) Reridgings done at 50 and 80 DAP reduced the incidence of the pest in the roots considerably. Though this method had been suggested as a practice for controlling the incidence of C. formicarius, the optimum stage for the adoption of this practice was worked out for the first time. The commencement of egg laying on tubers at 56 DAP and the peak of it at 91 DAP, indicated the high activity of gravid females in the root zone during this period. Obviously the reridgings between 50 and 80 DAP would limit their movements in and out of the soil for mating and egg laying and thus result in the reduction in the population.

vi) Trappings of adults as a control method had already been suggested by earlier workers. The various steps for this practice were standardised through the experiments in the present investigations. The traps fabricated with wire mesh (four per square inch) and baited with sweet potato tubers of 6 cm diameter cut to give 100 g weight were found most suitable. The setting up of the traps at 16.00 h spaced at 5 m and the removal and destruction of the weevils attracted to the bait at 06.00 h next day were ideal. Such collections done four times, at 10 day interval from 50 DAP reduced the pest incidence and increased the yield remarkably.

vii) It was observed in the survey that in locations where the harvest was done early (between 105-110 DAP) the tuber damage was significantly low. The studies on the incidence of the pest at different growth stages of the crop revealed that the grubs of the weevil were abundantly available in tubers even at the time of harvest (105 DAP). Obviously the retention of the crop beyond 105 DAP will be detrimental. Hence harvest should be done early around 105 DAP in Kerala.

viii) Collection and removal of crop residues immediately after harvest had been recommended from very early days (Reinhard, 1923; Murakami, 1933a) and the practice had been stressed by recent workers too (Villanueva, 1981; Sanchez *et al*., 1984). The observations made in the present studies revealed the presence of limited populations of all the life stages of C. formicarius in the crown and large number of them in the tubers at harvest. If the residues of these are left in the field, large populations of adults will emerge and thrive in alternate hosts and harbouring plants, even if the next planting of sweet potato is done after a fallow and even after raising one or two crops unsuitable for the survival of C. formicarius. Hence for restricting the population of the insect in the areas under sweet potato, removal and destruction of crop residues at harvest should be adopted as an important practice.

5.11.2. Chemical control of C. formicarius

Because of the severe damage done by C. formicarius a vast array of insecticides have been tried and recommended against this pest from time to time. The chlorinated hydrocarbons were being extensively recommended world over for the control of C. formicarius. The realization of adverse residual effect led to the replacement of organochlorines with newer organophosphates, carbamates and even pyrethroids. The technology was quite effective in controlling the pest. But repeated application of costly chemical recommended in the technique were prohibitively expensive and hence it was seldom adopted in the field. In recent years the use of these chemical as soil drench with a lesser frequency has been suggested. The studies carried out in the present investigations clearly established that drenching with endosulfan, fenthion or fenitrothion 0.05 per cent emulsion at 50 and 80 DAP would give satisfactory control of the pest in the field. But continuous adoption of the chemical method for several years may render the technique ineffective due to pest resistance and resurgence as observed in numerous instances in the field of applied entomology.

5.11.3. Cultural methods combined with chemical control

The chemical method of control as standardised in the present investigation is effective and viable. But it may become ineffective in the long run and the recent trend is to restrict the use of the toxic chemicals to the minimum possible level. Hence the integration of the cultural practices and chemical methods by substituting one of the reridgings in the former technology was felt desirable. As a single drench, the treatment done at 65 DAP was found most effective in the present investigations and hence it was included in the integrated control technique.

Incorporating the above said methods of control, a field experiment was carried out using the cultivar Kanhangad local and the results already presented showed that the cultural methods combined with chemical control was significantly superior with reference to percentage of tuber infestation, the DGI of tubers and number of adults emerged from stored tubers and the yield of marketable tubers. On the basis of cost-benefit ratio also this integrated method of control emerged as the best. It was closely followed by the methods consisting of cultural practices alone. The chemical control method was least effective but significantly superior to farmers' practice. The data on the percentage of larval parasitism also showed that the use of cultural methods alone or the cultural methods combined with one insecticidal drenching was better for conserving the natural enemies in the ecosystem.

A similar field experiment was conducted using a moderately resistant local cultivar Selopia and the results showed that the efficacy of three treatments in reducing the pest incidence was not as evident as in the experiment using the cultivar Kanhangad local. The cost-benefit ratio was either negligible or negative. This was due to the low incidence of the pest on the Selopia. The results also indicated the high potential of using a moderately resistant variety for containing the pest population in the field. This cultivar identified for the first time with relatively high level of resistance gave an yield on par with the most popular cultivar grown in Kerala, Kanhangad local.

In the analysis of chemical constituents Selopia was found to have a higher water and carotene content and lower dry matter, sugar and starch content compared to 76 OP 217 and Kanhangad local. But these were within the limits of many high yielding varieties evolved by AVRDC, Taiwan (Anon., 1982b). Results indicated the possibility for popularising this variety in Kerala and thus minimise the need for costly plant protection measures.

Though no systematic work was carried out in India on the integrated control of sweet potato weevil so far, the need and possibility of integrating known methods for controlling C. formicarius were suggested by earlier workers too (Butani and

Verma, 1976; Pillai et al., 1987). In China integrated control methods are being practised extensively for the control of C. formicarius (Bartolini, 1982). The practices followed in Taiwan consist of field sanitation, dipping of planting materials in carbofuran 0.05 per cent and crop rotation (Talekar, 1983). Integrated control method comprising, sanitation, trapping of adults and spraying with insecticides was recommended by Yu (1983). In Nigeria, the use of moderately resistant weevil lines with early planting, early harvesting and reridging was recommended as an integrated weevil management programme (Anon., 1986b).

5.12. Assessment of the reliability of different criteria adopted in various experiments for evaluation of C. formicarius

In the assessment of the incidence of C. formicarius in field various methods have been followed by scientists. In the present studies five criteria, two relating to the crown and three relating to the tubers, were adopted in all the observations. The reliability of these methods was tested by estimating the coefficient of variations in the data relating to each criterion in each experiment.

The results showed that the percentage of crown infestation was least dependable since under high pest pressure 100 per cent of the crowns got infested. When the intensity of attack was low the percentage of crown infestation and damage grade indices of crown were equally reliable.

The percentage of tuber infestation in different experiments showed distinctly higher CV values than in the other two criteria. It was thus clear that this method usually followed for the assessment of results in experiments was far inferior to the damage grade indices of tubers and the observation on the number of adults emerging from samples of infested tubers collected at harvest and stored for one month. Among the latter two methods the values were similar or varying slightly and inconsistently in different experiments. The results thus showed that the assessment of damage grade indices of tubers and the counting of the weevils emerging from stored tubers were more reliable than the other criteria followed in the present investigation. It may be desirable to follow both the methods in the assessment of results in the experiments relating to the incidence of *C. formicarius*.

SUMMARY

6. SUMMARY

Sweet potato is an important tuber crop grown all over the world. The incidence of sweet potato weevil *C. formicarius* has been identified as the major constraint in increasing the production and productivity of the crop. Methods for the control of the pest has been receiving the attention of researchers from very early days and many cultural and chemical methods have been proposed. Being high cost technologies, the recommendations are seldom adopted in field. A series of experiments were undertaken for evolving a cheaper and economically viable integrated technology for adoption. An elaborate survey was also carried out in the State covering the entire area under sweet potato, to assess the gravity of the problem posed by *C. formicarius*. The results obtained are briefly enumerated.

