IMPACT OF INSECTICIDES ON THE FLORA AND FAUNA IN THE SOIL ECOSYSTEM OF BANANA PLANTATION

By

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1993

DEDICATED

to

The Eternal Power

guiding me

DECLARATION

I hereby declare that this thesis entitled "IMPACT OF INSECTICIDES ON THE FLORA AND FAUNA IN THE SOIL ECOSYSTEM OF BANANA PLANTATION", 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.

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CERTIFICATE

Certified that this thesis entitled **"IMPACT OF INSECTICIDES ON THE FLORA AND FAUNA IN THE SOIL ECOSYSTEM OF BANANA PLANTATION"**, is a record of research work done independently by **Kum. J. Alice Retna Packia Sujeetha** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

Banana (Musa Paradisiaca L.) is the most important fruit crop in the tropical and subtropical regions. In India the crop is extensively grown in Kerala, Tamil Nadu, Maharashtra, Karnataka, Gujarat, Andhrapradesh and Assam. In Kerala it is grown in an area of 22 thousand hectares with an annual production of 2.9 lakh tonnes of fruits (Anon, 1993).

In the northern districts of Kerala the production and productivity of the crop are seriously affected by the incidence of rhizome weevil and different species of nematode pests while in Southern districts the incidence of devastating bunchy top disease is the major limiting factor in production. For containing these pest and disease problems prophylactic application of HCH, Carbofuran and phorate have been recommended (Kerala Agricultural University, 1989) and the treatment is being extensively adopted by the farmers.

It is now being recognised widely that the intensive and prolonged use of chemical fertilizers alone affects the soil health and in turn detrimental to sustained productivity. Further the escalating cost of synthetic fertilizers renders them beyond the reach of medium and marginal farmers. It is imperative to explore viable alternative technologies. The use of organic fertilizers like cowdung and compost for replacing chemical fertilizers partly and preferably in full to meet NPK requirement have been suggested. But the limited availability of these organic manures have become a major hurdle in the adoption of this technology. In this context the recycling of organic wastes available in urban and rural areas assumes vital importance in realising the cherished goal of sustained agriculture.

The soil organisms like earthworms, bacteria, actinomycetes, fungi etc. play a vital role in the degradation of organic wastes available in the agroecosystem and which can be harnessed and utilized in the farming practices. Obviously the application of synthetic insecticides like carbofuran and phorate which are highly toxic to nontoxic organisms and HCH, a Chlorinated hydrocarbon notorious for its long persistence in the ecosystem are likely to affect the biodegradation of organic wastes in the field through their side effects on the soil biota.

In this context an attempt to assess the extent to which the adoption of the recommended control measures against rhizome weevil, nematode pests and bunchy top disease of banana, affect the useful fauna and flora in banana fields was felt as a necessity since this information relating to Kerala Situations is totally lacking.

The present investigations were taken up with a view to assessing the impact of the insecticidal treatments on the population of earthworms; parasitic and non-parasitic nematodes; collembolans and mites; bacteria; actinomycetes and fungi. The influence of different soil factors viz. moisture, pH and organic matter on the soil organisms was also assessed through correlation analysis.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The literature on the important organisms in banana ecosystem viz, earthworms, nematodes, soil arthropods, soil microflora (fungi, bacteria and actinomycetes) reveals the impact of insecticides recommended for control insect pests of banana and the persistence of the selected insecticides in soil have been reviewed briefly in this chapter.

1.1. EARTHWORMS

1.1.1 Distribution

Kale and Krishnamoorthy (1976) reported that studies on the earthworm population around Bangalore city revealed wide range distribution of six different species of earthworms namely Megascolex mauritii, Pheretima elongata, Pontoscolex corethrurus (Muller), Octochaetoides beatrix. and Perionyx excavatus.

Reddy and Alfred (1976) evaluated monthly fluctuations in the biomass and population density of earthworms in a pine forest soil and noticed maximum abundance in July and minimum in April.

Kale and Krishnamoorthy (1981) observed the interspecific zonation in three species of earthworms viz., P. elongata, M. maurtii and P. corethrurus. The preferential feeding and burrowing activities of P. elongata and P. corethrurus were more confined to the soil layer containing dung than any other layer.

Kaleemurrahman and Ismail (1981) reported that earthworms were the dominant species in the soils of South Madras than any other soil organisms.

Mccredie et al. (1992) studied the population dynamics of the earthworm Aporoectodea trapezoides and found that at the time of the first showers the population consisted of juvenile and semimature individuals and clitellate earthworms emerged one month after the rains (ie) end of August.

Hauser (1993) reported that the highest casting activity was recorded with the commencement of regular rains in May and also the moistening of at least the upper 130 cm of the soil.

1.1.2 Influence of soil factors

Brady (1988) observed that earthworms were dominant in medium textured upland soils, where the moisture capacity was high.

Reddy and Alfred (1976) observed that earthworm population was comparatively small on the acidic side (5.80 to 6.25) of pH of the soil.

Haimi and Einbork (1992) noticed that earthworms thrived at a pH above 4.8 and their biomass increased.

Manickam (1993) reported that earthworms flourish only in soils that are well supplied with organic matter.

1.1.3. <u>Importance in Soil health</u>

Brown (1978) observed that earthworms, one of the major fauna of soil is the farmers friend. They play an important role in humification process. Their population was considered as an index of the physical nature of the soil. The physical effects of earthworms on soils result from their burrowing ingestion of soil and organic matter and decomposition of casts on the soil surface or beneath the surface.

Worm movements penetrating the layers of soil with different litter help mixing up of the litter for microbial degradation (Kale, and Krishnamoorthy, 1981).

Brady (1988) reported that earthworm casts on a cultivated field weigh about 18,000 kg/ha. These earthworm casts were rich in bacterial population, organic matter, total Nitrogen, exchangeable calcium, Magnesium, potassium and those organism play an important role in soil aggregation.

Haimi and Huhta (1990) noted that presence of earthworms in the soil increase either directly or indirectly in the proportion to the mineral N - available for plants at any time.

Hamilton et al (1990) reported that the earthworm middens of the mowed field supported higher density of microarthropods (Collembolans and Prostigmatid mites) which also play an important role in the humus formation.

Lee and Foster (1991) reported that the significant effects of soil fauna on soil structure are achieved mainly by earthworms, termites and ants. Soil macroporosity increased by earthworm burrows leads to increase in water infiltration, reduction in surface run off and decrease in soil loss by erosion.

Bhawalkar (1993) made a critical review of the benefiers of earthworms in soil environment and observed that earthworms are important in soil formation, soil pH, humus formation, improvement of soil structure, soil enrichment, water infiltration, moisture absorption, farm and waste management. Earthworms and the host of associated symbiotic and commensalic organisms contribute an organic system for plant nutrition. He observed that through vermiculture biotechnology earthworms are used as versatile natural bioreactors for effective recycling of non-toxic organic wastes to the soil, resulting in waste land development and sustainable agriculture.

1.1.4.1. Carbofuran

Kring (1969) reported that application of carbofuran @2 lb/ha had killed the earthworm sp. Lumbricus terrestris L. in tobacco fields.

Gilman and Vardanis (1974) reported that application of carbofuran at 2.24 Kg ai/ha reduced the earthworm population to 42% in a New Zealand pasture soil.

Sileo and Gilman (1975) found that tropical application of carbofuran induced muscle necrosis in the earthworm L. terrestris L.

Carbofuran applied at the rate of 3.4 kg ai/ha in pasture land reduced earthworm population significantly. (Tomlin and Gore, 1976).

Stenersan et al. (1978) tested the toxicity of carbofuran to the earthworm L. terrestris in Canada and found that the LD 50 of injected material was 1.3 mg/kg. They also found that the recovery was faster when carbofuran was treated between 1.5 and 5.0 μg than for worms treated with dasanit granules.

Kale and Krishnamoorthy (1981) reported that carbofuran and carbaryl produced toxicity in earthworms.

Veeravel and Bhaskaran (1981) studied the toxicity of granular insecticides to earthworms. They found out that out of all granular insecticides tried, carbofuran was the most toxic compound to the worms.

Veeresh (1983) found that the application of Carbofuran at 0.75 kg ai/ha was toxic to earthworms in tobacco nursery, betelvine gardens, paddy fields, etc.

1.1.4.2 Phorate

Edwards et al. (1967) noticed that application of phorate @4 lb/ac in garden lands had almost eliminated earthworms.

Way and Scoopes (1968) found that phorate at 250 ppm killed almost all earthworms in a sandy loam soil of pH 6.1.

Ruppel and Laughlin (1977) reported that phorate is highly toxic to the species of earthworm L. terrestris.

Naseema (1987) noticed that the earthworms dwelling in the rice field soils were adversely affected by phorate application. Significant reduction was noticed in plots treated with phorate even at the lowest dose of 1 kg ai/ha.

Suja (1987) observed that phorate at the rate of 1.5 kg ai/ha applied to the paddy soil caused 94.6% reduction in earthworm population during the first fortnight and 26.16% by the 5th fortnight of application.

1.2 NEMATODES

1.2.1 Distribution

Radopholus similis, (COBB 1893) Thorne, 1949 was reported for the first time in India in banana by Nair *et al*. (1966)

Feakin (1977) observed the nematodes associated with banana roots. He found out root lesion nematodes *Pratylenchus* spp. are commonly found associated with banana roots, *P coffeae* was widespread in America on banana but it was known more as a serious pest of a closely related crop, abaca.

Darekar and Khan (1978) reported a new nematode *Indokochinema conicuada* in banana soil in Maharashtra.

Venkitesan _et al_. (1981) reported _Merlinius brevidens_ (Allen) siddiqi associated with rice and banana in the three southern districts of Kerala.

Charles and Venkitesan (1984) reported the occurence of _Heterodera oryzicola_ for the first time in Kerala in banana plantation.

Mani _et al_. (1984) also reported that _Meloidogyne_, _Helicotylenchus_. Steiner, _Pratylenchus_. Filipjev and _Neotylenchus_. Thorne were found in banana soil.

Koshy _et al_. (1987) reported _H. oryzicola_ on banana in Goa. Prior to the isolation of the pests in banana _H. oryzicola_ was considered as an important pest of rice only.

Mohandas and Ramana (1988) noticed that the population of _R. similis_ reached maximum in the month of September/ October and minimum in the month of April/May. Black pepper was found to harbour more nematodes per gram of root compared to citrus, banana, coconut or arecanut.

Sheela _et al_.(1990) reported _R.similis_ has been recognised as an important pest of banana in the northern parts of Kerala and the rice cyst nematode _H. oryzicola_ was very serious in banana under monocropping system in reclaimed paddy land more than in homestead conditions prevailing in the southern parts of Kerala.

Koshy and Jasy (1991) noticed that coconut appeared to be the best host for R. similis followed by banana, arecanut, Sugarcane, black pepper, sweet potato and avacado.

A survey in southern states of Kerala revealed maximum frequency and population of R similis was noticed in coimbatore district (1728 nematodes/200 cm^3 of soil and 5 g of root) and in Kolar district 500 nematodes/200 cm^3 of soil) of Tamil Nadu followed by Karnataka and Kerala state (AICRP consolidated Biennial report 1991-93).

1.2.2 Influence of soil Factors

Mathur et al (1974) reported poor egg viability of H. avenae woll stored in wet (20.4% moisture) than dry (3.5%) soil.

Jayaprakash and Rao (1984) observed field moisture level of 60-90% to be suitable for the multiplication of H. oryzicola.

Khan et al. (1990) reported that temperature plays a predominating role as compared to soil moisture for nematodes in an apple orchard.

Maximum emergence of H. cajani koshy larvae was noticed from cysts at pH 10.5 (Koshy and Swarup, 1971).

Swarup and Gill (1972) noticed that the emergence of larvae from H. avenae cysts took place over a wide range of pH (3.5 to 11.5) and maximum emergence was obtained at pH 8.5.

1.2.3 Importance in soil health

Brown (1978) reported that nematodes do not contribute significantly to the breakdown of organic material in the soil, but as bacterial feeders they will have an indirect effect on decomposition.

Brady (1988) reported that nematodes are important primarily because of their interrelationships with the soil microflora which in turn play an important role in humus formation in soil.

1.2.4 Effect of insecticides

1.2.4.1 Carbofuran

Martin and Yates (1975) reported that carbofuran when applied as granules as 2.24 kg ai/ha reduced the population of Pratylenchus sp. and Heterodera sp.

Mehta (1976) reported that nematode population was low in carbofuran, phenamiphos, Fensulfothion and Dichlophenthion treated plot compared to control.

Granular nematicides, phenamiphos, ethoprop and carbofuran were found to be more effective than DBCP and to improve production of banana. (Vilardebo and Guerout 1976).

Application of carbofuran at 1 kg ai/ha with standing crop was toxic to the root lesion nematode P. indicus (Prasad and Rao 1978).

Prasad and Rao (1979) reported that application of carbofuran 1 kg ai/ha to soil as basal dose and again at 15 days after planting of paddy would be adequate to keep the Hirschmaniella mucronata populations below the economic injury level.

In a study to control banana nematodes, Nair (1981) noticed that nematode population was more in control followed by neem cake, furadan, thimet, temik, dasanit and minimum numbers in nemacur treated plots.

Prasad and Rao (1984) found that carbofuran treatment at 1 kg ai/ha reduced the incidence of Hirshmaniella sp. in paddy and increased the yields by 39%.

In a study for controlling banana nematode R. similis using different chemicals Ravichandra et al. (1987) found that carbofuran was the most effective pesticide and phorate was generally comparable to carbofuran and decamox proved to be better than phorate and other chemicals.

Idicule (1988) reported that the population of nematodes was more in control than in carbofuran and aldicarb treated plots in tomato crop and confirmed that both aldicarb and carbofuran have nematicidal property.

1.2.4.2 Phorate

Way and Scoopes (1968) found that phorate when applied to a sandy loam at 250 ppm killed almost all free living saprophytic and parasitic nematodes.

Nair (1979) reported that the application of Phorate in banana field reduced nematode population.

1.3. SOIL ARTHROPODS

1.3.1 Distribution

Studies on the population of collembola, Mitra et al. (1976) found that the collembolans were more in banana plantation (22.5%) followed by bamboo (22.38%), ixora (17.38%), grassy plot (16.02%) and sansivieria (12.27%).

Reddy and Alfred (1976) studied the microarthropods associated in the decomposition process of pitter litter of Meghalaya pine forests, and found that among microarthropods, Collembolans and Acarina play a major role in the decomposition process.

Pillai and Singh (1980) studied the micro arthropods in a grassland ecosystem of upper gangetic plain and found that acari was the most dominant group.

Haq *et al*, (1981) studied distribution and abundance of soil fauna in two vegetationally different sites in Trivandrum. Among 14 group of microarthropods, collembolans and mites were the most predominant group.