1. Survey on the incidence of *C. formicarius*

A detailed survey on the distribution of *C. formicarius* in major sweet potato growing areas of Kerala and the intensity of damage caused by the pest was carried out adopting a purposive and stratified random sampling technique. The surveyed areas included irrigated low/wet lands and rainfed uplands. The damages done to the crop was assessed in terms of percentage of crown infestation, damage grade index (DGI) of crown, percentage of tuber infestation, DGI of tuber and weevil population from samples of 10 plants selected at random in the field. The occurrence of natural enemies and alternate hosts of *C. formicarius* were also recorded in the survey. The salient findings include -

(a) The sweet potato weevil had got established in all the sweet potato growing tracts located in the three agro-climatic regions (northern region - Kasaragod and Malappuram, central region - Palghat and Trichur and southern region - Quilon and Trivandrum Districts) of Kerala, indicating the wide adaptability shown by _C. formicarius_ to varying agroclimatic situations.

(b) The intensity of pest incidence in low/wet lands of Kasaragod, Malappuram, Quilon and Trivandrum Districts was still not serious, while in the uplands of Kasaragod, Malappuram, Trichur, Palghat and Trivandrum Districts the pest had become a major limiting factor in the production and productivity of the crop. The major contributing factor to this phenomenon was identified as the irrigation given to the crop in the lowland areas.

(c) Based on District means for the different criteria and based on the statistical analysis of the data it was observed that the incidence of the pest in the different agro-climatic regions of the State did not show significant variations.

(d) The intensity of the pest attack in Kerala was almost on par with that of Orissa and Bihar where the area under cultivation is ten times than that of the State.

(e) Though the intensity of attack under different criteria showed wide variations within each District, contiguous areas with a particular level of pest incidence could not be identified within any District in the State.

(f) The soil type was found to influence the levels of pest incidence within the Districts. The incidence was higher in black loam and red loam soils than in alluvial soil.

(g) Retaining the crop in the field beyond 105 - 110 DAP was found as an important factor contributing to the pest build up and consequent crop damage.

(h) Based on mean percentages of tuber infestation, the crop rotation practices showed a significant association with pest incidence. Crop sequence with more than one crop of sweet potato in a year showed a significant higher pest incidence in lowland areas. But under other criteria adopted, in lowland, the crop rotation did not show any significant effect on pest incidence. The crop rotation practices followed in the uplands showed a significant association with the pest incidence under the criteria percentage of crown infestation and percentage of tuber infestation. However under remaining criteria, the crop rotation had no significant effect on the pest incidence in the uplands.

(i) The parasitoids Rhaconotus sp. and Bracon sp. and the predator Drapetis sp. were prevalent in significant levels in all the locations covered in the present survey.

(j) I. purpuria and I. biloba were the alternate hosts recorded in all the Districts covered in the survey. I.paundurata had restricted distribution in Malappuram and Palghat while I. hispida was found in Kasaragod, Quilon and Trivandrum Districts.

These supported the weevil population during the off season of the crop. *Amaranthus viridis* and *Vigna sinensis* harboured the adults of *C. formicarius* in the surveyed areas.

(k) The annual yield loss caused by *C. formicarius* was estimated as Rs. 96.04 lakhs and 53.77 per cent of this loss was accounted by Palghat District alone. The losses in Malappuram and Kasaragod Districts were 19.91 and 19.38 per cent respectively.

2. Screening of sweet potato varieties for resistance to *C. formicarius*

Forty varieties/cultivars obtained from different research centres in India and through a survey done in Kerala were screened for their relative resistance to *C. formicarius* in the field in three successive seasons. The results were assessed in terms of percentage of tuber infestation, damage grade indices of tubers and number of weevils emerged from infested tubers stored in laboratory. The entries showing lower weevil incidence under different criteria in pooled analysis of this data were chosen and consistent performance of these varieties in the different seasons was assessed. The results revealed that -

(a) Selopia a local cultivar was significantly superior to all other entries. Two hybrids H 268 and 76 OP 217 obtained from CTCRI were found to be on par and superior to other entries with reference to their reaction to the pest and yield. Though H 620 and Maruthipooven also came on par with above varieties regarding their reaction to *C. formicarius*, the yields obtained from them were too low.

(b) A correlation of the morphological characters of different entries with the incidence of C. formicarius showed that white skinned varieties/cultivars having white flesh were more susceptible than red skinned entries having yellow or orange flesh. The latex content of tuber and depth of tuber in the soil were found negatively correlated with levels of resistance. There was no significant correlation between the vine pigmentation, leaf lobing or tuber shape with pest incidence.

(c) No definite correlation between the chemical composition (moisture, dry matter, starch, sugar, total phenols, OD phenols and carotene content) of tubers and the resistance of the entries to C. formicarius could be identified. Less number of adults emerging from the inoculated tubers of 'moderately resistant' and 'less resistant' entries compared to 'less susceptible' and 'most susceptible' entries showed the existence of antibiosis as an important factor contributing to the resistance observed in sweet potato.

3. Incidence of C. formicarius on different growth stage of sweet potato

The incidence of the pest in the crown and tubers of sweet potato grown in the field at different growth stages of the crop was studied through two field experiments. The population of the life stages of the pest in crown and tubers were assessed at weekly intervals till harvest. The results showed that -

(a) The insect generally completed one life cycle each in the crown and tuber prior to harvest (105 days).

(b) The egg laying on the crown commenced from 42 DAP and the number of immature stages within the crown reached peak between 70-77 DAP and then the population showed a declining trend. Hence the susceptible stage of the crown was between 42 and 77 DAP.

(c) The egg laying on tubers commenced from 56 DAP and showed a sharp rise between 70 and 91 DAP.

(d) The adult weevils emerging from the crown did not generally reinfest the crown but migrated to the tubers for egg laying.

(e) The tubers should be protected adequately around 50 DAP and 70 DAP from ovipositing weevils.

(f) If harvested in time (105 to 110 DAP) the insect would not get sufficient time to complete the second generation inside the tubers.

(g) The larval and pupal stages in the tubers were at peak levels at the time of harvest and hence the crop residues left in the field at harvest must be burnt or burried deep in soil to prevent the population build up of the pest.

4. Reridging as a cultural method for controlling *C. formicarius*

The efficacy of reridging as a cultural practice for controlling the sweet potato weevil was assessed through two field experiments. The treatment consisting of seven reridgings at 10 day intervals between 30 and 90 DAP was kept as the mid point. The preceding and succeeding treatments were obtained by deleting one reridging each from the final or initial extremes. By assessing the effect of dropping reridgings from the extremes the phase of the crop during which the cultural operation proved effective could be assessed. The results showed that (a) reridgings done at 10 day interval between 30 and 90 DAP was the best and (b) the reridgings done between 50 and 80 DAP were as effective as reridgings done from 30 to 90 DAP. Hence reridgings at 50 and 80 DAP may be recommended as a method of cultural control for reducing the pest incidence.

5. Use of organic amendments for controlling *C. formicarius*

The efficacy of eight organic amendments for the control of *C. formicarius* was assessed in a field experiment repeated for two seasons. Based on the consistent results under different criteria adopted for evaluation and also for the two seasons, the application of leaves of *Eupatorium* or peruvalam at 3 t ha^{-1} at 30 DAP was found effective in the control of sweet potato weevil.

6. Use of organic cakes and wood ash for the control of *C. formicarius*

The efficacy of neem cake, mahwa cake, punna cake and wood ash, each at three different doses, applied at 30 and 50 DAP was assessed in terms of all the four criteria. The experiment was repeated in two seasons. Mahwa cake applied @ 1000 kg ha^{-1} or neem cake @ 1500 kg ha^{-1} applied at 50 DAP was consistently effective. The lower doses of these cakes and wood ash were ineffective.

7. Standardisation of techniques for trapping the weevils in the field

The method of trapping weevils of C. formicarius in the field was standardised through a series of laboratory and field experiments. The important findings are -

(a) Among different bait materials and their combinations tried, fresh sweet potato tuber was significantly superior to all the other treatments.

(b) The activity of the adult weevils in the field, assessed in terms of the numbers attracted to the trap at two hour intervals for 24 hours, indicated the period of peak activity of the insect was between 16.00 and 22.00 h.