A comparative study of paddy field and adjoining uncultivated soil in Trivandrum district revealed that the latter was richer in microarthropods quantitatively and collembolans, acari and dipteran larvae also were present. Acari was the most dominant group in both soil types (Pai and Prabhoo, 1981).

Raina *et al*. (1981) observed the litter of evergreen forest and grasslands of Kashmir Himalayas and found that in all habitats acari were the dominant group followed by collembola.

Rishi (1981) reported that Kashmir Valley is extremely rich and heterogeneous in arthropod fauna.

The studies by Singh and Mahajan (1981) of the quantitative composition of soil mesofuana in tropical arable and deciduous forest soils revealed that acari were dominant in arable and forest soil while in forest litter collembola was dominant.

Vatsauliya and Alfred (1981) studied soil arthropods in Jhum ecosystem and found that the population was maximum during August and minimum during November in lower soil layers, while they were maximum during November to December for the upper soil layers.

Reddy and Alfred (1989) noticed the seasonal abundance of microarthropods in pine plantation and found that collembola Isotoma trispinata was dominant.

Perdue and Crossley (1990) reported that most soil mites were found in the top soil of 0-5 cm depths.

1.3.2. Influence of soil factors

In a study on the seasonal population fluctuations of Collembola and acarina in a deciduous forest at Ranchi. Sinha et al. (1988) found out a high organic carbon content was found to have a significant direct effect and the population was maximum in the monsoon period and in winter the populations were constant and high.

Reddy and Venkataiah (1990) reported that the arthropods were least abundant during summer (April to Mid June) and more in number during the rainy season (Mid June to

September). They recorded a greater number in tree planted areas than grassland.

Bhattacharya and Raychodhuri (1979) observed two peaks in the population of cryptostigmata and collembola, a pronounced one during post monsoon period (September - October) and a minor one during premonsoon period (May - June), in a waste land of Santiniketan.

1.3.3 <u>Importance in soil health</u>

Some species of insects live in the gut of Collembolans as symbionts and probably assist in the digestion of plant material (Brown, 1978).

Mites because of their numbers, probably play an important role in the decomposition of organic substances. (Brawn, 1978)

Amelswoort <u>et al</u>. (1988) studied the impact of Collembola on humification and mineralization of soil organic matter and observed that larger collembolans stimulated mineralization processes by selective feeding of fungi.

1.3.4. <u>Effect of insecticides</u>

1.3.4.1 Carbofuran

Carbofuran applied at 0.56 kg ai/ha to fields of lucerne with grasses grown for hay caused significant reduction in the number of thysanoaptera and phytophagous coleopteran larvae in soil (Dondale, 1972)

Martin et al. (1975) found that carbofuran at 2.24 kg ai/ha applied in soil reduced the sminthurid population and slightly reduced the populations of other collembola and larger arthropods.

Kumar and Agarwal (1983) reported that aldicarb and carbofuran applied at 1.0kg ai/ha had more toxic effect on Collembola and other arthropods than on mites. In the plots treated with disulfoton or phorate, the mite population increased faster than in plots treated with aldicarb and carbofuran probably because the former two insecticides were more toxic to predacious mites.

1.3.4.2 Phorate

Way and Scoopes (1968) reported that phorate at 10 ppm and 250 ppm applied in sandy loam soil killed almost all collembola and acarina. They also found that their population began to increase when residue of phorate equivalent decreased to about 2 ppm and after 15 months the population came on par with that of untreated plots.

1.4 MICROORGANISMS

1.4.1 Distribution

Wakesman (1952) found that the most abundant species of bacteria in soil was *Bacillus subtilis* cohn.

Rangaswamy (1966) observed that the most predominant genera of actinomycetes in soil were *Nocardia*, *streptomyces* and *Micromonospora*.

Murthy *et al*. (1976) reported that *Aspergillus* sp. was the most predominant one in Okra soil.

Jha *et al*. (1992) studied the ecology of soil microflora and mycorrhizal symbionts in degraded forests at different altitudes and found that bacterial population was higher than the fungal population.

1.4.2 Influence of soil factors

Alexander (1961) reported that maximum bacterial density was found in regions of fairly high moist content and the optimum level for the activities of aerobic bacteria was 50-75% of the moisture holding capacity. Actinomycetes did not occur under water logging condition ie 85-100% water holding capacity. Fungi was positively correlated with moisture content.

Alexander (1961) reported high acid or alkaline conditions tend to inhibit many common bacteria as the optimum for most species was near neutrality. The greater the hydrogenion concentration smaller generally was the size of the bacterial population. Actinomycetes were not tolerant to low pH and the population size was inversely related to the hydrogen ion concentration. The population was most abundant in soils of about pH 6.5 to 8.0. Where as fungal population was dominant in the areas of low pH.

1.4.3 Importance in soil health

Brown (1978) reported that bacteria play a major role in the degradation of pesticides and are also important for circulating nutrients such as carbon, phosphorus and nitrogen in the soil.

Mishra (1986) reported that Micro organisms play a major part in ammonification process, nitrification (mainly bacteria) and soil enzymatic activities are responsible for the decomposition of organic matter and many other chemical transformations.

Micro organisms induce many biochemical transformations in the soil. These include microrganisms which induce many biochemical transformations in the soil.

These include mineralization of organically basic forms of nutrients that exchange reactions, fixation of atmospheric nitrogen and various other changes leading to better availability of nutrients already present in the soil. The group of microorganisms responsible for nitrogen fixation, phosphorus solubilisation and compost decomposition are being put to beneficial use in the form of biofertilizers. Such common useful organisms are Rhizobium, Azotobacter, Azospirillum and Blue Green Algae (Verma, 1993).

Alexander (1961) reported that actinomycetes play an important part in the fermentation of composts and manures. Many others are important for the production of antibiotics.

Brady (1988) reported that actinomycetes are undoubtedly of the greatest importance in the decomposition of soil organic matter and the liberation of nutrients there from. Apparently they reduce to simpler forms even the more resistant compounds, such as cellulosechitin and phospholipids.

Brown (1978) reported that the quality and quantity of organic matter present in soil have a direct bearing on fungal numbers in soil since most fungi are heterotrophic in nutrition.

In this ability to decompose organic residues, fungi are the most versatile and perhaps the most persistent of any group. They play a major role in decaying plant residues and in humus formation (Brady, 1988).

Subba Rao (1986) reported that fungi like Aspergillus, Alternaria, Humicola produce substances similar to humic acid in soil and hence may be important in the maintenance of the soil organic matter. Some fungi capable of forming ectoparasitic association with the root system of forest trees such as pine belonging to the genera Boletus and Lactarius help in the mobilization of soil 'P' and nitrogen into plants. This is one of the chief sources of decaying woody tissues.

1.4.4 Effect of insecticides

1.4.4.1 Carbofuran

Tu (1972) reported that nematicides like Dasanit, Carbofuran, D.D and Vorlex applied in loamy sand indicated that the bacterial and fungal populations initially decreased with some nematicides like carbofuran.

Hubbel et al. (1973) found that the application of carbofuran had no effect on the number of bacteria of the rhizosphere and non rhizosphere soil in sorghum and tobacco cultivated fields.

Mathur _et al_. (1980) reported that carbofuran at 6 Kg ai/ha increased bacterial and fungal populations in a carrot field with organic soil.

Visalakshy _et al_. (1980) reported that Carbofuran when used at recommended dose did not affect the microbial activity especially bacteria and actinomycetes in rhizosphere of rice.

Application of carbofuran at 2 ppm, and 5 ppm did not cause much variation in the nitrification process. _Nitrobacter_ group was more sensitive to carbofuran than the _Nitrosomonas_ (Palaniappan and Balasubramanian, 1986).

Microbial biomass assays showed an increase in specific carbofuran degrading bacteria in soils that are pretreated with carbofuran (Dzantor and Felsot, 1989).

Kale and Raghu (1989) reported that carbofuran at normal (N) and ten times field concentration (10 N) had no inhibitory effect in microbial numbers and respiration in vertisol and Alfisol.

1.4.4.2 Phorate

Cowley and Lichtenstein (1970) reported that insecticides like aldrin, lindane, parathion, phorate or carbaryl inhibit the growth of most fungal spp. This inhibition was a result of a particular insecticide fungus combination.

Phorate at the rate of 10 kg/ha applied to blackgram soil had no influence on the total population of bacteria, fungi or actinomycetes in soil but increased Azotobacter beijerinle and clostridium prazmowski population and at a higher dose of 20 kg/ha it was found to be toxic to fungi, Azotobacter and clostridium with no significant effect on actinomycetes or Rhizobium population (Chelliah, 1972).

Singh and Gulathi (1972) found that phorate at 100 ppm applied in cotton soil had an adverse effect on the ammonifiers and nitrifiers in the soil, but the conversion from nitrite to nitrate was not inhibited. They also noted that the adverse effect was more pronounced in the initial stages and it was overcome towards the later stages.

Tewari et al. (1972) indicated an increase in the soil fungal population during the first three weeks following application of phorate to groundnut soil and increase in actinomycetes population through out the season, They also reported that phorate inhibited the Azotobacter population in the soil.

Satpathy (1974) found that phorate when applied at 2 Kg ai/ha around brinjal seedlings showed moderate antifungal action and was less toxic to soil bacteria. More than 50% reduction in bacterial colony was observed 10 days after application in the treated plots and the toxic effect of phorate was reduced considerably, later.

Application of phorate significantly increased the bacterial and fungal populations. Carbofuran however, significantly depressed the bacterial population and numerically lowered the prevalence of fungal population and actinomycetes population decreased at all the stages (Kandaswamy et al, 1975).

Chendrayan and Prasad (1976) found that phorate at 5 Kg ai/ha reduced the soil bacteria and Rhizobium in groundnut soil.

Visalakshy (1977) reported that phorate stimulated the population of fungi and suppressed the population of actinomycetes were negatively correlated with residues of phorate in soil while the population of bacteria was positively correlated.

Pandiyan and Balasubramanian (1978) found that phorate increased bacterial population and the increase was proportional to dose. The population was more in clayey soil. In the case of fungi the population was reduced by 26.2%. Reduction in population was high in black cotton soil, followed by clay soil, red soil and sandy loam. The actinomycetes population was more in clay soil followed by black cotton, red and sandy loam soils.

Visalakshy and Nair (1978) reported that phorate at a higher dose used for the control of pests of cowpea significantly increased the fungal and bacterial population and suppressed actinomycetes.

Visalakshy et al. (1981) reported that phorate at 1.5 kg ai/ha and 3.0 Kg ai/ha in soil did not affect the population of fungi but it stimulated the actinomycetes and bacterial populations for a period of 7 months after application.

Kishorekumar et al. (1984) noticed that phorate at the rate of 1.0 Kg ai/ha did not adversely affect the soil microorganisms and accelerated their colonisation.

Das (1986) observed that phorate applied at 1.25 kg ai/ha reduced the fungal and actinomycetes population but increased the bacterial population in red loam.

Naseema (1987) found that the population of bacteria was significantly reduced by the application of phorate up to 7th day and the population showed an increasing trend from 14th day onwards.

Varshney and Rana (1987) noticed that phorate didn't affect the population of fungi, bacteria or actinomycetes when applied at the rate of 1.68 ai/ha in sandy loam soil.

1.5. PERSISTENCE

1.5.1. HCH

BHC is not as persistent as DDT, only about 60 percent remaining one year after the insecticide is applied, but is more volatile and generally more effective as the soil insecticide (Edwards, 1966).

Edwards (1971) reported that DDT is the most persistent of organochlorine insecticides followed by dieldrin, toxaphene, endrin, isodrin, chlordane, heptachlor, aldrin and benzene hexachloride.

Venkataramaiah and Singh (1973) studied the distribution of BHC residues in the soil at kallar region of the coffee plantation in Karnataka which ranged from 0.025 to 0.125, 0.01 to 0.05 and non- detectable to 0.015 ppm at a depth of 0 to 15, 31 to 45 and 51 to 75 cm, respectively.

Sethunathan *et al*. (1981) reported that organochlorine compounds are more persistent than the organophosphates and carbamates in aerobic conditions, where as in anaerobic conditions as in flooded soils certain organochlorine compounds exhibit similar low persistence curves as the organophosphates and carbamates. In fact BHC, an organochlorine was relatively less persistent than carbamates.

Mishra (1986) reported organochlorine which are more persistent in soil due to their less biodegradability than organophosphates. BHC is detrimental to some extent but it is relatively less persistent.

Samuel et al. (1988) Studied the persistence and binding capacity of ^{14}C - P,P' - DDT and ^{14}C - γ - HCH in a sandy loam soil of Delhi over monsoon, winter and summer seasons under field conditions, both organochlorine dissipated most rapidly during the initial 60 days.

1.5.2. Carbofuran

Carbofuran persisted 16 weeks in a sandy loam and for 25 weeks in a muck soil (Harris, 1969).

Read (1969) reported that carbofuran (10 ppm) persisted for 3 months in an acidic soil.

Carbofuran granules when placed 3/4th inch deep in a mineral soil was found to show an easily detected upward movement in soil (Read, 1971).

Caro et al. (1973) have reported that persistence of carbofuran in soil was more in furrow application than in the case of broadcast application. They also observed that 0.5 to 2.0 percent of the carbofuran applied was lost in run-off from an infurrow application than was lost from a broadcast application.

Martin (1974) reported that most of the residues of carbofuran, fensulfothion, fenitrothion and DDT remained in the top 3 cm of the soil when the insecticides were applied at the rate of 2.24 Kg ai/ha to a pasture.

Homeyer (1975) reported that carbofuran in a single application at drilling and at planting time in slightly acid or neutral soil usually remains effective for 10 - 12 weeks and that the initial effect was best in high moist soils.

Das et al. (1976) reported that carbofuran when compared with phorate, Mephosfolan and disulfoton ranked third in persistent toxicity to *Aphis craccivora* in laterite and black soils.

The degradation of carbofuran was found particularly slow in a poorly drained clay muck, a well drained clay muck and a poorly drained clay by Willams et al,(1976).

Studies by Rajukannu _et al_. (1977) on the persistence and degradation of carbofuran in black soil under flooded condition revealed that carbofuran when applied at 1.25 Kg ai/ha was found to degrade slowly and reached to 1.55 ppm level after 30 days of application. They also found that the persistence of carbofuran was quite longer than phorate which has only brief persistence.

Talekar _et al_. (1977) found that the degradation resulted in only 32% recoveries, at the end of the fall of the winter seasons and that the break down was further acclerated during the hot, rainy, spring and summer months when these recoveries were lower.

Thirumurthi and Lebrum (1977) assayed carbofuran residues using _Folsomid Candida_ (collembola) as test organism. Toxic residues persisted for 10 weeks after application at the the rate of 2 Kg ai/ha and the collembola population in the soil was found to recover after 16 weeks. But when applied at higher dose of 10 Kg ai/ha the population showed no sign of recovery even after 24 weeks after the application.