(c) Setting the trap at 16.00 h and collecting and destroying the catch at 06.00 h the next day was on par with the collections obtained at other frequencies. It showed that the insects attracted to the bait did not move away from it during the whole night. This timing for the removal of weevils from the trap will be convenient for adoption.

(d) Tubers of 6 cm diameter cut lengthwise or crosswise and changed every 24 h was the best for trapping the weevils in field.

(e) Tuber cut to weigh 100 g was found as the optimum quantity for each trap.

(f) Setting the traps with 5 m spacing in the field was the best for collecting the weevils.

(g) The trapping done at 10 day intervals between 50 and 80 DAP gave significant reduction in the incidence of C.formicarius on sweet potato. This result was on par with the trappings done at 7 and 3 day intervals and was significantly superior to the trappings done at 15 day intervals. However the method did not give absolute control as compared to that of fenthion 0.05 per cent maintained as a check for comparison.

8. Chemical control of C. formicarius

Among quinalphos, fenthion, endosulfan, monocrotophos, fenitrothion (all used as 0.05 per cent emulsion), phorate and carbofuran (@ 1.5 kg ai ha^{-1}) applied as granules at 50 and 80 DAP, endosulfan, fenitrothion and fenthion were found significantly superior and consistent under the different criteria and in terms of the good tuber yield obtained. Residues of the insecticides were not detectable in harvested tubers. The populations of actinomycetes, bacteria and fungi in the soil were not significantly affected by the treatments.

The effect of drenching the soil with the insecticide at different growth stages of the crop was studied in a field experiment and the treatments done at 50 + 80 DAP or 60 + 90 DAP were found superior and it was followed by the single treatment at 65 DAP. Tobacco decoction was less toxic compared to the insecticides, but it also gave good control of the pest.

The persistent toxicity of the above insecticides applied in the soil was assessed through bioassay studies in the laboratory using the adults of C. formicarius as the test insect. The results showed that synthetic insecticide gave high toxicity (mortality above 50 per cent) for four weeks and tobacco decoction for two weeks after treatment.

9. Integrated control of C. formicarius

Based on the conclusions drawn from the different experiments a new strategy for the control of C. formicarius was drawn up. Three sets of treatments consisting of, cultural methods alone (removal and destruction of alternate hosts, selection of pest free planting material, mulching with Eupatorium leaves @ 3 t ha^{-1} at 30 DAP, reridging at 50 and 80 DAP, trapping of adult weevils from 50 to 80 DAP at 10 day intervals using 100 g sweet potato pieces as bait in traps placed 5 m apart and proper disposal of crop residues), chemical methods alone (drenchings with endosulfan 0.05 per cent at 50 and 80 DAP) and cultural methods combined with one chemical drenching at 65 DAP along with the deletion of re-ridging at 80 DAP were evaluated in a field experiment using 'less susceptible' Kanhangad local. The results revealed that the chemical methods combined with one drenching of insecticide was the most effective and beneficial. This treatment was followed by the chemical method of control and cultural methods alone. Cost-benefit ratios of the above treatments were in the reverse order.

A similar experiment using a moderately resistant cultivar Selopia detected in the survey and screened through repeated field experiments, was carried out and the results showed that though the variety was not immune to the pest, the level of incidence and damage were very low in the field. The effect of the different treatments was not evident in this experiment. The cost-benefit ratios also were either negligible or on the negative side. This indicated that the variety can be grown in Kerala without costly protection measures against C. formicarius.

An integrated technology consisting of cultural methods with one insecticidal drenching was found to be the best against C. formicarius. This technology will manage the pest population without causing detrimental side effects. The integrated technology if adopted extensively for a few cropping seasons in sequence will reduce the population of C. formicarius to negligible levels in the agro-ecosystem.

10. Assessment of the reliability of different criteria adopted for evaluation of C. formicarius incidence

The coefficient of variations in the data relating to the different criteria adopted for the assessment of results in the present investigations showed that the damage grade indices of the tubers and the collection of adult weevils from samples of infested tubers stored for one month were more reliable than the percentage of crown infestation, damage grade indices of crown and/or the percentage of tuber infestation.

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APPENDICES

APPENDIX I Incidence of *C formicarius* on different varieties of sweet potato and yield (mean of two replications)