Venkateswarlu _et al_. (1977) reported that carbofuran persisted in an acid sulphate soil even after several weeks of flooding which they assigned to exceedingly low pH 4.2.

Carbofuran applied 3 and 7 days after liming in soil persisted for more than 21 days, probably due to the inactivation of the group of soil microorganisms involved in the biodegradation and active detoxication of carbofuran particularly if their competitive ability is low (Rajagopal, 1979).

Greenhelgh et al. (1981) found that carbofuran was when applied to a humic mesisol at 2.24 and 4.48 Kg ai/ha in the field the half life of carbofuran was 15-38 days.

Gorder et al. (1982) Carried out field and lab studies on persistence of soil applied carbofuran and found that soil mositure was found to be a very important factor in carbofuran persistence and found that 22 weeks after application no carbofuran residue was detected in soil below 7.5 cm in depth.

Copin et al (1984) reported that residue of carbofuran in the top soil layer is very small and becomes undetectable within 3 months.

1.5.3. Phorate

Lindely (1963) reported that rate of application and soil type were the factors influencing biological persistence of phorate. In mineral soil less phorate was required than in peat soil with a maximum of 35% organic matter.

Parker and Dewey (1965) observed that when phorate was applied @ 3 lb/acre in the field the breakdown was greatest during the first week and almost completed with in a month.

Patterson and Rawlions (1968) found that the residues of phorate applied in soil had disappeared in the summer after two months and in autumn the residues persisted longer and in winter, when the soil was frozen, there was almost no loss of residue. It was also reported that the degradation in soil was dependant on temperature and the rate of degradation was increased with soil temperature.

Way and Scoopes (1968) observed that 50 percent of phorate disappeared in 68 days when applied at 10 ppm and persisted for two years at 250 ppm in sandy loam soil.

Kearney _et al_., (1969) defined persistence as the time required to reduce the pesticidal concentration to 75 to 100 percent of the amount initially applied to the soil.

Metabolism of phorate in soils can be rather rapid. Getzin and Shanks, (1970) could detect the conversion of 13 percent of applied phorate to phorate sulfoxide in zero day samples.

Menzer _et al_, (1970) recovered large amounts of phorate sulfoxide, phorate sulfone and oxyphorate sulfoxide from phorate treated soils. They also recovered minute quantities of oxyphorate and oxyphorate sulfone.

Suett, (1971) obtained longer persistence of phorate in peaty soil than in sandy loam when applied in June @ 2Kg ai/ha.

Phorate was more mobile in brown forest soils than in degraded 'chernozen' and black marsh soil indicating that soil absorbency was important for the translocation of pesticides (Ostogic _et al_., 1972).

Dixit _et al_. (1974) reported that residues of phorate declined by 100% within 70 days when applied @ 1.5 g / metre.

Agnihotri _et al_. (1975) found that phorate persisted for 45 days under irrigated conditions and for 60 days under non irrigated conditions when applied @ 1.5 Kg ai/ha .

Phorate at different doses of 0.25, 0.5, 0.75 and 1.0 Kg ai/ha persisted in the soil for more than 75 days and the degradation was more with increase in period (Pandiyan, 1975).

Visalakshy (1977) observed that phorate when applied @ 100 ppm ai the residues persisted most in the forest soil followed by alluvial, red, lateritic and sandy soils. The half life of the insecticide in these soils was 48.5, 30.2, 16.8, 15.7 and 13.4 days respectively.

Krishnaiah and Kalra (1978) reported that phorate disappeared almost completely from soil with in 15 days of application even when applied @ 4.0 Kg ai/ha.

Venkataramaiah and Singh (1978) found that quick degradation of phorate occurred with in 24 hours when applied to soil of pH 6.2.

However, Chapman et al. (1982) could not find significant differences in the persistence of phorate residues in different soil types. They found that phorate disappeared more rapidly in natural soils than in sterile soils, irrespective of the soil type.

Singh et al. (1984) found an initial content of 35 ppm of phorate in soil which reduced to 2.9 ppm by 120 days after application when applied @ 4 Kg ai/ha.

Rao et al. (1986) could detect 0.38 ppm of phorate in soil 30 days after application when applied @ 1kg ai/ha 30 days before harvest of paddy crop. The half life worked out to be 4.93 to 6.14 days.

Naseema (1987) observed that insecticide persistence was highest in lateritic soils and lowest in sandy soils.

SitaRama Rao (1989) observed that phorate persisted at effective levels for 75 days in sandy, 90 days in lateritic upland and 105 days in black cotton soil.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field trial was conducted to study the impact of different insecticides, recommended for the control of pests of banana (rhizome weevil, aphids and nematodes) on different organisms in the soil.

The experiment was laid out in the instructional farm, college of Agriculture, Vellayani, during 1992.

2.1. Lay out of the experiment

Design of the experiment	:	RBD
Number of the treatments	:	4
Number of replications	:	5
Variety	:	Nendran
Spacing	:	2x2 m
Plot size	:	$12 \times 10m^2$

The crop was grown as per the package of practices recommendations of Kerala Agricultural University for cultivation of banana (1989). Strong bunds were raised all around each of the plots to prevent adjacent effects. The samples were taken at random from the experimental plots avoiding one metre periphery .

2.2. Treatments

1. Suckers were dipped for 30 minutes in HCH 0.2% suspension (BHC 50 WDP of M/s. S.N. Chemical Industries, Faridabad) before planting as recommended for the control of rhizome weevil.

2. Phorate 2.5 g ai/plant (Parrytox 10g of M/s EID parry (India) LTD, Madras) at 20 DAP, 75 DAP and 165 DAP is used as recommended for the control of banana aphid to contain bunchy top disease of banana.

3. Carbofuran 1 g ai/plant (Furadon 3G of M/s. Rallis India LTD, Bombay) at planting and at 105 DAP is used as recommended for the control of nematodes.

4. Control (untreated)

2.3. Estimation of soil organisms

The population of earthworms, parasitic nematodes, non parasitic nematodes, collembolans and mites, bacteria, actinomycetes and fungi were estimated in soil samples once prior to the planting ,then at monthly intervals. Soil samples were taken from the basins one foot away from the basal region of the plant.

2.3.1. Earthworms

Sampling was done randomly from two different spots in each plot. Soil was dug out from an area of 20 x 20 cm to a depth of 20 cm using a spade from each sample one litre soil was taken for assessing the earthworm population and the number was counted by hand sorting (Svendson, 1955)

2.3.2. Nematodes

Soil samples were taken (500 ml) randomly from two different spots in each plot to a depth of 20cm, from which representative samples of 100 ml was taken for nematode extraction. Nematodes in the samples were extracted following the method of Cobb's sieving and decanting technique modified by Christie and Perry (1951). Then the extracted nematode suspension was cleared from the filtrate by the petridish method. The suspension was poured over a tissue paper placed over a wire gauze kept on petridish containing water in such a way that the suspension was just in contact with water. This was kept undisturbed and at the end of complete recovery, the nematode suspension in the dish was made upto 100 ml. An aliquot of 5 ml was pipetted out into a counting dish and the nematodes present were counted under a binocular microscope. The process was repeated three times and the average of three countings multiplied by 20 gave the nematode population in 100 ml. soil.

2.3.3. Soil micro arthropods

Soil samples were collected using a soil augor. One litre soil sample along with litter materials were taken randomly from four different locations in each plot with minimum disturbance to the soil. Microarthropods in the samples were extracted by Berlese - Tullgren funnel method (Macfadyen, 1961). The soil along with the litter sample was placed on a wire gauze over a steep sided funnel and the soil was heated gently using a 40 watts electric bulb. Heating was continued for a day, and the soil arthropods moved down and they were eventually collected in the collecting vial kept at the tail of the funnel containing water. This provision was to create a gradient in the relative humidity for soil arthropods to move down. The content in the collecting vial was directly transferred to a counting dish and the population of collembolans and mites were counted under a binocular microscope.

2.3.4. Microorganisms

For estimating the microbial population rhizosphere soil samples (10 g each) were collected from two different spots in each plot. The total count of bacteria, actinomycetes and fungi were taken by serial dilution plate technique of Johnson and curl, (1972). Nutrient agar, Kausters agar and Martins Rose Bengal media were used for the isolation of bacteria, actinomycetes and fungi respectively. Serial dilutions of different rhizosphere samples were prepared upto 10^{-7} dilution, by using appropriate sterile water blanks. One ml of 10^{-7}, 10^{-5} and 10^{-3} dilutions were transferred to petri plates of bacteria, actinomycetes and fungi. Twenty five ml of appropriate medium was then added to each plate. Three replications were maintained for each treatment. The plates were incubated at room temperature (29-31^{o}c) for a period of 14 days. The fungal colonies were counted daily from third to seventhday, bacterial colony counts were taken from third to tenth day and for actinomycetes counts were taken from sixth to fourteenth day. The population of bacteria, actinomycetes and fungi in 10 g sample was computed from the counts obtained.

2.4. Assessment of important parameters of soil environment relating to the experimental field

2.4.1. Soil moisture

Soil moisture was determined by gravimetric method as described by Khanna and Yadav, (1979). Five gram soil sample (one from each plot) was transferred into a squat shaped weighing bottle and the bottle with the soil was weighed in a chemical balance. Then it was allowed to dry in an electric oven at 105°c. It was cooled in a dessicator and again weighed in a chemical balance. From the loss in weight of the sample the percentage of moisture was calculated.

2.4.2. Soil P^H

Soil P^H was determined electrometrically by using P^H meter as described by Khanna and Yadav (1979). Ten gram sample was transferred into a 50 ml beaker. 25 ml water was added into it and it was stirred at regular intervals for 20 to 30 minutes. Then the P^H was read in the P^H meter.

2.4.3. Organic matter

Organic matter was determined by the Walkley and Black's rapid titration method as described by Hesse (1971). One gram finely ground soil was weighed into a 500 ml conical flask and 10 ml potassium dichromate solution was pipetted into the flask. 20 ml concentrated sulphuric acid was added and the content was mixed thoroughly and the flask was allowed to stand on a sheet of asbestos for 30 minutes. Finally 200 ml distilled water and Ferrion indicator 2-3 drops were added into it. The content was titrated against the ferrous solution, the end point was noticed by the change in colour from blue to green. The organic matter content was calculated from the titre values.

2.5. Statistical analysis

The data obtained were subjected to analysis of variance to draw valid conclusions using appropriate transformations. The correlations between the soil organisms and soil parameters in different treatments were also worked out to assess their association if any (Snedecor, 1961).

RESULTS

RESULTS

3.1. Effect of insecticides on the population of earthworms in banana plots

Effect of different insecticides on the population of earthworms in banana fields is presented in Table 1 and Figure 1.

The pretreatment population of earthworms in the experimental field ranged from 3.72 to 4.88 and the variations were not statistically significant.

One month after the planting of HCH treated suckers the population of earthworms in the plots showed a significant reduction over that of control plots the numbers being 2.10 and 4.86/l soil respectively. During the second month also the difference between the treatment and control remained significant the populations being 4.11 and 6.95/l soil respectively. In subsequent months the population of earthworms in plots treated with HCH ranged between 2.15 and 4.6 while in control plots the population fluctuated from 2.42 to 4.36. The differences between the numbers in HCH treated and control plots did not show statistical significance in any of the observations.

In the case of carbofuran which was applied at the time of planting the population observed one month after

Table 1. Mean number of earthworms in banana plots treated with different insecticides for pest control, observed at monthly intervals after planting

Treatments	Pre treatment population	Mean population in 1000 ml soil observed at different intervals after planting (months)									
		1	2	3	4	5	6	7	8	9	10
HCH	4.85 (2.41)	2.10 (1.76)	4.11 (2.26)	2.15 (1.77)	3.58 (2.14)	2.89 (1.97)	2.83 (1.96)	2.55 (1.89)	3.34 (2.03)	3.89 (2.21)	4.60 (2.36)
Carbofuran	3.92 (2.27)	3.21 (2.05)	2.32 (1.82)	2.52 (1.87)	0.89 (1.37)	1.96 (1.72)	2.93 (1.99)	1.29 (1.51)	1.27 (1.50)	2.45 (1.86)	3.39 (2.09)
Phorate	3.72 (2.17)	0.87 (1.37)	3.03 (2.00)	1.12 (1.46)	3.28 (2.06)	1.81 (1.68)	2.02 (1.74)	1.81 (1.68)	2.32 (1.82)	2.52 (1.88)	2.39 (1.84)
Control	4.88 (2.42)	4.86 (2.42)	6.95 (2.82)	3.43 (2.10)	3.89 (2.21)	3.95 (2.22)	3.54 (2.13)	2.42 (1.85)	4.27 (2.29)	3.72 (2.17)	4.36 (2.31)
CD		0.57	0.45		0.52				0.52		

HCH - Suckers dipped in 0.2 per cent suspension before planting
Carbofuran - 1 g ai/plant at planting and 105 days after planting
Phorate - 2.5 g ai/plant at 20,75 and 165 days after planting

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

planting (3.21/l soil) did not show statistically significant difference from that of untreated plot (4.86/l soil). But the mean count during the second month in the treated and control plots (2.32 and 6.95/l soil respectively) showed significant difference. But the effect was seen lost during the third month when the population levels reached at 2.52 and 3.43/l soil in treated and control plots respectively. There was significant reduction in the population one month after the second application of carbofuran (0.89/l soil) compared to the population in control (3.89/l soil). In the subsequent observation ie. two months after the second application population in treated plots (1.96/l soil) came on par with that of control (3.95/l soil). Among the remaining six observations data relating to the population of earthworms in carbofuran treated plots and those in control did not show significant variations except in the 8th observation where the population in carbofuran treated plot was significantly lower (1.27/l soil) than that of control (4.27/ l soil). The population levels in treated plots ranged between 1.27/l soil to 3.39/l soil while the corresponding range in control plot was 2.42 to 4.36/l soil.

In the case of phorate the population of earthworm reached a significantly lower level (0.87/l soil) compared to control (4.86/l soil) during the first observation after the treatment ie. within 10 days from the date of application.