Varieties (Hybrids/ Local cultivars)	Crown DGI			Mean infestation on tubers: % based on weight of infested tuber			Mean infestation on tubers: DGI			Mean infestation on tubers: No of adults emerged 30 days after harvest per kg of infested tuber			Yield kg/4 8 m²		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Selopia	2 7 (1 643)	2 1 (1 449)	1 9 (1 378)	8.6 (17.05)	10.4 (18 77)	10 1 (18 53)	1 2 (1.103)	1 5 (1 225)	1 3 (1 140)	50 4 (1.702)	65 9 (1 819)	39 7 (1 599)	5 75	6 00	4 05
H 268	3 0 (1 746)	3.0 (1 732)	2 3 (1 557)	28 0 (31.94)	22 8 (28 50)	14 3 (22 20)	2 6 (1 506)	2 7 (1 643)	1 9 (1 378)	110 9 (2 045)	114 3 (2 058)	107.9 (2 033)	6 10	6 26	3 80
70 OP 217	2 3 (1 516)	2 0 (1 414)	1 9 (1 378)	28.8 (32.46)	28 8 (32.48)	13 0 (21 10)	1 7 (1 303)	2 8 (1 672)	2.0 (1 399)	90.4 (1 956)	177 0 (2 248)	96 6 (1 985)	5 45	7 25	4 60
70 OP 219	2 8 (1 655)	2 1 (1 466)	2.2 (1 482)	23.9 (29 24)	38.8 (38 52)	24.9 (29 90)	2 6 (1 612)	2 6 (1 610)	1 9 (1 380)	171 8 (2 235)	182 0 (2 260)	84 3 (1 926)	3 25	6 25	3.35
F 620	3 0 (1 731)	2 6 (1 611)	2 8 (1 658)	25 8 (30 50)	21 9 (27 87)	23 1 (28 64)	2.2 (1 483)	2 5 (1 581)	2 1 (1 449)	105 0 (2 021)	109 9 (2 041)	128 8 (2 110)	4 05	4 20	2 00
H 633	3 2 (1 788)	3 3 (1 816)	3 1 (1 760)	34.3 (35 85)	35 3 (36.42)	30 3 (33 42)	3 2 (1 789)	3 1 (1 760)	2 3 (1 516)	249.0 (2 396)	226 5 (2 355)	145 5 (2 162)	3 85	6 05	2 75
X 5	3 2 (1 789)	3 1 (1 760)	2 5 (1 581)	29 4 (32 81)	34.1 (35 70)	31 8 (34.30)	3 1 (1.760)	3 0 (1 732)	2 6 (1 611)	211 3 (2 325)	209 9 (2 322)	239 3 (2 379)	4 25	6.20	3 60
C 43	3 0 (1.732)	3 0 (1.732)	3.2 (1.775)	50.4 (45 25)	43 7 (41.36)	31 6 (34.21)	3 2 (1.775)	2.8 (1 672)	2.9 (1.703)	231 7 (2 365)	150 3 (2 177)	204 2 (2.310)	2.70	5 60	1 80
Kalmegh	3.1 (1.760)	3 4 (1 844)	2 9 (1.703)	24.0 (29.34)	30.3 (33.39)	28.0 (31.92)	2 9 (1 703)	2.9 (1.703)	2.2 (1.482)	175 4 (2 244)	201 8 (2.305)	133.7 (2.126)	2 70	4.20	2 20
IB 440	3 1 (1 760)	3.3 (1.816)	3 4 (1 830)	32 5 (34.78)	27.6 (31.70)	31.6 (34 21)	3.1 (1.759)	2 9 (1 703)	3 0 (1 746)	189 2 (2.277)	167 5 (2 224)	248 3 (2 395)	3 60	4 50	1.75
H 2743	3 1 (1 760)	3 2 (1 788)	2.8 (1 673)	47.5 (43 55)	29 2 (32 69)	24 9 (29 90)	3 2 (1 774)	3.1 (1 760)	2 1 (1 449)	212 3 (2 327)	202.3 (2.306)	118 6 (2 074)	3 05	5 50	3 80
'aruthipoovan	3 5 (1 871)	3 1 (1 760)	2 9 (1 688)	22 4 (28.27)	22.1 (28.04)	25.7 (30 48)	2 8 (1 673)	2.8 (1.672)	2 1 (1 449)	121.6 (2 085)	123 3 (2 091)	153 5 (2 186)	2 70	4.70	3 65
Kanhangad	3 1 (1 700)	3.0 (1.732)	2 8 (1 673)	24.5 (29 70)	30.7 (33 64)	30.5 (33.40)	3 2 (1.775)	3 0 (1 732)	2.5 (1 581)	232 8 (2 367)	206 5 (2 315)	208 4 (2 319)	6 60	6 25	5.30
..ttavella	2 8 (1 672)	3 5 (1.869)	2 8 (1 672)	31 8 (34.32)	42 1 (40 48)	25 4 (30.24)	2.1 (1.466)	3 0 (1 732)	2 4 (1 548)	97 0 (1 987)	206 5 (2 315)	167 9 (2 225)	3.35	7 45	4 75
X 4	3 6 (1 897)	3 2 (1.788)	3.3 (1 816)	41.3 (40.01)	53 5 (47.01)	43 3 (41.07)	3 7 (1 910)	3.5 (1.871)	3 5 (1 870)	350.0 (2 544)	281 8 (2.450)	311 9 (2.494)	2.70	3.40	2 75
X 24	3 3 (1.816)	3.4 (1 844)	3 0 (1.746)	52.5 (46.44)	37.6 (37.80)	31.2 (33.97)	3.0 (1.732)	3.6 (1 897)	3 0 (1 732)	212 8 (2 328)	304 9 (2 484)	283 1 (2 452)	3 90	2 90	2 60
V 35	3 6 (1 897)	3.7 (1.922)	3 3 (1.803)	37 3 (37 66)	57.4 (49 24)	23.6 (29.08)	3.2 (1.789)	3 2 (1 816)	2.7 (1.643)	294.4 (2 469)	260 0 (2 415)	203 2 (2 308)	2 30	4 20	2 00
C /	3 6 (1 897)	3 6 (1 897)	3 3 (1 798)	50.0 (44.98)	52 2 (46 27)	37 5 (37 79)	3 0 (746)	3.2 (1 789)	2 9 (1 688)	142 9 (2 155)	213 3 (2.329)	233 3 (2.368)	2.20	2.75	3 25
75 OP 1	4.6 (2 156)	3 3 (1 816)	3 3 (1 816)	60 0 (50 80)	47.7 (43.68)	43 3 (41.16)	3 5 (1.866)	3 8 (1.949)	3 2 (1 775)	297 2 (2.473)	307 6 (2 488)	265 5 (2 424)	1.30	3 75	1 65
75 OP 5	3 1 (1 775)	3 4 (1 843)	3 0 (1 746)	52 7 (46.53)	53.2 (46.86)	34 7 (36 09)	3 2 (1.789)	2.8 (1 673)	2.6 (1 597)	193 2 (2 286)	145 9 (2.164)	204 2 (2 310)	1 60	2.75	3 10
75 OP 57	3.6 (1.897)	3 9 (1.975)	3 0 (1.732)	17.0 (24.37)	34 1 (35.71)	32.8 (34.96)	2 9 (1 703)	3 5 (1 871)	2 9 (1.703)	151 1 (2 180)	302 7 (2 481)	212 8 (2 328)	3.00	3.40	2 30
H 506	3.6 (1.936)	3 2 (1 788)	3 3 (1 816)	59 0 (50 18)	61.2 (51.48)	60 0 (50 76)	4.1 (2.012)	4 1 (2 025)	3 5 (1 871)	516 4 (2 713)	505 8 (2.704)	316.2 (2 500)	3 30	3 70	2 90
CO 1	4 2 (2 049)	3.7 (1.923)	3.2 (1 802)	47.2 (43.39)	50 1 (45.07)	42 2 (40.49)	4.3 (2.074)	3 6 (1.897)	3 1 (1.760)	457.0 (2.660)	325 0 (2 512)	256 5 (2 409)	2 10	3 60	2 40
CO 2	3.5 (1 870)	3.3 (1 816)	3.2 (1.802)	47.0 (43.29)	52 5 (46.43)	42.4 (40 65)	3.6 (1 894)	3 4 (1 841)	3 0 (1.732)	300 6 (2.478)	271 0 (2 433)	214 3 (2 331)	3.25	1 25	2 65
CO 3	3 0 (1.746)	3.2 (1.788)	3.0 (1.746)	31.6 (34.22)	47.5 (43 59)	35.0 (36.29)	3 0 (1.717)	3 6 (1 897)	3.0 (1.732)	202.8 (2 307)	308.3 (2 489)	220 3 (2.343)	5 25	4.60	4.25
IB 700	4.1 (2.025)	3.4 (1 843)	3.4 (1 830)	53.8 (47 15)	44.2 (41.65)	47.5 (43.56)	3.7 (1.923)	3 6 (1 894)	3.2 (1.775)	372 1 (2 571)	327 3 (2.515)	264.5 (2.422)	2.20	4 60	2 50
H 4126	3 8 (1 949)	3.4 (1.844)	3.1 (1 775)	57.5 (49 29)	46.1 (42.77)	47.7 (43.59)	3.4 (1.841)	3 5 (1 871)	2 9 (1 703)	376 7 (2.576)	373 3 (2 572)	250 6 (2 399)	3.75	5 05	2 65
H 4021	3.5 (1 871)	3 4 (1.844)	3 2 (1 802)	34 6 (36.05)	31 7 (34.25)	30.3 (33.42)	3 2 (1 796)	3.0 (1 732)	3.2 (1.774)	261 2 (2 417)	211.3 (2 325)	273 5 (2 437)	4.10	4.80	2.70
S 30	3 6 (1.894)	3.1 (1.760)	2.8 (1.672)	47 0 (43.29)	52.5 (46.43)	42.4 (40 65)	4.0 (1 987)	3.8 (1.949)	3.0 (1.740)	435 5 (2 639)	441 6 (2 645)	292 1 (2 466)	3.40	3.80	2 25
Chedivella	3 2 (1 788)	3 8 (1.949)	2.9 (1 703)	43.5 (41.25)	38.5 (38.33)	33.2 (35 18)	3 3 (1.884)	3 7 (1 923)	2 6 (1 613)	329 6 (2.518)	400.9 (2 603)	216 8 (2 336)	6 75	7.00	4 90
Ethenvella	3.5 (1.869)	3.7 (1.922)	3 3 (1.802)	54.2 (47.42)	43.0 (40.95)	57.6 (49 34)	4 3 (2.062)	3.9 (1.975)	3.6 (1.936)	482 0 (2 683)	444 6 (2 648)	369 0 (2 567)	6.45	7.15	3.75
Anacomban	3.9 (1.962)	3.6 (1.897)	3.1 (1.760)	48.3 (44.03)	58 9 (50.12)	56.2 (48.58)	4.1 (2.012)	3.8 (1 949)	3.7 (1.962)	425.6 (2 629)	374.1 (2 573)	369 0 (2.567)	3 60	3 50	2 75
Kadukkavalla	4.1 (2.025)	3.3 (1.816)	3.7 (1 923)	47.8 (43.72)	30.4 (33 45)	52.0 (46.16)	4.1 (2.025)	3 6 (1.897)	3.4 (1 857)	449 8 (2 653)	395 4 (2 597)	320 6 (2.506)	1 50	3.70	2 60
Bhadrakalichuvala	3 6 (1.896)	3 6 (1.897)	3 1 (1 760)	35 8 (36 76)	32 6 (34 76)	47.8 (43 69)	3 4 (1.843)	3.4 (1 844)	3 3 (1.816)	286 4 (2 457)	322 9 (2 509)	290 4 (2 463)	4 00	4 90	2 60
Parinkamavinchuvala	3 2 (1.789)	3.2 (1 788)	3.1 (1.756)	42.4 (40 62)	42 2 (40.49)	42.1 (40 47)	3 9 (1 962)	3 3 (1 816)	3 1 (1.760)	434 5 (2 638)	293 1 (2 467)	235 5 (2 372)	3 20	5 30	2 25
Nedinjilchuvala	2.9 (1.701)	2 4 (1.544)	3.1 (1 760)	30 3 (33 38)	21 4 (27.55)	33.7 (35.47)	3.4 (1 844)	3.4 (1 843)	2 7 (1 643)	273 5 (2 437)	353 2 (2 548)	228 6 (2 359)	7 10	6 50	3 80
Kaavivella	3.7 (1 922)	3 7 (1.923)	3 6 (1 884)	41 8 (40.30)	41 8 (40 28)	48.5 (44 13)	4 0 (2 012)	3.7 (1 908)	3 3 (1 830)	516 4 (2 713)	329 6 (2 518)	295.1 (2 470)	5 60	5 50	4 25
Poineervella	3.1 (1 760)	3 2 (1 789)	3 1 (1.760)	38 3 (38.24)	39 6 (39 00)	36 5 (37 17)	3.6 (1 871)	3 6 (1 896)	3 3 (1 823)	296 5 (2.472)	316 2 (2 500)	284 5 (2 454)	5 30	4 70	3 30
Panineervella	3.3 (1.816)	3 5 (1 866)	3.1 (1.701)	34 4 (35 92)	48.0 (43 86)	30 1 (33 26)	3 7 (1 910)	3 8 (1 949)	3 0 (1 732)	373 3 (2 572)	456 0 (2 659)	261 2 (2 417)	4 10	4 20	3 10
Kottaramchuvala	3 2 (1 788)	3 5 (1 869)	3 1 (1.760)	37 6 (37 80)	42 5 (40 69)	35 5 (36.54)	3 3 (1 816)	3 2 (1 789)	3 1 (1 746)	297 2 (2 473)	242 1 (2 384)	256 5 (2 409)	3 05	2 80	3 25
C D at 5 per cent	(0.136)	(0 145)	(0 119)	(6 09)	(8 55)	(6 10)	(0 125)	(0 125)	(0 091)	(0.123)	(0.151)	(0 092)	1 14	1 49	0 74