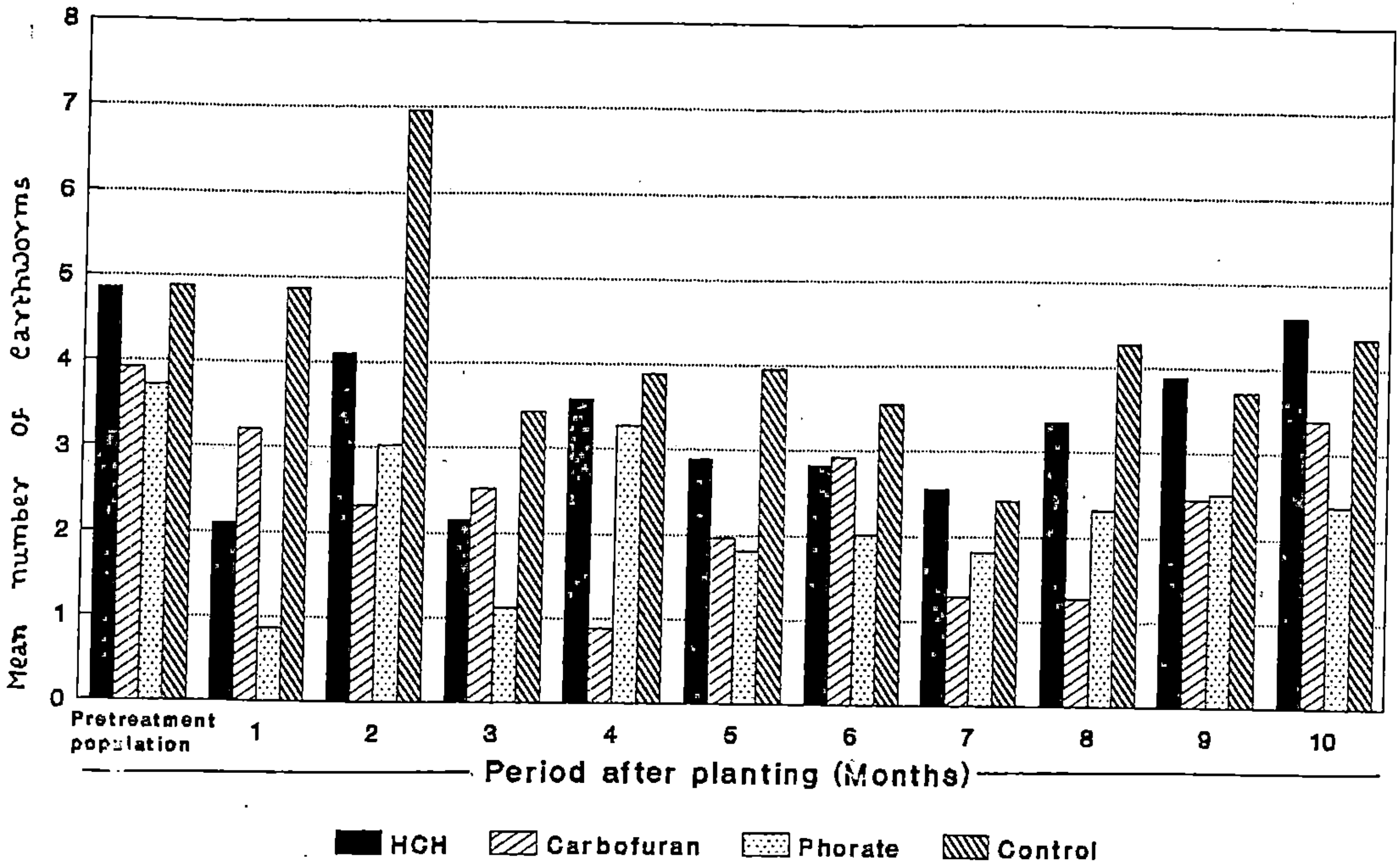

Fig. 1. Mean number of earthworms in banana plots treated with different insecticides for pest control

In the second observation also the population in phorate treated plots (3.03/l soil)was significantly lower than that of the control plot (6.95/l soil). But in the third observation the mean population in the treated and control plots came on par. (1.12 and 3.43/l soil respectively).

The third treatment with phorate done on 165 DAP did not cause significant reduction of population (2.02 /l soil) when compared to that of control (3.54 / l soil). In all the subsequent counts the number of earthworms in phorate treated plots remained on par with those of control the ranges being 1.81 to 2.5 and 2.42 to 4.27 respectively.

Population in plots treated with different insecticides showed significant variation during the 1^{st}, 2^{nd}, 4^{th} and 8^{th} month after planting only. During the first month the lowest population was in plots treated with phorate (0.87/ l soil) and it came on par with that of HCH (2.10/l soil). During the second observation all the treatments were on par the population in HCH, carbofuran and phorate being 4.11, 2.32, 3.03 / l soil respectively. During the fourth month the population in carbofuran treated plot (0.89 / l soil) was significantly lower than those of HCH (3.58 / l soil) and phorate (3.28 / l soil), the latter two being on par. In the 8^{th} observation the populations in the three treatments came on par.

3.2. Effect of insecticides on the population of parasitic nematodes in banana plots

Effect of different insecticides on the population of parasitic nematodes in banana fields observed at monthly intervals is presented in Table 2 and Figure 2.

The pretreatment population of parasitic nematodes in the experimental field ranged from 16.22 to 32.51/100 ml soil and the variations were not statistically significant. Upto three months the population of parasitic nematodes in the treated plots did not show any statistical difference. The population of parasitic nematodes in HCH treated plots ranged between 14.11 to 23.87 while in control the population ranged from 20.07 to 29.69/ 100 ml soil. During the fourth month a significant difference was noticed between the treatments and control but population HCH treated plots and those in control were on par those being 18.53 and 26.27/100 ml soil respectively. In subsequent months also the population of parasitic nematodes in the plots treated with HCH ranging from 9.24 and 23.59 and those of control ranging from 16.19 and 33.52 did not show statistically significant variations.

In the case of carbofuran it was applied at the time of planting and the population of parasitic nematode varying from 13.37 to 18.99 /100 ml of soil in carbofuran

Table 2. Mean number of parasitic nematodes in banana plots treated with different insecticides for pest control, observed at monthly intervals after planting

Treatments	Pre treatment population	Mean population in 100 ml soil observed at different intervals after planting (months)									
		1	2	3	4	5	6	7	8	9	10
HCH	21.98 (4.79)	16.87 (4.22)	14.11 (3.89)	23.87 (4.98)	18.53 (4.42)	23.59 (4.96)	17.22 (4.27)	17.41 (4.29)	17.96 (4.35)	9.29 (3.02)	13.25 (3.78)
Carbofuran	16.39 (4.06)	15.52 (4.06)	13.37 (3.79)	18.99 (4.48)	12.98 (3.74)	16.81 (4.22)	14.36 (3.92)	12.09 (3.61)	13.52 (3.81)	15.64 (4.08)	16.59 (4.19)
Phorate	16.22 (4.14)	8.67 (3.10)	16.16 (4.14)	14.31 (3.92)	17.51 (4.30)	17.01 (4.24)	10.10 (3.33)	11.14 (3.48)	8.02 (3.00)	14.44 (3.89)	16.09 (4.13)
Control	32.51 (5.78)	22.29 (4.83)	20.07 (4.59)	29.69 (5.54)	26.27 (5.22)	33.52 (5.87)	19.89 (4.57)	27.39 (5.32)	23.82 (4.99)	16.19 (4.15)	19.55 (4.53)
CD					1.44			1.02			

HCH - Suckers dipped in 0.2 per cent suspension before planting
Carbofuran - 1 g ai/plant at planting and 105 days after planting
Phorate - 2.5 g ai/plant at 20,75 and 165 days after planting

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

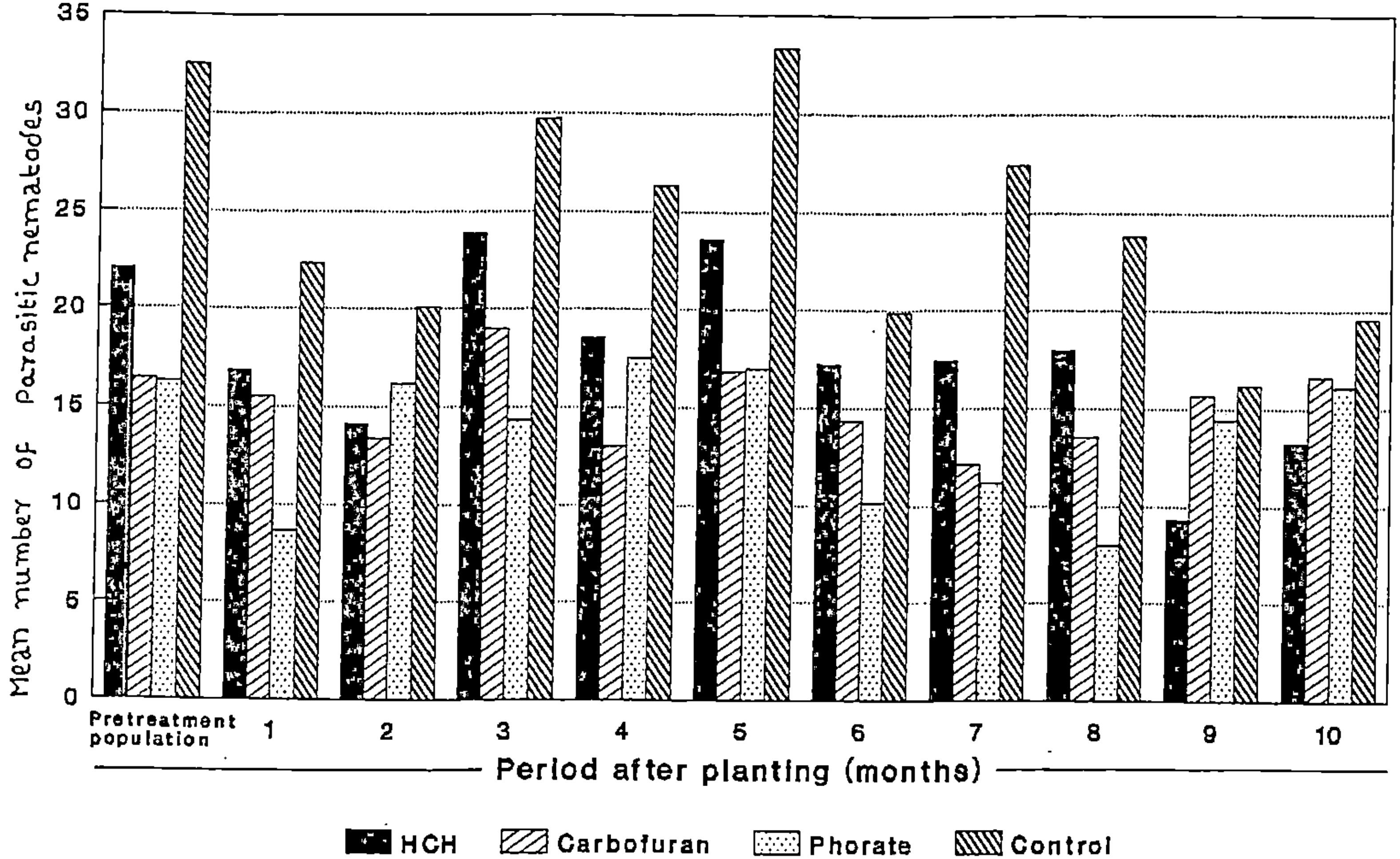

Fig. 2. Mean number of parasitic nematodes in banana plots treated with different insecticides for pest control

treated plots and from 20.07 to 29.69 in control did not show statistical significance. During the fourth month the population of parasitic nematodes in the treatment (12.98) was significantly lower than that of control (26.27). In two subsequent observations the population in treatments were 16.81 and 14.36 while corresponding counts in control were 33.52 and 19.89 respectively. But the variations were not statistically significant. However, significant difference was noticed during seventh month between the carbofuran treated plots and control, the population of parasitic nematodes in the treated and control plot being 12.09 and 27.39/ 100 ml soil respectively. In subsequent months the population of the nematode in plots treated with carbofuran ranged from 13.52 to 16.59 while in control the population fluctuated from 16.19 to 23.82/ 100 ml soil respectively. The differences between the observations in carbofuran treated and control plots did not show statistical significance in any of these observations.

In the case of phorate upto three months after treatment no significant difference was noticed in the population of parasitic nematodes, which ranged from 8.67 to 16.16 in comparison with control where the population ranged from 20.07 to 29.69 /100 ml soil respectively. In the 4^{th} month, significantly lower population was noticed in phorate treated plots (17.51/ 100 ml soil) compared with control

(26.27/100 ml soil). In subsequent two observations no significant difference was noticed between the population in phorate treated plot (17.01 and 10.10) and in control (33.52 and 19.89). The third treatment with phorate done on 165 DAP showed significant effect, the number being 11.14 and 27.39/100 ml soil respectively in treatment and control. But the effect was seen lost during subsequent three months since the population ranging between 8.02 to 16.09 in phorate treated plots and 16.19 to 23.82 in control came on par.

Population in plots treated with different insecticides showed significant variations at fourth and seventh month after planting only. During the fourth month the lowest population was in plots treated with carbofuran (12.98/100 ml soil) and it was significantly lower than those of phorate (17.51/ 100 ml soil) and HCH (18.53 /100 ml soil) and control (26.27/100 ml soil) the latter three being on par. In the seventh month of observation the population in the three treatments came on par. The population in HCH, carbofuran and phorate being 17.41, 12.09 and 11.14/100 ml soil respectively.

3.3. Effect of insecticides on the population of non parasitic nematodes

The population of non parasitic nematodes in banana fields with different insecticides is presented in Table 3 and Figure 3.