Figures in parentheses in the column are transformed values of $\sqrt{x}$, arc Sin $\sqrt{x}$ and log x for DGI (Damage grade index), per cent and number of adults respectively

S_1 First season S_2 Second season S_3 Third season

APPENDIX II Incidence of C formicarius at different growth stages of sweet potato grown in field (mean of two replications)

Period of observation (DAP)	Infestation on crown % S_1	Infestation on crown % S_2	Infestation on crown DGI S_1	Infestation on crown DGI S_2	Tuber damage % S_1	Tuber damage % S_2	Tuber damage DGI S_1	Tuber damage DGI S_2	No of adults emerged from 1 kg infested tuber S_1	No of adults emerged from 1 kg infested tuber S_2
7	0 0 (0 0)	0 0 (0 0)	0 0 (1 0)	0 0 (1 0)	0 0 (0 0)	0 0 (0 0)	0.0 (1 0)	0 0 (1 0)	7 00 (0 301)	0 0 (0 301)
14	0.0 (0 0)	0 0 (0 0)	0 0 (1 0)	0 0 (1 0)	0 0 (0 0)	0 0 (0 0)	0 0 (1 0)	0.0 (1 0)	0 0 (0.301)	0 0 (0.301)
21	0.0 (0.0)	0 0 (0 0)	0 0 (1 0)	0 0 (1 0)	0 0 (0 0)	0 0 (0 0)	0 0 (1 0)	0 0 (1 0)	0 0 (0 301)	0 0 (0 301)
28	14 6 (22 50)	0 0 (0 0)	0 6 (1 26)	0 0 (1 0)	0 0 (0 0)	0 0 (0 0)	0 0 (1 0)	0 0 (1 0)	0 0 (0 301)	0 0 (0 301)
35	10.8 (19 7)	18 3 (25 33)	0 4 (1 18)	0 2 (1 08)	0 0 (0 0)	0 0 (0.0)	0 0 (1 0)	0 0 (1 0)	0 0 (0 301)	0 0 (0 301)
42	44 2 (41 67)	28 0 (31 92)	0 7 (1 30)	1 0 (1 41)	0 0 (0 0)	0 0 (0 0)	0 0 (1 0)	0 0 (1 0)	0 0 (0 301)	0 0 (0 301)
49	50 6 (45 35)	38 3 (32 23)	1 0 (1 40)	1 3 (1 53)	0 0 (0 0)	0 0 (0 0)	0.0 (1 0)	0 0 (1 0)	0 0 (0 301)	0 0 (0 301)
56	48 3 (44 05)	5 9 (42 62)	1 2 (1 47)	1 6 (1 61)	0 0 (0 0)	20 7 (27 08)	0 0 (1 0)	0 7 (1 32)	0 0 (0 301)	8 0 (0 998)
63	45 9 (42 62)	79 3 (62 94)	1 8 (1 67)	1 7 (1 64)	17 1 (24.46)	24.60 (29 74)	0 8 (1 34)	1 0 (1 40)	12 7 (1 167)	19 2 (1 327)
70	60 0 (50 82)	86 8 (68 72)	2 1 [illegible]	2 0 ([illegible] 73)	29 7 ([illegible]3 02)	18 3 (25.34)	1.2 (1 47)	1 2 (1 48)	34 6 (1 564)	42 5 (1 648)
77	75.8 (60 55)	90 0 (71 57)	2 5 (1.87)	2 8 (1 95)	33 8 (35 53)	30 8 (33 68)	1 8 (1 66)	1 9 (1 70)	82 1 (1 925)	90 3 (1 965)
84	84 0 (66 39)	91 3 (72 85)	3 0 (2 00)	3 2 (2 05)	39 5 (38 94)	30 5 (33 52)	2 0 (1 73)	2 7 (1 93)	114 7 (2 067)	11[illegible] 4 (2 062)
91	74 0 (59 37)	82 8 (65 50)	3 4 (2 10)	3 5 (2 13)	46.1 (42 76)	42 3 (40 57)	3 0 (2 00)	3 6 (2 13)	137 3 (2 144)	144 6 (2 166)
98	85 2 (67 34)	[illegible] 8 (76 21)	3 9 (2 22)	4 2 (2 29)	48 3 (44.03)	45 6 (42 47)	3 5 (2 11)	3 8 (2 18)	167 4 (2 229)	164 0 (2 220)
105	82 6 (65 31)	96 1 (78 61)	4 2 (2 27)	4 0 (2 24)	53 0 (46 72)	51 3 (45 77)	4 3 (2.30)	4 2 (2 28)	227 1 (2 360)	229.2 (2 364)
C D at 5%	(8 12)	(14 17)	(0 09)	(0 12)	(2 71)	(5 46)	(0 09)	(0.08)	(0 097)	(0 079)

Population on (10 plants) — Crown

Period of observation (DAP)	Egg S_1	Egg S_2	Larva S_1	Larva S_2	Pupa S_1	Pupa S_2	Adult S_1	Adult S_2
7	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
14	0 0 (0.301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
21	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
28	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	1 5 (0 540)	0 0 (0 301)
35	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	1 5 (0 540)	4 5 (0 812)
42	8 6 (1 025)	9 2 (1 050)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	8 0 (0 998)	1 5 (0 545)
49	15 0 (1 230)	12.9 (1 72)	6 5 (0 929)	7 8 (0 991)	0 0 (0 301)	0 0 (0 301)	4.9 (0 841)	1 5 (0 540)
56	26 0 (1 447)	16 5 (1 266)	11 5 (1 130)	10.4 (1 092)	0 0 (0 301)	0 0 (0 301)	2 5 (0 651)	3 7 (0 753)
63	39 5 (1 618)	27 4 (1 468)	19 9 (1 341)	13 0 (1 175)	4 7 (0 827)	5 0 (0 827)	1 5 (0 540)	0 8 (0 452)
70	36 8 (1 589)	35 4 (1 573)	29 8 (1 503)	19 9 (1 341)	14 7 (1 224)	15 3 (1 239)	3 9 (0 772)	0 8 (0 452)
77	43 5 (1 658)	13 4 (1 188)	43 4 (1 657)	27 3 (1 467)	28 0 (1 477)	13 0 (1 175)	8 0 (0 999)	13 6 (1 192)
84	18 9 (1 321)	10 0 (1 078)	30 9 (1 517)	8 0 (0 998)	15 0 (1 230)	12 5 (1 159)	11 0 (1 113)	9 0 (1 040)
91	15 9 (1.253)	1 2 (0.500)	31 5 (1 525)	7 0 (0 952)	17 0 (1 278)	17.6 (1 292)	18 0 (1 292)	7 5 (0 977)
98	7 4 (0 972)	0.0 (0 301)	24 4 (1 421)	0 8 (0 452)	20 0 (1 342)	5 5 (0 874)	19.0 (1 322)	14 1 (1 208)
105	0 8 (0 452)	0 0 (0 301)	6 4 (0 923)	0 0 (0 301)	8 0 (0 998)	12.1 (1 148)	6.5 (0 929)	7 5 (0 977)
C D at 5%	(0 205)	(0 209)	(0.148)	(0 186)	(0 170)	(0 198)	(0.317)	(0 384)

Population on (10 plants) — Tuber

Period of observation (DAP)	Egg S_1	Egg S_2	Larva S_1	Larva S_2	Pupa S_1	Pupa S_2	Adult S_1	Adult S_2
7	0.0 (0 301)	0.0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
14	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
21	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
28	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
35	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
42	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
49	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
56	0 0 (0 301)	22 3 (1 385)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
63	18 8 (1 319)	19 9 (1 341)	0 0 (0 301)	16 3 (1 263)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)
70	28 5 (1 484)	33 9 (1 555)	9 0 (1 041)	16 0 (1 255)	0 0 (0 301)	0 0 (0 301)	0 0 (0 301)	0 [illegible] (0 301)
77	40 5 (1 628)	50 8 (1 725)	19 9 (1 341)	28 0 (1 477)	0 0 (0 301)	1 7 (0 573)	0 0 (0 301)	0 0 (0 301)
84	78 2 (1 904)	89.8 (1 963)	32 4 (1 536)	40 3 (1 620)	[illegible] 2 (1 0[illegible]0)	23.7 (1 410)	0 0 (0 301)	0 0 (0 301)
91	101 8 (2 016)	104 4 (2 027)	53 7 (1 746)	82 3 (1 926)	29 0 (1 491)	24 4 (1 421)	6 9 (0 943)	12 0 (1 145)
98	71 1 (1 864)	53 7 (1 746)	80 6 (1 917)	100 3 (2 010)	42 5 (1 648)	73 7 (1 879)	15 2 (1 [illegible])	24 4 (1 [illegible])
105	42 5 (1.648)	39 4 (1 617)	126 5 (2 109)	62 5 (1 810)	67 0 (1 839)	102 2 (2 018)	42 0 (1 643)	53 3 (1 743)
C D at 5%	(0 125)	(0 104)	(0 081)	(0 067)	(0 093)	(0 246)	(0 103)	(0 068)

Figures in parentheses in the column are arc Sin $\sqrt{x}$, $\sqrt{x+1}$ and log (x + 2) transformed values for per cent, DGI and number of adult emergence and population respectively

S_1 First season

S_2 Second season

DGI Damage grade index

DAP Days after planting

APPENDIX III

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

Table 3

Source	df	% Crown infestation	Crown DGI	% Tuber infestation	Tuber DGI	Weevil population
Crop rotation:						
Treatments	3	27.46	0.401	85.88**	0.1004	495.87
Error	44	31.05	0.242	15.18	0.1259	449.60

Table 7 and APPENDIX I

Source	df	Crown DGI	% Tuber infestation	Tuber DGI	No.of adults emerged	Yield
Appendix I						
Season 1:						
Replication	1	0.0074	21.664	0.0074	0.0084	0.840
Varieties	39	0.0303**	112.344**	0.0713**	0.1159**	4.491**
Error	39	0.0045	9.061	0.0037	0.0037	0.319
Season 2:						
Replication	1	0.0006	0.273	0.0001	0.0019	0.050
Varieties	39	0.0344**	114.963**	0.0489**	0.0928**	3.631**
Error	39	0.0052	17.885	0.0038	0.0056	0.545
Season 3:						
Replication	1	0.0017	13.770	0.0001	0.0013	0.392
Varieties	39	0.0257**	102.518**	0.0698**	0.0850**	1.616**
Error	39	0.0035	9.090	0.0020	0.0021	0.135
Table 7						
Pooled						
Seasons	2	0.0966**	82.88**	0.0593**	0.3280**	26.950**
Varieties	39	0.0356**	128.230**	0.0756**	0.6880**	3.783**
Season x Varieties	78	0.0047	18.012*	0.0147*	0.0167*	0.698*
Pooled error	117	0.0044	12.005	0.0032	0.0038	0.333

Table 8

Source	df	Crown DGI	% Tuber infestation	Tuber DGI	No.of adults emerged
Vine pigmentation:					
in Varieties	2	0.0060	60.57	0.088	0.082
Error	37	0.0133	47.32	0.040	0.035
Tuber skin pigmentation:					
in Varieties	2	0.0003	83.66	0.1618**	0.1631*
Error	37	0.0300	40.49	0.0201	0.0311
Flesh colour:					
in Varieties	2	0.0299	157.30*	0.1205**	0.2776**
Error	37	0.0109	36.37	0.0214	0.0295
Tuber shape:					
in Varieties	2	0.0035	0.31	0.0686	0.0060
Error	37	0.0125	0.22	0.0260	0.0198
Leaf lobing:					
in Varieties	3	0.0440	119.66	0.0657	0.0610
Error	36	0.0157	59.53	0.0403	0.0532
Latex content:					
in Varieties	1	0.0825**	440.29**	0.2019**	0.7270**
Error	38	0.0039	10.328	0.0091	0.0342

Table 9

Source	df	Moisture	Drymatter	Sugar	Starch	Total phenols	OD phenols	Carotene	No.of weevils developed
Varieties	4	73.15**	75.60**	0.80	10.60	63.54	14.28**	0.641**	0.241**
Error	12	10.96	11.00	0.45	8.33	32.56	2.04	0.080	0.027

* Signi[illegible]