Table 3. Mean number of non parasitic nematodes in banana plots treated with different insecticides for pest control, observed at monthly intervals after planting

Treatments	Pre treatment population	Mean population in 100 ml soil observed at different intervals after planting (months)									
		1	2	3	4	5	6	7	8	9	10
HCH	36.31 (6.02)	40.17 (6.42)	37.41 (6.91)	23.96 (4.99)	20.32 (4.62)	20.49 (4.63)	19.11 (4.48)	19.08 (4.48)	23.32 (4.93)	19.74 (4.55)	21.18 (4.70)
Carbofuran	27.09 (5.30)	30.02 (5.58)	28.02 (5.39)	13.81 (3.85)	14.73 (3.97)	18.50 (4.41)	19.29 (4.50)	17.28 (4.27)	14.72 (3.97)	16.68 (4.20)	13.79 (3.84)
Phorate	16.32 (2.44)	16.44 (4.18)	27.62 (5.35)	20.90 (4.68)	17.58 (4.31)	17.49 (4.29)	9.97 (3.31)	15.61 (4.08)	17.27 (4.27)	16.59 (4.19)	14.70 (3.96)
Control	34.50 (5.95)	35.59 (6.05)	59.02 (7.74)	33.51 (5.87)	24.56 (5.05)	27.50 (5.34)	26.58 (5.25)	25.65 (5.16)	28.89 (5.47)	21.18 (4.70)	22.54 (4.85)
CD			1.28								

HCH - Suckers dipped in 0.2 per cent suspension before planting
Carbofuran - 1 g ai/plant at planting and 105 days after planting
Phorate - 2.5 g ai/plant at 20,75 and 165 days after planting

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

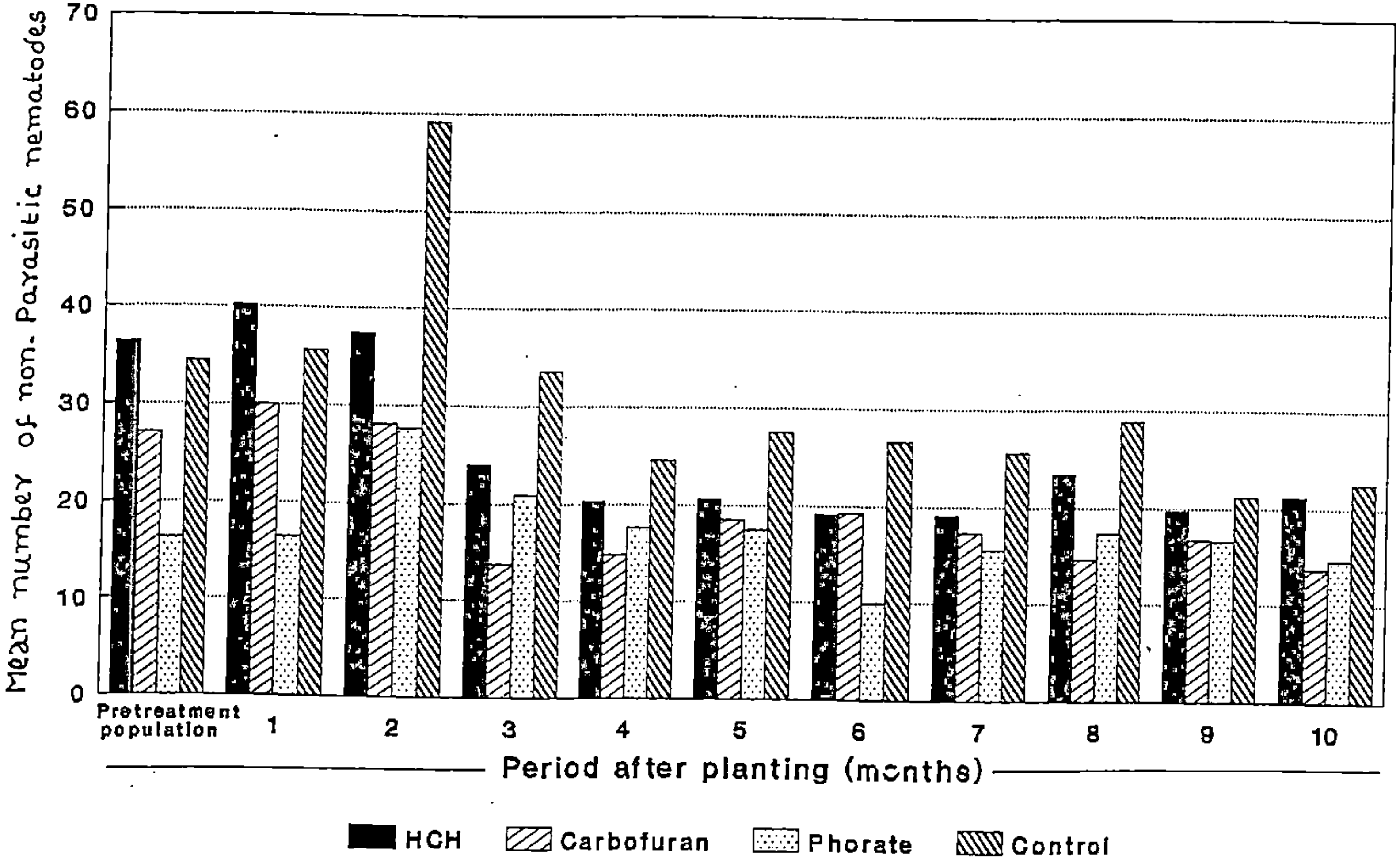

Fig. 3. Mean number of non parasitic nematodes in banana plots treated with different insecticides for pest control

The pretreatment population of non parasitic nematodes in the experimental field ranged from 16.32 to 36.31 and the variations in the treatment plots and control were not statistically significant.

One month after the application of HCH the population of non parasitic nematodes in the treated plots did not show statistically significant difference over that of control plots, the numbers being 40.17 and 35.59/100 ml soil respectively. During the second month in the treated (37.41/100 ml soil) and control plots (59.02/100 ml soil) significant difference was noticed in the population of non parasitic nematodes. But the effect was seen lost from the third month onwards and the population of non parasitic nematodes in plots treated with HCH ranged between 19.08 to 23.96 while in control plots, the population fluctuated from 21.18 to 33.51/100 ml soil. The differences between the observations in HCH treated and control plots did not show statistical significance in any of these observations.

In the case of carbofuran which was applied at the time of planting the population observed one month after (30.02/100 ml soil) did not show statistically significant difference from that of untreated plot (35.59/100 ml soil). But the mean count during the second month in the carbofuran treated plot 28.02 showed significant difference from the untreated 59.02/100 ml soil. But the effect was seen lost from the third month onwards and the observations on the population of non parasitic nematodes in carbofuran treated plots and those in control did not show significant variations. The population levels in treated plots ranged between 13.79/100 ml soil to 19.29/100 ml soil respectively while the corresponding range in control plot was 21.18 to 33.51/100 ml soil.

In the case of phorate the population of the non parasitic nematodes did not show any significant reduction during the first month of observation, the population being 16.44/100 ml soil in the treated plots and 35.59/100 ml of soil in untreated soils. In the second month of observation the population in phorate treated plots (27.62/100 ml soil) was significantly lower than that of the control plots (59.02/100 ml soil). But from the third month's observation the population in treated plots 9.97 to 20.90/100 ml soil and control plots 21.18 to 33.51/100 ml soil came on par.

Population in plots treated with different insecticides showed significant variation during the second month only. During the second month the lowest population was in plots treated with phorate (27.62/100 ml soil) and it came of par with that of Carbofuran (28.02/100 ml soil) and HCH (37.41/100 ml soil).

3.4. Effect of insecticides on the population of collembolans and mites in banana plots

The population of collembolans and mites influenced by different insecticides in banana fields at monthly intervals is presented in Table 4 and Figure 4.

The pretreatment population of collembolans in the experimental field ranged from 9.89 to 23.22 in the different plots and variations were not statistically significant.

The differences between the observations in HCH treated and control plots did not show statistical difference during first month of observation. Here the population in HCH treated plot was 25.53/l of soil and in untreated plots it was 21.46/l of soil. In the second month of observation population in HCH treated plots (20.14/l of soil) and control plots (15.90/l of soil) were on par. No significant difference was noticed in the subsequent months between treatments and control. The population of collembolans and mites in plots treated with HCH ranged from 10.03 to 17.59/l of soil and in control 11.19 to 18.92/l of soil.

In the carbofuran treated plots significant reduction was seen during second month observation, the population being 8.38/l of soil in carbofuran treated plots and 15.90/l of soil in untreated plots. In subsequent two

Table 4. Mean number of collembolans and mites in banana plots treated with different insecticides for pest control, observed at monthly intervals after planting

Treatments	Pre treatment population	Mean population in 1000ml soil observed at different intervals after planting (months)									
		1	2	3	4	5	6	7	8	9	10
HCH	23.22 (4.92)	25.53 (5.15)	20.14 (4.59)	10.03 (3.32)	13.75 (3.84)	17.59 (4.31)	12.68 (3.69)	11.95 (3.59)	12.03 (3.61)	13.78 (3.84)	14.56 (3.94)
Carbofuran	18.57 (4.42)	19.40 (4.52)	8.38 (3.06)	10.89 (3.45)	8.56 (2.75)	6.75 (2.78)	9.51 (3.24)	11.21 (3.49)	9.05 (3.17)	8.68 (3.11)	14.97 (3.97)
Phorate	9.89 (3.30)	8.36 (3.06)	4.67 (2.38)	4.16 (2.27)	6.79 (2.79)	7.45 (2.90)	5.41 (2.53)	9.93 (3.30)	7.50 (2.97)	7.52 (2.92)	13.06 (3.75)
Control	22.35 (4.83)	21.46 (4.74)	15.90 (4.11)	12.22 (3.63)	13.61 (3.82)	18.92 (4.46)	12.36 (3.65)	15.16 (4.02)	12.87 (3.72)	11.19 (3.49)	17.92 (4.35)
CD			0.90			1.03					

HCH - Suckers dipped in 0.2 per.cent suspension before planting
Carbofuran - 1 g ai/plant at planting and 105 days after planting
Phorate - 2.5 g ai/plant at 20,75 and 165 days after planting

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

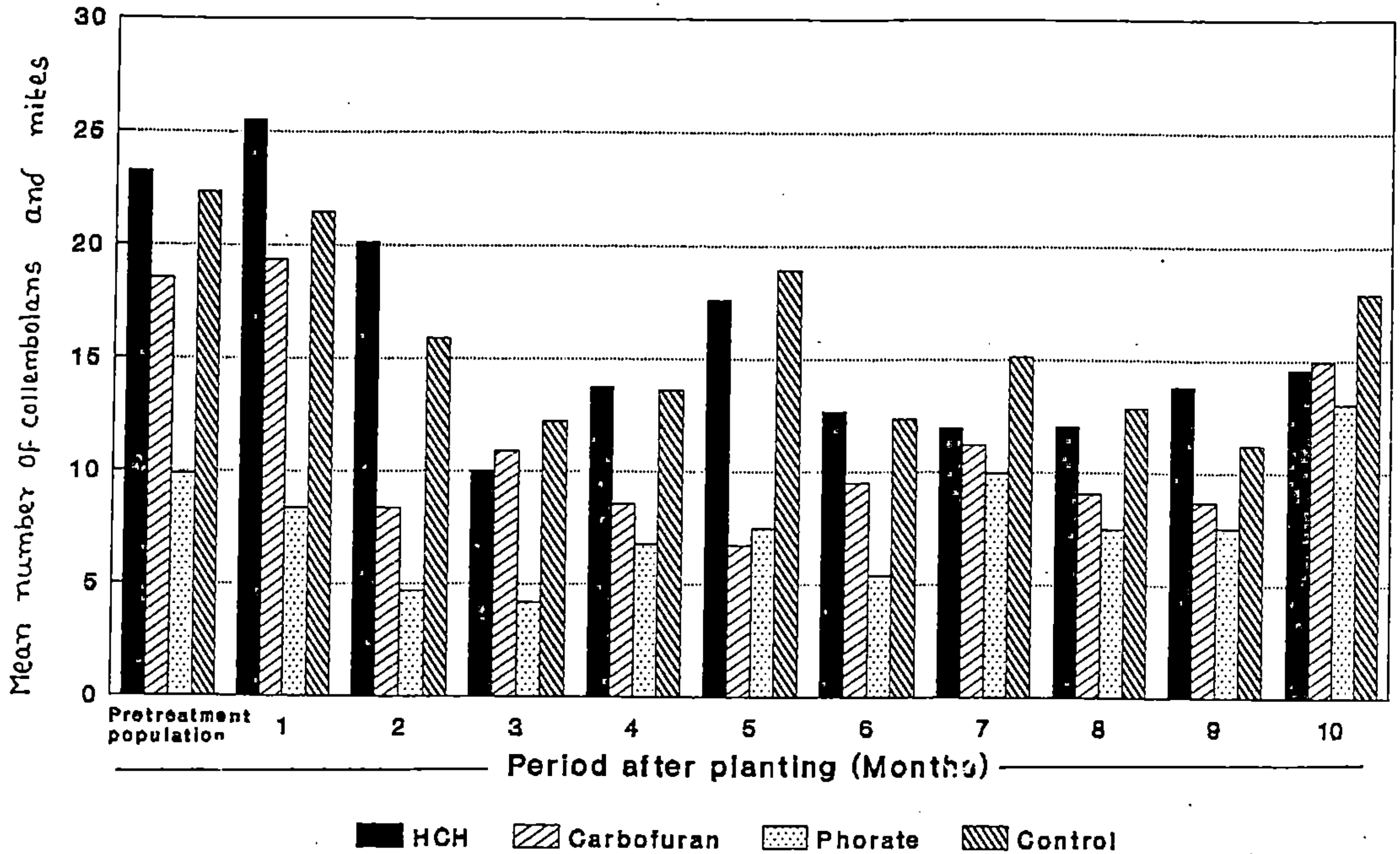

Fig. 4. Mean number of collembolans and mites in banana plots treated with different insecticides for pest control

observations data did not show significant variations though the population in treatments ranged from 8.56 to 10.89/l of soil in carbofuran treated plots while in untreated plots it ranged from 12.22 to 13.61. The population of collembolans and mites in carbofuran treated plots and those in control showed highly significant variations in the fifth month, the population being 6.75/l of soil and 18.92/l of soil respectively. In the subsequent observations no significant differences were noticed in the population of collembolans and mites in treatment and control, the population ranged between 9.05 and 14.97/l of soil in the former and between 11.19 and 17.92/l in the latter.

In the case of phorate the population of collembolans and mites reached significantly lower level (4.67/l of soil) when compared to control (15.90/l of soil) in the second month of observation. But at third and fourth month no significant difference was noticed though the population in treated plot was comparatively lower. At fifth month significant difference was noticed, the population being 7.45/l of soil in phorate treated and 18.92/l of soil in the control plots. In subsequent observations the population of collembolans and mites in plots treated with phorate ranged between 5.41 and 13.06 while in control it was from 11.19 to 17.92.

Population in plots treated with different insecticides showed significant variations during the second month and fifth month only. During the second month the lowest population was in plots treated with phorate (4.67/l of soil) and it came on par with carbofuran (8.38/l of soil). During the fifth month the lowest population was in Carbofuran treated plots (6.75/l of soil) and it came on par with phorate treated plots (7.45/l of soil).

3.5. Effect of insecticides on the population of bacteria in banana plots

The population of bacteria in banana fields as influenced by the application of different insecticides observed at monthly intervals is presented in Table 5 and Figure 5.

The pretreatment population of bacteria was assessed in the experimental field from the different plots, the population ranged from 50.22 to 76.32 and the variations were not statistically significant.