APPENDIX III Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

Table 10 and APPENDIX II

Source	df	% Crown infestation	Crown DGI	% Tuber infestation	Tuber DGI	No.of adults emerged per kg	Weevil population on crown				Weevil population on tuber			
							Egg	Larva	Pupa	Adult	Egg	Larva	Pupa	Adult
Appendix II														
Season 1.														
Growth stage	14	1228.01**	0.4598**	816.98**	0.4470**	1.5530**	0.6090**	0.6250**	0.4680**	0.2380**	1.0890**	0.9970**	0.6580**	0.3647**
Error	15	14.28	0.0016	1.59	0.0242	0.0020	0.0092	0.0048	0.0063	0.0220	0.0034	0.0015	0.0019	0.0023
Season 2.														
Growth stage	14	1960.70**	0.4767**	700.14**	0.4860**	1.4980**	0.5000**	0.3970**	0.3700**	0.2280**	1.0600**	1.0137**	0.8226**	0.4670**
Error	15	43.45	0.0033	6.46	0.0014	0.0014	0.0096	0.0076	0.0086	0.0324	0.0024	0.0001	0.0133	0.0010
Pooled:														
Seasons	1	98.43	0.0007	5.39	0.0219*	0.0192	0.4744**	0.6753**	0.0292	0.1210	0.0944	0.1263	0.0270	0.0144
Growth stage	14	1506.65**	0.4311**	728.42**	0.4624**	1.5089**	1.0449**	0.9260**	0.8150**	0.4210**	2.0690**	1.9390*	0.7236**	0.8280**
Season x Growth stage	14	80.96	0.0909	30.37	0.0045	0.0172	0.0647**	0.0960**	0.0086	0.0545*	0.0795**	0.0716**	0.0083	0.0033*
Pooled error	30	28.87	0.0025	4.03	0.0128	0.0017	0.0094	0.0062	0.0074	0.0272	0.0029	0.0008	0.0076	0.0016

* Significant at 5%   ** Significant at 1%

APPENDIX III Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

Table 11

Source	df	Crown DGI	% Tuber infestation	Tuber DGI	No. of Adult emerged per kg infested tuber
Season 1:					
Replication	1	0.0033	0.003	0.0026	0.0021
Treatments	13	0.0047	109.059**	0.0377**	0.1002**
Error	13	0.0054	12.685	0.0014	0.0082
Season 2:					
Replication	1	0.0031	0.149	0.0023	0.0093
Treatments	13	0.0154	56.981**	0.0441**	0.0909**
Error	13	0.0065	12.027	0.0089	0.0083
Pooled:					
Seasons	1	0.0180	207.970**	0.0164**	0.1800**
Treatments	13	0.0450	71.488**	0.0397**	0.0928**
Season x treatments	13	0.0621	11.989	0.0025	0.0217
Pooled error	26	0.0060	12.356	0.0051	0.0083

Table 12

Source	df	Crown DGI	% Tuber infestation	Tuber DGI	No. of Adult emerged per kg infested tuber
Season 1:					
Replication	2	0.0095	37.058	0.0009	0.0043
Treatments	8	0.0063	196.106**	0.0228**	0.0438**
Error	16	0.0055	14.578	0.0038	0.0039
Season 2.					
Replication	2	0.0078	25.255	0.0001	0.0026
Treatments	8	0.0095	668.821**	0.0947**	0.0432**
Error	16	0.0063	27.303	0.0025	0.0046
Pooled:					
Seasons	1	0.0139	193.192	0.0271	0.0016
Treatments	8	0.0162	218.610**	0.0559**	0.0248**
Season x treatment	8	0.0112	69.429	0.0070	0.0017
Pooled error	32	0.0059	20.941	0.0031	0.0043

Table 13

Source	df	Crown DGI	% Tuber infestation	Tuber DGI	No. of Adult emerged per kg infested tuber
Season 1.					
Replication	1	0.0006	36.693	0.0001	0.0068
Treatments	24	0.0059	164.510**	0.0322**	0.0241**
Error	24	0.0045	12.543	0.0022	0.0022
Season 2:					
Replication	1	0.0012	49.059	0.0002	0.0087
Treatments	24	0.0096	189.786**	0.0219**	0.0342**
Error	24	0.0079	13.737	0.0015	0.0040
Pooled:					
Seasons	1	0.0005	185.512**	0.0001	0.0260**
Treatments	24	0.0080	175.307**	0.0244**	0.0279**
Season x Treatment	24	0.0074	14.678	0.0020	0.0015
Pooled error	48	0.0062	13.140	0.0019	0.0031

** Significant at 1%

APPENDIX III Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

Source	Table 14		Table 15		Table 16				Table 18		Table 19	
	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Treatments	27	36.472**	11	7.629**	2	0.148	6	13.236	4	23.260**	3	18.377**
Error	112	0.599	36	0.[illegible]59	18	0.049	42	0.083	20	0.375	16	0.226

Table 17

Source	df	First day	Second day	Third day	Fourth day	Fifth day	df	Pooled
Days	-	-	-	-	-	-	4	47.3275**
Treatments	23	6.6546**	9.1882**	11.2310**	7.8600**	13.4050**	23	14.1117**
Error	96	0.2330	0.329	0.2210	0.1645	0.3668	92	1.5037

Table 20

Source	df	% Crown infestation	Crown DGI	% Tuber infestation	Tuber DGI	No.of adults emerged	Marketable tuber	Total yield
Treatments	5	103.348**	0.4513**	74.913**	0.0786**	0.3612**	1.0616**	1.3045**
Error	18	2.931	0.0309	12.135	0.0086	0.0479	0.0704	0.0833

Table 21

Source	df	Crown DGI	% Tuber infestation	Tuber DGI	No.of adults emerged	Yield
Replication	2	0.0035	10.854	0.0484	0.0126	0.476
Treatments	7	0.0409**	891.682**	0.3350	0.7837**	1.297*
Error	14	0.0053	49.584	0.0165	0.0065	0.409

Table 22

Source	Actinomycetes					Bacteria@				Fungi@			
	df	50DAP	52DAP	80DAP	82DAP	df	52DAP	80DAP	82DAP	df	52DAP	80DAP	82DAP
Treatments	7	0.189	0.473	0.272	0.259**	7	0.197	1.056	0.109	7	6.344	2.561	0.599
Error	14	0.464	0.220	0.1[illegible]	0.038	13	0.247	1.174	1.215	13	4.035	1.257	0.481

@ ANACOVA with pretreatment counts

Table 23

Source	df	% Crown infestation	Crown DGI	% Tuber infestation	Tuber DGI	No.of adults emerged	Yield
Replication	2	5.285	0.0593	29.800	0.0408	0.0318	0.0670
Treatments	28	254.355**	1.1780**	293.800**	0.1860**	0.4635**	1.1786**
Error	56	2.507	0.0446	12.918	0.0006	0.0113	0.0692

* Significant at 5%   ** Significant at 1%

APPENDIX III Contd.

SUMMARY OF ANALYSIS OF VARIANCE RELATING TO

Table 24

Source	df	Days after insecticidal drenching 1	7	14	21	28	df	35	42	df	49	df	56
Replication	2	2.893	1.132	5.063	8.859	20.828	2	8.914	4.041	2	1.761	2	4.730
Treatments	28	571.047**	485.047**	442.502**	903.446**	1157.661**	24	2055.764**	2903.724**	20	2024.601**	16	2056.291**
Error	56	3.822	2.590	3.843	3.825	9.323	48	4.170	1.865	40	3.591	32	2.000

Table 25

Source	df	Infestation on Crown		Infestation on Tuber		No.of adults emerged	Total yield	Good yield	% parasitisation
		%	DGI	%	DGI				
Treatments	3	1434.850**	0.3281**	734.730**	0.7626**	1.4916**	3.5476**	2.1687**	75.450**
Error	16	27.560	0.0067	15.740	0.0053	0.0028	1.0136	0.1087	14.8078

Table 26

Source	df	Infestation on Crown		Infestation on Tuber		No.of adults emerged	Total yield	Good yield	% parasitisation
		%	DGI	%	DGI				
Treatments	3	165.70**	0.1088**	136.240**	0.0732**	0.5446**	4.5034**	3.9801**	27.123
Error	16	13.30	0.1094	1.607	0.0037	0.0046	0.4605	0.7613	14.549