One month after the application of HCH the population of bacteria in the treated plots showed a reduction over that of control plots the numbers being 43.85 and 64.56/ 10 g soil respectively but the difference was not significant. In the second month the difference between the

Table 5. Mean number of bacteria in banana plots treated with different insecticides for pest control, observed at monthly intervals after planting (Population expressed in 10 g soil x 10^7) on wet basis

Treatments	Pre treatment population	Mean population in 10 g soil observed at different intervals after planting (months)									
		1	2	3	4	5	6	7	8	9	10
HCH	50.22 (7.15)	43.85 (6.69)	44.96 (6.78)	59.09 (7.75)	46.26 (6.88)	36.84 (6.15)	46.09 (6.86)	37.44 (6.20)	37.22 (6.18)	51.25 (7.22)	46.94 (6.92)
Carbofuran	75.38 (8.73)	66.02 (8.18)	32.48 (5.79)	68.34 (8.32)	26.89 (5.28)	30.42 (5.60)	26.01 (5.19)	51.33 (7.23)	43.49 (6.67)	72.34 (8.56)	78.11 (8.89)
Phorate	65.32 (8.14)	35.54 (6.12)	68.78 (8.35)	93.14 (9.70)	52.72 (7.32)	36.46 (6.12)	57.58 (7.65)	80.56 (9.03)	40.65 (6.45)	66.81 (8.23)	65.98 (8.18)
Control	76.32 (8.79)	64.56 (8.09)	72.16 (8.55)	74.25 (8.67)	66.75 (8.32)	62.43 (7.96)	31.82 (5.72)	77.96 (8.89)	72.47 (8.57)	77.35 (8.85)	50.87 (7.20)
CD		1.59	0.74		1.67	1.36	1.71	1.78			

HCH - Suckers dipped in 0.2 per.cent suspension before planting
Carbofuran - 1 g ai/plant at planting and 105 days after planting
Phorate - 2.5 g ai/plant at 20,75 and 165 days after planting

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

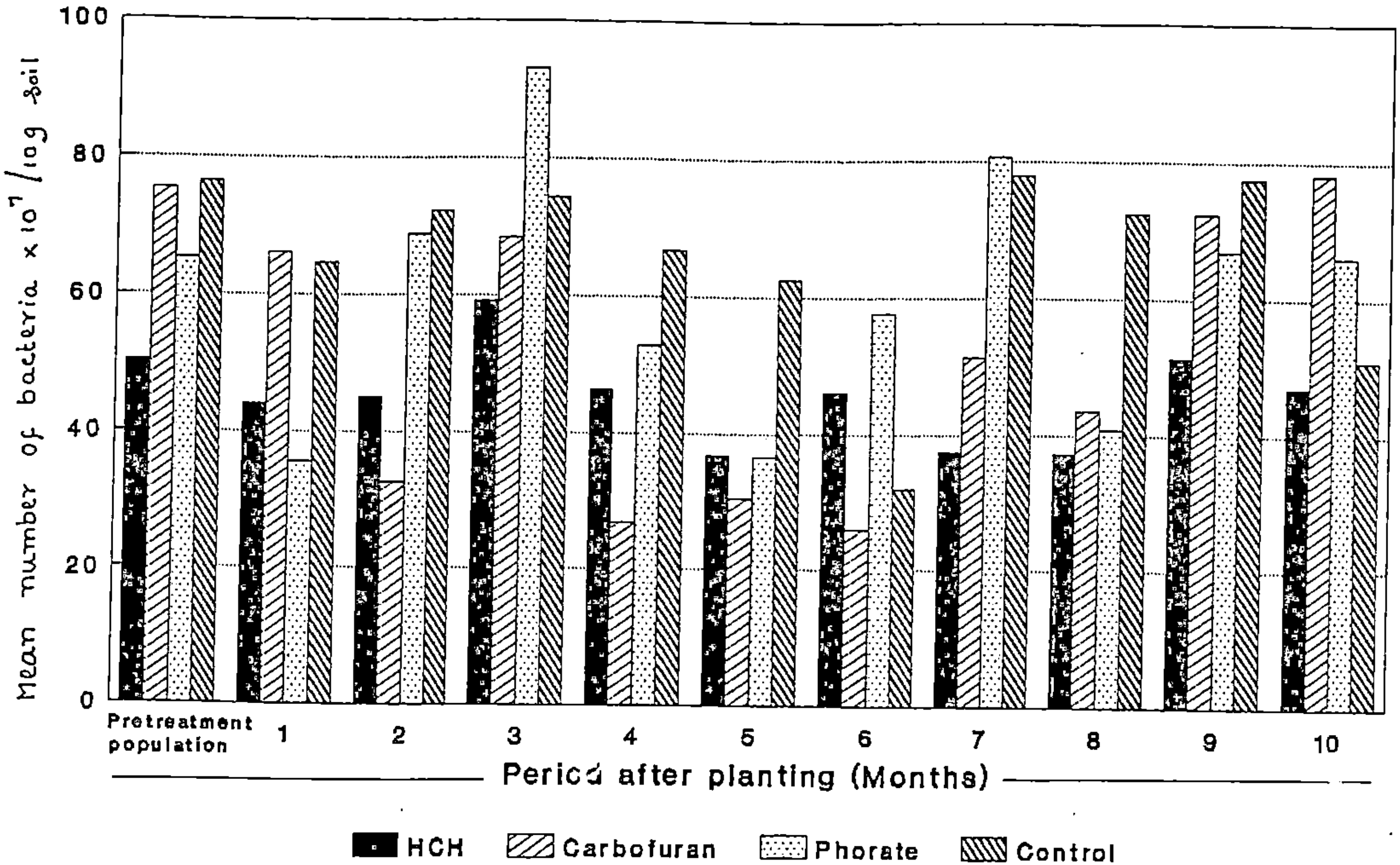

Fig. 5. Mean number of bacteria in banana plots treated with different insecticides for pest control

treatment(44.96/10 g soil) and control plots (72.16/10 g soil) was significantly different. At 120th DAP also significant reduction was seen in treated plot (46.26/10 g soil) compared to control (66.75/10 g soil). During the fifth month also significant reduction in the population of bacteria was noticed in HCH treated plots (36.84/10 g soil) over untreated plot (62.43/10 g soil), while during sixth month observation the population of bacteria in plots treated with HCH (46.09/10 g soil) and in control (31.82/10 g soil) came on par. However, the population during seventh month in HCH treated plots (37.44/10 g soil) compared to the population in control (77.96/10 g soil) was significantly lower. In the remaining three observations data relating to the population of bacteria (37.22 to 51.25/10 g soil) in HCH treated plot, and in control plots (50.87 to 77.35/10 g soil) did not vary significantly.

In the case of carbofuran which was applied at the time of planting and the population observed one month after planting did not show statistically significantly difference from that of untreated plot. But the mean count during the second month in the treated plot (32.487/10 g soil) and control plots (72.16.10 g soil) showed highly significant difference. Significant difference was again noticed during the fourth month of observation and the count being (26.89/10 g soil) in treated plots with carbofuran compared to

(66.75/10 g soil) in untreated control plots. In the subsequent three months also significant difference was observed between the treatments 30.42, 26.02 and 51.33/10 g soil compared to 62.43, 31.82 and 77.96/10 g soil respectively. The last three months of observation did not show any statistical significance and the population ranged between 43.49 to 78.11/10 g soil in carbofuran treated plots and in control it was 50.87 to 77.35/10 g soil.

In the case of phorate the population of the bacteria reached significantly lower level (35.54/10 g soil) compared to control during the first observation after the treatment ie within 10 days from the date of application (64.56/10g of soil) . In the second month observation slight difference was noticed between phorate treated plots (68.78/10 g soil) and control (72.16/10g soil) respectively and it was not significant. During the fourth month of observation the population of the bacteria in control plot (66.75/10 g soil was on par with treated plots (51.72/10 g soil). Significant reduction in the population of bacteria was seen in phorate treated plots (36.46/10 g soil) as against control (62.43/10 g soil) during the fifth month observation. However, significant increase in the bacterial population was seen during the sixth month observation, the population being 57.58/10g soil in phorate treated plots compared to 31.82/10g soil in untreated control plots. In the seventh month the population in phorate treated plots land in control were on par. In the last three observations no significant difference was noticed and the population of bacteria ranged between 40.65 to 66.81 in treated plots while in control the population ranged from 50.87 to 77.96/10g soil respectively.

Population in plots treated with different insecticides showed significant variations during the first, second, fourth, fifth, sixth and seventh month of observations. During the first month the lowest population was in phorate treated plots (35.54/10 g soil) and it came on par with HCH plots (43.85/10 g soil). During the second month observation the lowest population was in carbofuran treated plots (32.48/10 g soil). In the fourth month lowest population was in carbofuran treated soils (26.89/10 g soil) and it came on par with HCH treated plots (46.26/10 g soil). Again HCH treated plots and phorate treated plots (52.72/10 g soil) came on par with carbofuran. In the fifth month all the treatments came on par in HCH, carbofuran and phorate treated soils the population being 36,84, 30.42 and 36.46/10g soil respectively and all were significantly lower than that of control (62.43/10 g soil). In the sixth month all treatments came on par with control except phorate which showed slightly higher population . During the seventh month the lowest population was in HCH treated plot 37.44 and it came on par with carbofuran treated plot 51.33/10g soil and latter was on par with control.

3.6. Effect of Insecticides on the Population of actinomycetes in banana plots

The effect of different insecticides on the population of actinomycetes in banana fields is presented in Table 6 and Figure 6.

The pretreatment population of actinomycetes in the experimental field ranged from 32.79 to 41.55 and the variations in the different plots and control were not statistically significant.

Significant differences were observed in the observations taken at 90, 120, 180 and 240 DAP. At 90 DAP population in HCH treated plot was 38.58 and as against 30.77/10 g soil in control both being on par. During the fourth and eighth month the population of actinomycetes was significantly lower (22.11 and 14.45/10 g soil) compared to control (43.49 and 47.23/10 g soil) while it was (38.87/10 g soil) came on par with control plot (24.84/10 g soil) during the sixth month. The population of actinomycetes observed

Table 6. Mean number of actinomycetes in banana plots treated with different insecticides for pest control, observed at monthly intervals after planting (Population expressed in 10 g soil x 10^5) on wet basis

Treatments	Pre treatment population	Mean population in 10 g soil observed at different intervals after planting (months)									
		1	2	3	4	5	6	7	8	9	10
HCH	35.75 (6.06)	41.05 (6.48)	42.41 (6.58)	38.58 (6.29)	22.11 (4.80)	31.75 (5.72)	38.87 (6.31)	22.95 (4.84)	14.45 (3.93)	25.99 (5.19)	23.21 (5.72)
Carbofuran	41.55 (6.51)	37.70 (6.22)	36.67 (6.13)	38.85 (6.31)	21.01 (4.69)	27.89 (5.37)	14.39 (3.92)	42.04 (6.56)	20.78 (4.67)	21.75 (4.78)	13.72 (5.27)
Phorate	32.79 (5.72)	26.17 (5.21)	22.93 (4.89)	14.94 (3.99)	21.13 (4.70)	31.82 (5.90)	20.73 (4.66)	34.38 (5.94)	31.30 (5.68)	22.60 (4.86)	31.73 (4.92)
Control	38.09 (6.25)	28.85 (5.46)	40.89 (6.47)	30.77 (5.64)	43.49 (6.67)	38.02 (6.24)	24.84 (5.08)	47.78 (6.98)	47.23 (6.94)	38.41 (6.28)	26.76 (3.84)
CD				0.92	1.40		1.12		1.65		

HCH - Suckers dipped in 0.2 per cent suspension before planting
Carbofuran - 1 g ai/plant at planting and 105 days after planting
Phorate - 2.5 g ai/plant at 20,75 and 165 days after planting

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

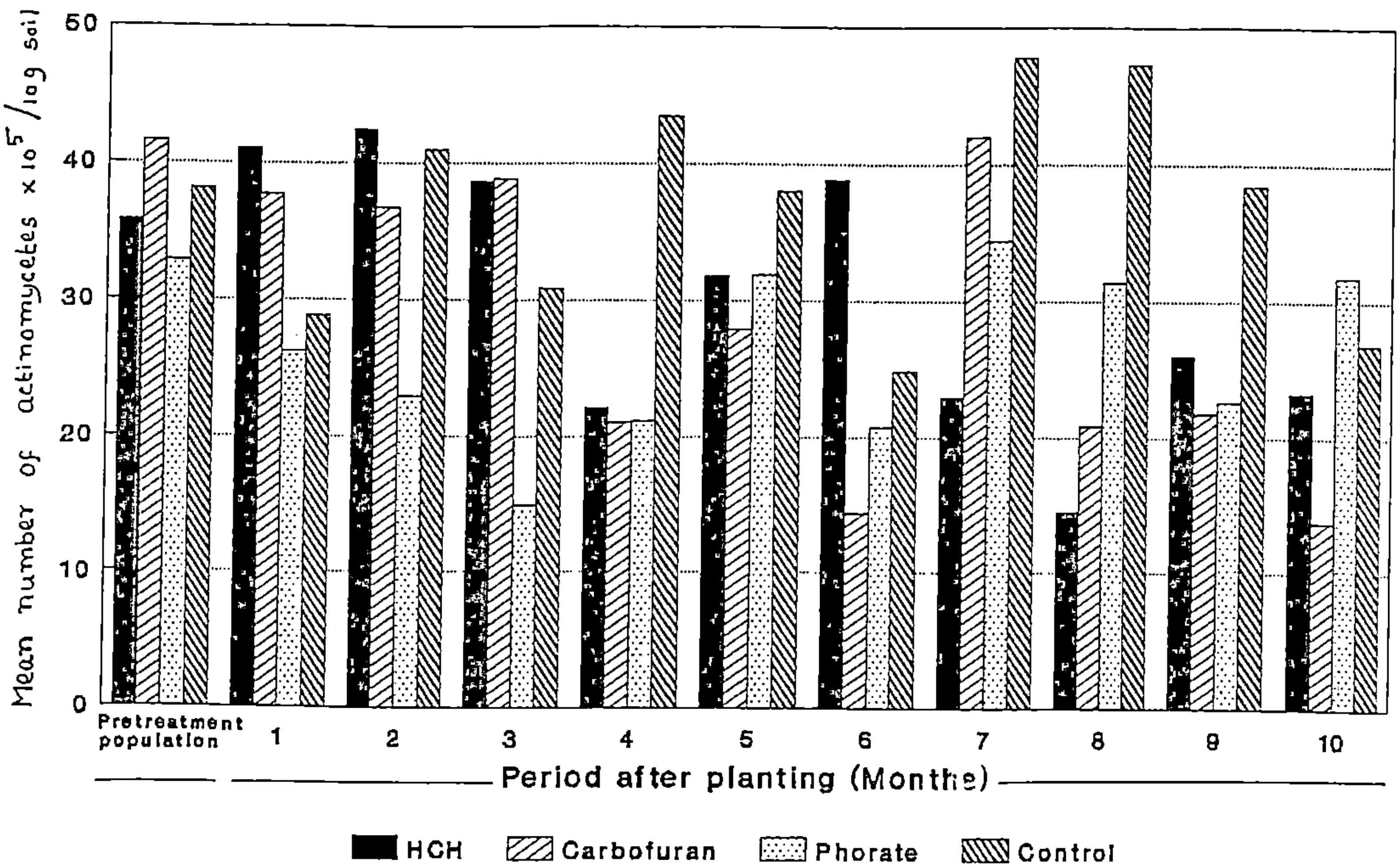

Fig. 6. Mean number of actinomycetes in banana plots treated with different insecticides for pest control

during the other intervals, fifth, seventh, ninth and tenth months lower population was seen in the HCH treated plots (31.75, 22.95, 25.99, 23.21/10 g soil) in comparison to control plots (38.02, 47.78, 38.41 and 26.76/10 g soil) but the variations where not significantly different.

In the first three observations the population was 37.7, 36.67 and 38.85/10 g soil in the treated plots as against 28.85, 40.89 and 30.77/10 g soil in control respectively, the variations being non significant. From the fourth month onwards, there was a decline in the population of actinomycetes upto the last observation, significant reduction being shown only during fourth, sixth and eighth month of observation. The values were 21.01, 14.39 and 20.78/10 g soil in the carbofuran treated plots and 43.49, 24.84 and 47.23/10 g soil in control plots respectively. The actinomycetes population observed during the fifth, seventh, ninth and tenth months were 27.89, 42.04, 21.75 and 13.72 while in control, the population was 38.02, 47.78, 38.41 and 26.76 respectively and they were on par.

In the case of phorate one month after the application of insecticide, the population of actinomycetes in the treated plots and control plots did not show any statistical difference where as during the third and fourth month (after the second application of insecticide) highly significant reduction of actinomycetes population was noticed over that of control plots and the population being 14.94 and 21.13 in phorate treated plots and 30.77 and 43.49/10 g soil in untreated control plot. In subsequent months also there was reduction in population of actinomycetes, whereas in the sixth month and eighth month significant reduction was noticed in treated plots 20.73 and 31.30/10 g soil and 24.84 and 47.23/10 g soil in untreated plots.

The population in plots treated with different insecticides showed significant variations during the third, fourth, sixth and eighth months after planting only. The lowest population was on plots treated with phorate (14.94/10 g soil), it was significantly lower than those of carbofuran (38.85/10 g soil) and HCH (38.58/10 g soil) during the third month of observation. In the fourth month the population in the three treatments came on par and the population being 22.11, 21.01, 21.13/10 g soil in HCH, carbofuran and phorate treated soils. During the sixth month the lowest population was in carbofuran treated plots (14.39/10 g soil) and it came on par with phorate treated plots (20.73/10 g soil). In the eighth month the lowest population was in HCH plots 14.45/10 g soil and it was significantly lower than that of phorate (31.38/10 g soil) and on par with carbofuran (20.78/10 g soil).

3.7. Effect of Insecticides on the Population of Fungi in banana plots

The population of fungi in banana fields as influenced by application of different insecticides is presented in Table 7 and Figure 7.

The pre-treatment of fungi in the experimental field ranged from 89.22 to 112.52 and the variations were not statistically significant.

The first two months after the application of HCH, the population of fungi in the treated plots did not show any significant variation. During the third month the population of fungi in the treated plots showed a significant reduction over that of control, the counts being 49.12 and 114.40/10 g soil respectively. During the fourth month also the difference between the treatment and control remained significant, the populations being 78.35 and 109.60/10 g soil respectively. In the sixth month significant variation was lacking between the HCH treated plots (97.27/10 g soil) and untreated plots (129.63/10 g soil). In the subsequent months the population of fungi in plots treated with HCH ranged between 57.85 and 70.54 while in control plots the population fluctuated from 53.33 to 111.56; but the variations were not significant statistically.

Table 7. Mean number of fungi in banana plots treated with different insecticides for pest control, observed at monthly intervals after planting (Population expressed in 10 g soil x 10^3) on wet basis

Treatments	Pre treatment population	Mean population in 10 g soil observed at different intervals after planting (months)									
		1	2	3	4	5	6	7	8	9	10
HCH	89.22 (9.49)	75.31 (8.73)	85.40 (9.29)	49.12 (7.08)	78.35 (8.40)	107.48 (10.41)	97.27 (9.91)	57.85 (7.67)	65.83 (8.18)	70.54 (8.46)	68.59 (8.34)
Carbofuran	102.33 (10.16)	89.32 (9.50)	91.33 (9.60)	68.19 (8.32)	47.91 (6.99)	80.94 (9.05)	82.08 (9.11)	101.24 (10.11)	90.78 (9.58)	70.47 (8.45)	81.21 (9.07)
Phorate	98.70 (9.98)	97.82 (9.94)	107.28 (10.40)	123.30 (11.49)	60.28 (7.83)	77.44 (8.86)	141.97 (11.96)	115.15 (10.78)	93.54 (9.72)	90.51 (9.57)	73.49 (8.63)
Control	112.52 (10.65)	70.00 (8.43)	108.29 (10.45)	114.40 (10.74)	109.60 (10.52)	116.60 (10.84)	129.63 (11.83)	87.23 (9.39)	60.95 (7.87)	111.56 (10.60)	53.33 (7.37)
CD				1.85	2.05		2.15				

HCH - Suckers dipped in 0.2 per.cent suspension before planting
Carbofuran - 1 g ai/plant at planting and 105 days after planting
Phorate - 2.5 g ai/plant at 20,75 and 165 days after planting

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

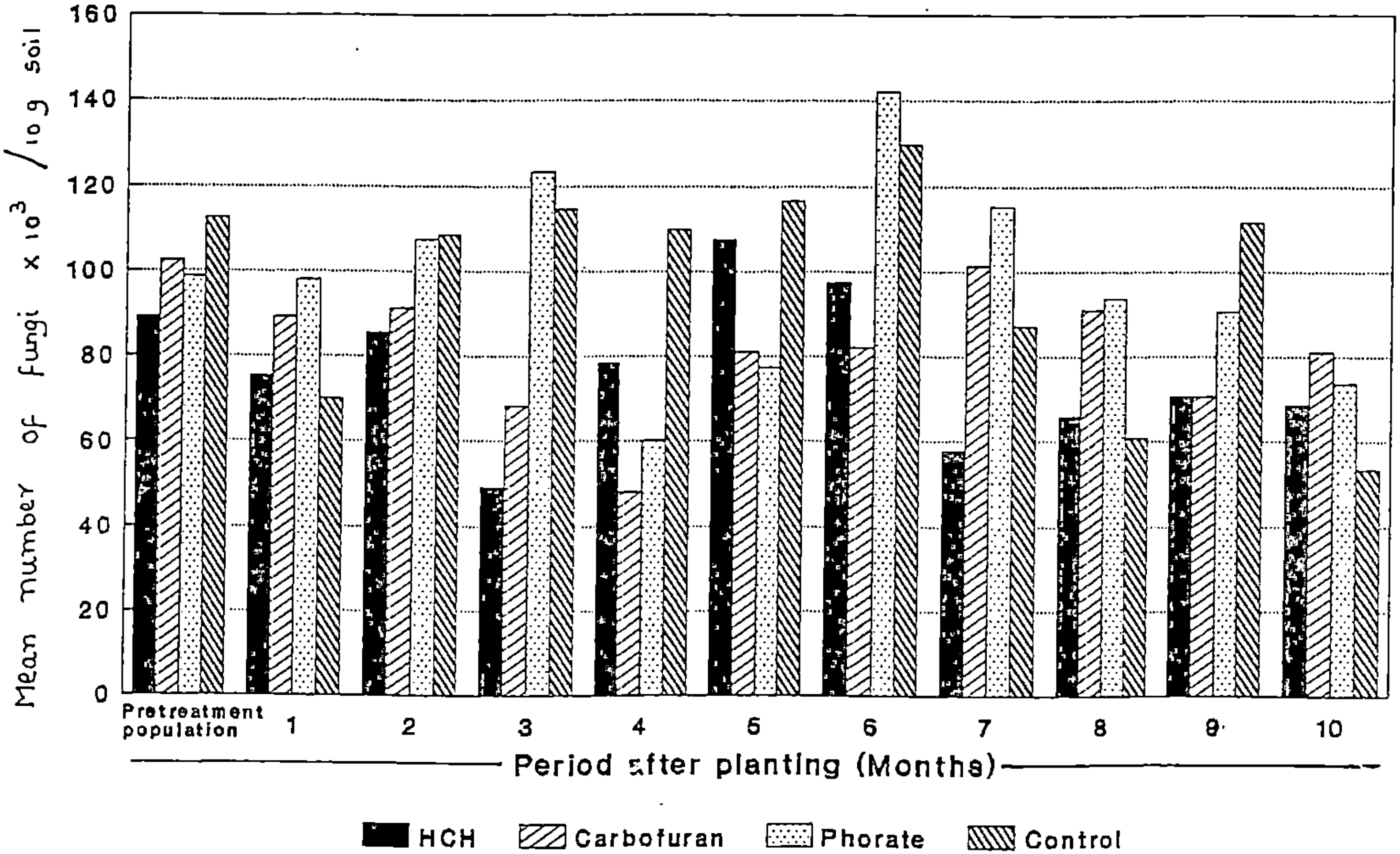

Fig. 7. Mean number of fungi in banana plots treated with different insecticides for pest control

In the third month the difference between treatment and control remained significant, the population being 68.19 and 114.40/10 g soil respectively. In the fourth month, the population of fungi in plots treated with carbofuran was 47.91 while in control it was 109.60/10 g soil. During the sixth month the population in carbofuran treated plots (82.08) while in control it was 129.63/10 g soil. In the subsequent four months no significant variation was seen in the population of fungi in plots treated with carbofuran which ranged between 70.47 to 101.24, while in control plots population fluctuated from 53.33 to 111.56/10 g soil respectively.

During the third month's observation the population in phorate treated plot (123.30/10 g soil) was on par with control (114.40/10 g soil). During the fourth month plots treated with phorate (60.28/10 g soil) was significantly lower than that of control (109.60/10 g soil). During the sixth month also population in control and treatment came on par (129.63 and 141.96/10 g sample). In the subsequent months no significant variation was noticed and the population in treated plots ranged from 73.49 to 115.15/10 g of soil while in control this range was 53.33 to 111.56/10 g soil respectively.

Population in plots treated with different insecticides showed significant variations during the third, fourth and sixth month after planting only. During the third month the lowest population was in HCH treated plots (49.12/10 g soil) and it came on par with carbofuran treated plots (68.19/10 g soil). In the fourth month observation the lowest population was in carbofuran treated plots (47.91/10 g soil) and all the treatment came on par population in phorate and HCH treated plots being 60.28 and 78.35/10 g soil. In the sixth month observation, the lowest population was seen in carbofuran treated plots (82.08/10 g soil) and it came on par with HCH treated plots, (97.27/10 g soil) the latter being on par with phorate treated plot (141.96/10 g soil).

3.8. Soil parameters in the experimental field

Moisture levels, pH and organic matter content of the soil collected at monthly intervals during the period of the experiment are presented in table 8. The mean moisture content in control plot was 19.3 percent while in plots treated with HCH, carbofuran and phorate the percentages were 21.1, 20.6 and 20.5 respectively. The range in moisture content in the above four treatments were 18 to 20, 18 to 23, 18 to 25 and 18 to 25 respectively. The number of observations in which the moisture percentage in control, BHC, carbofuran and phorate treated plots fell below the mean were 5, 6, 6 and 4 (out of 10) respectively.

Table 8. Soil parameters in banana plots treated with different insecticides for pest control, observed at different intervals after planting (months)

Treatment	1	2	3	4	5	6	7	8	9	10	Range	Mean
					SOIL MOISTURE (%)							
HCH	23	22	23	23	22	20	18	18	22	20	18-23	21.1
Carbofuran	25	20	18	22	18	19	22	22	19	21	18-25	20.6
phorate	19	18	20	20	18	22	23	22	18	25	18-25	20.5
control	18	18	22	20	18	20	21	18	18	20	18-20	19.3
					SOIL pH							
HCH	5.01	5.0	5.2	4.86	4.95	4.93	5.06	5.09	5.58	5.18	4.86-5.58	5.08
Carbofuran	5.23	4.93	4.83	5.23	5.06	4.73	5.48	5.32	5.34	4.90	4.73-5.48	5.10
Phorate	5.49	4.87	5.66	5.29	4.87	4.98	5.40	5.15	5.50	5.09	4.87-5.66	5.23
control	5.29	5.22	5.86	5.01	4.92	5.82	5.25	5.04	4.89	5.12	4.89-5.86	5.24
					ORGANIC MATTER (%)							
HCH	4.32	4.26	4.12	4.51	4.56	4.61	4.32	3.91	3.78	3.99	3.78-4.61	4.24
Carbofuran	4.07	4.98	4.28	4.38	4.21	4.09	4.19	4.26	3.95	4.03	3.95-4.98	4.24
Phorate	4.32	3.98	3.98	4.29	4.20	4.26	4.22	4.21	3.72	3.93	3.72-4.32	4.11
control	4.52	3.78	4.74	4.01	4.19	4.51	4.13	4.09	4.53	4.01	3.78-4.53	4.25

Time of Planting - July 1992.

Mean pH was least in BHC treated plots (5.08) and it was followed in plots treated with carbofuran (5.10), phorate (5.24) and control (5.24). The range in the treatments were 4.86 to 5.58, 4.73 to 5.48, 4.87 to 5.66 and 4.89 to 5.86 respectively. The number of observations in which the values went below the mean in the four treatments were 5, 5, 3 and 5 respectively.

Mean percentage of organic matter in HCH, carbofuran, phorate treated plots and control were 4.24, 4.24, 4.11 and 4.25 respectively. The range in the treatments were 3.78 to 4.61, 3.95 to 4.98, 3.72 to 4.32 and 3.78 to 4.35 respectively. The number of observations in which the organic content fell below the mean were 4, 6, 4 and 7 respectively.