** Significant at 1%

APPENDIX IV

Weather data during 1984-1986

Months	1984				1985				1986			
	Temp. °C		R.H. (%)	Rain fall (mm)	Temp. °C		R.H. (%)	Rain fall (mm)	Temp. °C		R.H. (%)	Rain fall (mm)
	Maximum	Minimum			Maximum	Minimum			Maximum	Minimum		
January	31.2	23.6	73.0	35.6	30.7	22.9	80.5	61.2	31.9	21.8	75.0	21.6
February	32.5	25.3	72.0	85.0	31.8	23.8	82.0	26.0	31.9	20.8	76.0	86.0
March	32.2	23.5	78.0	46.4	32.4	25.6	81.5	8.1	31.8	20.8	59.0	8.6
April	32.4	19.2	75.5	191.0	33.5	22.3	77.5	38.4	34.5	23.6	73.6	125.3
May	32.8	20.4	69.0	100.0	31.5	25.1	74.5	231.9	33.7	23.1	73.0	132.1
June	30.3	22.9	72.5	215.8	28.5	23.1	79.0	322.1	31.2	22.6	76.0	224.3
July	28.9	23.7	80.0	131.6	28.2	22.4	76.5	71.0	31.0	22.9	79.0	94.4
August	28.8	23.8	69.5	22.4	28.6	23.6	83.0	21.7	30.3	22.4	74.0	449.3
September	30.3	23.8	75.5	83.2	30.3	23.6	81.0	0.0	30.3	23.4	74.0	102.4
October	28.6	22.1	71.5	201.8	30.6	22.8	85.0	387.0	30.8	22.6	74.0	80.2
November	30.7	23.8	79.5	120.6	29.8	23.0	79.0	449.6	30.6	21.4	69.7	183.4
December	30.6	22.6	78.0	5.4	33.2	22.0	68.0	112.8	30.4	21.3	70.8	25.4

INTEGRATED CONTROL OF SWEET POTATO WEEVIL *CYLAS FORMICARIUS* FABRICIUS

By

M. S. PALANI SWAMI

ABSTRACT OF A THESIS
submitted in partial fulfilment of the
requirement for the degree
DOCTOR OF PHILOSOPHY
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
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1987

ABSTRACT

The incidence of sweet potato weevil *Cylas formicarius* Fabricius (Coleoptera : Curculionidae), and intensity of damage done to sweet potato (*Ipomoea batatas* (L.)) in Kerala were assessed in an elaborate survey adopting a purposive and stratified random sampling technique.

A series of experiments were conducted in the Instructional Farm, College of Agriculture, Vellayani, during 1984-'86, for standardising the different methods of control for integrating the same in a viable technology. The incidence of the pest and intensity of damage in the survey and in different experiments were assessed in terms of percentage of crown infestation, crown damage grade index (DGI), percentage of tuber infestation, tuber DGI and number of weevils obtained from samples of infested tubers stored for 30 days.

The survey revealed that sweet potato weevil has got established in all the sweet potato growing areas of Kasaragod, Malappuram, Palghat, Trichur, Quilon and Trivandrum Districts located in the three agro-climatic regions of the State, indicating the extreme adaptability of the insect to varying agro-climatic situations. Though the pest was not found serious in low/wet lands, it was found as a major limiting factor in the production of sweet potato tubers in the upland cultivation. Among the Districts there was no significant variations in the intensity of pest incidence. But within each District there was wide variations in the occurrence of the pest and in the intensity of

damage noted. But no contiguous areas could be identified within the District having higher or lower intensity of damage. The pest was less in alluvial soils and early harvest (105-110 days after planting) reduced the damage. In general, crop rotation had little effect on the incidence of the pest. The parasitoids (*Rhaconotus* sp. and *Bracon* sp.) and a predator (*Drapetis* sp.) were observed in all the tracts having sweet potato crop. *Ipomoea purpuria* and *I. biloba* were the alternate hosts found in all the Districts, while *I. paundurata* was seen in Malappuram and Palghat Districts and *I. hispida* was noted in Kasaragod, Quilon and Trivandrum Districts only. *Amaranthus viridis* and *Vigna sinensis* were found harbouring the adults of *C. formicarius* in the field. The yield loss caused by the pest was estimated as Rs. 96.04 lakhs annually and of this Palghat, Malappuram and Kasaragod Districts incurred 53.77, 19.91 and 19.38 per cent loss respectively while the remaining Districts together accounted for 6.95 per cent only.

In a screening experiment having 40 entries, a local cultivar Selopia was located as 'moderately resistant' and it was significantly superior to all other entries. The varieties H 268 and 76 OP 217 were 'moderately resistant' and 'less resistant respectively. All the three were on par with reference to yield. Entries with red skin and yellow or orange flesh, higher latex content and deeply set tubers were found less susceptible. Definite correlations between chemical constituents and resistance were not observed in the studies. Antibiosis was observed as a factor contributing relative resistance to the weevil.

Data on the incidence of *C. formicarius* at different growth stages of sweet potato showed that the crown was more susceptible from 42 to 77 DAP. The number of eggs on tubers were high between 50 and 70 DAP. Immature stages of the pest in tubers did not reach the peak even at harvest (105 DAP).

Reridging done as a cultural practice, reduced the pest incidence significantly and the optimum period was between 50 and 80 DAP.

Application of *Eupatorium* or *Clerodendron* leaves @ 3 t ha^{-1} at 30 DAP was effective in reducing the weevil damage in field.

Among locally available organic cakes and wood ash tried at varying doses and growth stages of the crop mahwa cake @ 1000 kg ha^{-1} or neem cake @ 1500 kg ha^{-1} applied at 50 DAP reduced the weevil incidence significantly.

In a series of experiments the methods for trapping the adults of *C. formicarius* in field, as a control measure, were standardised. It was observed that (i) fresh sweet potato tubers of 6 cm diameter cut to 100 g piece was the best bait material for the trap, (ii) the peak collection of the weevils in the trap was between 16.00 h and 22.00 h, (iii) setting up of the trap at 16.00 h and collecting and destroying the weevils from the bait at 06.00 h the next day were found effective and convenient, (iv) optimum spacing for setting the traps in field was found as 5 m (v) four trappings done at 10 day intervals between 50 and 80 DAP were found to be optimum for reducing the weevil population in field.

A field experiment showed that endosulfan, fenthion or fenitrothion 0.05 per cent emulsion used as soil drench at 50 and 80 DAP were very effective against the pest and their residues in tuber at harvest were non-detectable. The treatments did not affect the soil microflora significantly.

Drenchings done at different growth stages of the crop showed that the applications at 50 and 80 DAP were effective. Tobacco decoction, though less toxic, was also effective in controlling the pest.

The toxicity of endosulfan, fenthion, fenitrothion or tobacco decoction applied in soil, bioassayed using adults of C.formicarius as test insect, remained high (above 50 per cent) for four weeks and that of tobacco decoction for two weeks.

An integrated pest control technology, consisting of - removal of alternate hosts, selection of pest free planting materials, mulching with Eupatorium or Clerodendron leaves @ 3 t ha^{-1} at 30 DAP, a reridging at 50 DAP, trapping the weevils at 10 day intervals between 50 and 80 DAP and one soil drenching with endosulfan, fenthion or fenitrothion 0.05 per cent at 65 DAP, early harvesting (105-110 DAP) and proper disposal of crop residues at harvest, was found to be the most effective against C.formicarius and the natural enemies were least affected in the treatment. It also gave the best cost-benefit ratio. It was followed by the treatment in which all the above cultural practices were adopted with the addition of a reridging at 80 DAP and deletion of insecticidal drenching at 65 DAP. The third treatment consisting of chemical method (soil drenchings at 50 and 80 DAP) alone also was quite effective and economically viable. The cost-benefit ratio was least in this treatment. The integrated technology if adopted extensively for a few cropping seasons in succession will reduce the insect population to negligible levels in the agro-ecosystem.

The coefficient of variations of the data obtained in the various experiments showed that the assessment of the damage grade indices of the tubers and number of adults emerging from tuber samples collected from treatments and stored for one month, were more reliable methods for estimating the incidence of *C. formicarius*.