3.9. Correlation between soil parameters and soil organisms

The coefficients of correlation are presented in Table 9. It was observed that the associations among different parameters and the population of earthworms, parasitic nematodes and non-parasitic nematodes were not statistically significant. With reference to collembolans and mites in carbofuran and phorate treated plots there was significant positive association with soil moisture while in HCH treated plots the association was positive and in control it was negative, both being statistically insignificant. In

Table 9. Correlation between soil organisms and soil parameters in banana plots treated with different insecticides for pest control, observed at monthly intervals after planting

	Soil parameters	Earthworms	Parasitic nematodes	Non-Parasitic nematodes	Collembolans& mites	Bacteria	Actinomycetes	Fungi
HCH	Soil moisture	0.0230	0.0858	0.2322	0.2389	0.2170	0.4080**	0.0862
	Soil pH	0.0247	-0.1754	-0.1136	-0.1353	0.1968	-0.1080	-0.2570
	Organic matter	-0.0445	0.1215	0.0142	0.1487	0.0028	0.4087**	0.0028
Carbofuran								
	Soil moisture	-0.0304	0.1469	0.1661	0.3208*	0.1096	0.1188	0.1392
	Soil pH	-0.2722	-0.1606	-0.0581	-0.0248	0.1115	0.2003	0.1042
	Organic matter	-0.1354	-0.1196	0.1977	-0.2129	-0.3900**	0.2458	0.0338
Phorate								
	Soil moisture	-0.0051	-0.1117	-0.2026	0.2807*	0.1566	0.1439	0.0550
	Soil pH	-0.2264	-0.1026	0.0059	0.0268	0.3047*	-0.1933	0.5096
	Organic matter	-0.0975	-0.1346	-0.1511	-0.1524	-0.4005**	0.0897	0.0044
Control								
	Soil moisture	-0.2249	0.1252	-0.1555	-0.1359	-0.0366	-0.1162	0.0848
	Soil pH	-0.0457	0.0474	0.1341	-0.0961	-0.2038	-0.3430*	0.1878
	Organic matter	-0.2151	0.0255	-0.1711	-0.1646	-0.0418	-0.3175*	0.1845

* Significant at 5% level ** Significant both at 1% and 5% level

carbofuran and phorate treated plots the bacterial population showed a significant negative associations with organic matter content while a significant positive correlation was observed in phorate treated plots alone. The actinomycetes population showed a significant positive correlation with soil moisture and organic matter content while in control the soil pH and organic matter content had significant negative association with soil pH and organic matter content.

DISCUSSION

DISCUSSION

Effect of different soil insecticides, commonly used for the control of banana pest in Kerala, on the population of beneficial organisms in the ecosystem, have been investigated through a field experiment and related laboratory observations in the present research programme.

4.1. Effect on earthworms

The result presented in para 3.1 showed that even when the suckers dipped in HCH suspension was planted in the field the population of earthworms was slightly but significantly reduced and the effect persisted for the second month also. The population in treated plots came on par with those of control plots in all the subsequent observations. Many of the earlier studies have shown that HCH was not toxic to earthworm population (Gunthart, 1947; Morrison, 1950). Bauer, (1964) reported even a stimulating effect of BHC on earthworm population. However, Hoy (1955) observed that BHC killed earthworms when larger amounts were applied. The reduction in population brought about by the small quantum of insecticide in the ecosystem indicated the high toxicity of the chemical to earthworms. The persistent effect, however did not last for more than two months. Many of the earlier studies have shown that HCH was least persistent in soil among organochlorine insecticides (Edwards, 1966; Edwards, 1971; Sethunathan, 1981; Mishra, 1986). Samuel et al. (1988) observed through radiotracer studies that the insecticide dissipated rapidly during the initial sixty days after application in Delhi situation. Recovery of the earthworm populations in the ecosystem may be related to this level of persistence of the insecticide under our conditions.

In the case of carbofuran the effect of first application given at the time of planting got manifested in the second observation ie. second month after treatment and the effect of second application given ie at 105 DAP got manifested in the succeeding observation. The populations in treatments came on par with control at third month and fifth month ie., one and a half months after the first and second treatments. Adverse effect of the toxicant was not reflected in any of the subsequent observation. The immediate and persistent toxicity of carbofuran to earthworms in the banana ecosystem was not studied earlier. Many of the earlier reports showed that carbofuran was very toxic to earthworms even at doses ranging from 2 kg to 3.5 kg ai/ha. (Kring, 1969; Gilman and Vardanis, 1974; Tomlin and Gore, 1976). Veeresh (1983) reported that at 0.75 kg ai/ha carbofuran was highly toxic to earthworms in tobacco nursery.

In the case of phorate the first application done at 20 DAP reduced the population significantly as seen in the observation taken 15 days after treatment and the effect persisted in the subsequent observation taken at one and a half months after treatment. But no adverse effect of the toxicant was observed with the second and third application of the pesticide done at 75 and 165 DAP. Edwards et al. (1967) reported that phorate at 4 lb/ac eliminated earthworms from gardenlands. Low doses of 1 to 1.5 kg ai/ha of phorate was reported highly toxic to earthworms in rice fields. (Naseema, 1987, Suja, 1987). In the present investigations a high dose of 25 g/plant ie 6.25 kg ai/ha did not produce persistent adverse effect on earthworms in the ecosystem though some initial kill was there. The fast and active absorption of the toxicant from the soil environment by the growing banana plants may be attributed for the low adverse effect on earthworms.

Earthworms recognised as the most important component of the beneficial organisms in the soil environment are treated as farmers friend which play an important role in humification, (Brown, 1978; Kale and Krishnamoorthy, 1981; Bhawalkar, 1993) in improving the physical properties (Brady, 1988; Lee and Foster, 1991) as well as the chemical properties and nutrient status (Brady, 1988; Haimi and Huhta, 1990; Hamilton, 1990; Bhawalkar, 1993) of soil. Vermiculture is being advocated as a modern tool in agriculture for effective recycling of non-toxic organic wastes to the soil with a view to achieving waste land development and sustainable agriculture. In this context the impact of toxic chemicals introduced in any agroecosystem for pest control on earthworms assumes importance. The application of BHC, carbofuran and phorate in banana ecosystem does not appear to be persistent to earthworms.

4.2. Effect on parasitic nematodes

The results presented in para 3.2 shows that planting of HCH treated suckers in banana fields did not affect the population of parasitic nematodes throughout the crop period in the field. The result agree with the earlier finding also (Edwards, 1965).

Though the population of parasitic nematodes was relatively less in carbofuran treated plots throughout the period of observation, significant reduction in comparison with control was seen in the fourth observation which was after the second application of the nematicide. The suppressing effect seems to be lost in subsequent observations though in the seventh observation, without any additional treatment, the population in carbofuran treated plot was seen significantly lower. This cannot be attributed to the insecticidal treatment. An effective reduction of the parasitic nematode population was seen only for a short period between the fourth and the fifth month. The efficacy of carbofuran against several species of nematodes have been reported by earlier workers (Martin and Yates, 1975; Mehta, 1976; Vilardebo and Guerout, 1976; Prasad and Rao, 1978 and 1979; Nair, 1981; Idicule, 1988). Reduction of individual species of nematodes have not been recorded in these studies since the objective was to assess the overall effect of the treatments on the nematode population. The low levels of nematode populations in the experimental field, which was far below the economic threshold levels of parasitic species would have, caused the lack of statistical significance in variations among the population levels in treated and control plots.

Significant reduction in phorate treated plots was observed during the seventh month only ie after the three consecutive applications of the toxicant. The population came on par with the control from the eighth month onwards. Thus the overall reduction of the populations of parasitic nematodes caused by phorate was not significant. Nematicidal effect of phorate also has been reported by earlier workers (Way and Scoopes, 1968; Nair, 1979b; Ravichandra et al., 1987). As in the case of carbofuran the low population level of nematodes would have suppressed the manifestation of the potential of the chemical in the soil medium as a nematicide.

4.3. Effect on nonparasitic nematodes

The results presented in para 3.3. showed that the application HCH did not have any significant effect on the population of nonparasitic nematodes in the banana ecosystem. Though carbofuran and phorate treated plots showed lower levels of the population of non parasitic nematodes the variations in the data was statistically significant during the second month only and the populations in carbofuran and phorate treated plots were significantly lower than those of control. Low population levels in the soil may be attributed to the low level of response to the toxicant and lack of significant variations in the data.

The nematode fauna in the soil do not have direct bearing on humus formation in the soil, but as bacterial feeders and due to their interaction with other microflora it exerts an indirect role on humus build up (Brown, 1978; Brady, 1988). These organisms also were not significantly affected by the insecticidal input in the soil.

4.4. Effect on collembolans and mites

Results are presented in para 3.4. HCH treatment did not significantly influence the population of collembolans and mites in the soil. Adverse effect of BHC on mites (Hitchcock, 1953; Baring, 1957; Karg, 1965) have been reported earlier. A stimulatory effect of BHC on collembolan population in the soil environment was also recorded (Richter, 1953; Dobson and Lofty, 1956; Schmitt, 1964). Two months after the first application of carbofuran and phorate and two months after the second application of the toxicants the population in the treated plots came significantly lower than those of corresponding controls. But the effect of the two toxicants did not vary significantly. In the remaining observations the variations in the data were not statistically significant. Such adverse effect of carbofuran (Martin, 1975; Kumar and Agarwal, 1983) and phorate (Way and Scoopes, 1968) have been reported earlier also.

Collembolans and mites play a major role in the decomposition of organic substances (Brown, 1978) and mineralization processes was aided by larger collembolans by selective feeding on fungi (Amelswoort, 1988). These organisms had a suppression with phorate and carbofuran in the soil but the population recovered in two months.

4.5. Effect on bacteria

The results presented in para 3.5 showed that the of bacteria colonies in treatment were generally lower than those of control throughout the period of observation. But the differences were statistically significant during the second, fifth and seventh month only. Since the insecticidal application was not repeated these variations in the HCH treated plots cannot be attributed to the insecticidal toxicity alone. Agnihotri, et al., (1981) reported the adverse effect of BHC on bacterial population.

First application of carbofuran reduced the bacterial population significantly during the second month of observation and it revived in the third month. The second application at 105 DAP suppressed the population again and there was full revival in two months and the population came on par with control in the sixth month. Population in treated and control plots were not significantly varying till the harvest of the crop. An inhibitory effect of carbofuran on bacterial population in soil had been reported by an earlier worker (Tu, 1972). The stimulating effect observed in some cases (Hubbel et al., 1973; Mathur et al., 1980; Visalakshy, 1980; Dzantor and Felsot, 1989; Kale and Raghu, 1989) were not observed in the banana ecosystem.

Phorate also suppressed the bacterial population after the first and second applications at 20 and 75 DAP respectively. Population was significantly lower in the treated plots in the first and fifth month. Suppression of bacterial population by phorate had been noted in fields cultivated with groundnut, (Tewari et al., 1972, Chendrayan and Prasad, 1976) blackgram, (Chelliah, 1972) and cotton

(Singh and Gulathi, 1972). Many reports on the stimulating effect of phorate on bacterial population in soil environment are available (Chelliah, 1972; Kandaswamy, 1975; Pandiyan and Balasubramanion, 1978; Visalakhy and Nair, 1978; Visalakshy et al., 1981; Das, 1986). Such stimulating effect was not significantly seen in the banana ecosystem though the third application of phorate at 165 DAP was followed by slightly higher levels of bacterial population in the treated plots compared to those in control. The suppressing effect was more for carbofuran than for phorate and the latter had shown slight stimulations when repeatedly applied in the soil.

Bacteria play a major role in circulating nutrients in soil (Brown, 1978) and in ammonification as well as enzymatic activities related to decomposing organic matter (Mishra, 1986; Verma, 1993) in soil and the inhibitory effect of the pesticides in the soil environment is bound to be deleterious. But the extent of suppression noted in the banana ecosystem was seen lost in a short period and the population was seen restored to normal level even before the harvest of the treated crop.

4.6. Effect on actinomycetes

Results presented in para 3.6. showed that the actinomycetes population in HCH treated plots was significantly lower than control in the fourth and eighth month and significantly higher than control in the sixth month. Since the application of the insecticide did not synchronise with the variations in population the latter cannot be attributed to the toxicity of the pesticide.

Carbofuran did not significantly affect the actinomycetes population upto the third observation. But in the fourth, sixth and eighth observations which were after the second application of the pesticide, the populations in the treated plots were significantly lower than those of controls. In the fifth and seventh observations also the population in treatment were lower. Thus a slight suppression effect of the toxicant was evident in the results. The stimulating effect reported earlier (Visalakshy, 1980, Kale and Raghu, 1989) was not observed in any of the observations in the present study.

The first and second application of phorate reduced the actinomycetes population significantly and it was restored on par with control from the sixth month after planting and the level remained unaffected till harvest. The results agree with earlier findings also (Visalakshy, 1977, Visalakshy and Nair, 1978; Das, 1986). The stimulatory effect of the toxicant on actinomycetes population (Chelliah, 1972; Tewari, 1972; Visalakshy <u>et al</u>., 1981; Varshney and Rana, 1987) was not seen in any of the ten observations covered in the experiment.

The actinomycetes population in the soil helps in the fermentation process, production of antibiotics controlling harmful bacteria, if present and in the decomposition of organic matter thus enriching the soil (Alexander, 1961; Brady, 1988). The study revealed that the temporary suppression of this group of organism by carbofuran and phorate in the soil was fast reduced in the banana ecosystem.

4.7. Effect on fungi

The results presented in para 3.7. showed that in HCH treated plots the population of fungi was significantly lower than in the control during third and fourth months only. The stimulatory effect of BHC on fungal population had been reported earlier (Agnihotri et al., 1981).

In carbofuran treated plots slight suppression of soil fungi was noted in the third month ie. 90 days after the first treatment and significant reduction in the fourth month ie. 15 days after the second application. But the population came on par with control during the fifth month thus showing that the effect was lost in a short time. The suppressive effect of carbofuran on soil fungi was reported by Tu, (1972). The pesticide did not show any stimulating effect in banana ecosystem though such an effect had been reported in another situation (Mathur et al., 1980).

In the case of phorate, significant suppression of the population was seen only in the fourth month (ie.) 45 days after the second application of the pesticide and the population remained on par with control till then and in the fifth month the suppression got lost. The third application had no suppressive effect on the fungi and in all the subsequent observations the number in treatments were higher than those of control though the variations were not statistically significant. The results indicated a tendency to boost the population of fungi with repeated application of the insecticide. Such stimulatory effect of phorate has been reported in the soil environment by earlier workers also (Chelliah, 1972; Tewari et al., 1972; Kandaswamy et al., 1975; Visalakshy 1977; Visalakshy and Nair, 1978; Visalakshy et al., 1981; Varshney and Rana, 1987). The inhibitory effect on soil fungi also have been reported extensively in literature (Lichtenstein, 1970; Pandiyan and Balasubramanion, 1978; Das, 1986).

It may be concluded from the data that the application of phorate at the rate of 30 g/plant thrice during that crop period does not affect the population of soil fungi in the banana ecosystem. The fungi are the most versatile and persistent group of soil microorganisms (Brady, 1988) which produce the humic substances in soil and thus help to maintain organic matter of the soil and sustained productivity (Subba Rao, 1986).

4.8. Effect of insecticides on the physical parameters of the soil

Earthworms, the most important component of beneficial organisms in the soil, are known to improve the soil condition and fertility significantly. Structurally stable burrows in the soil made by them are reported to allow easy water infiltration and each burrow act as a 'microdam' thus enhancing the water holding capacity of the soil. The 'Vermicast' which is remarkably stable in pH, around neutral or slightly alkaline level, helps to regulate the overall soil pH within ranges favourable for the build up of soil micro-organisms (Bhawalkar and Bhawalkar, 1993). The organic matter present in the soil gets converted into humus through the microbial activity and thus in turn exerts a positive influences on the physical and chemical properties on the physical and chemical properties of the soil. (Balasubramaniam, et al., 1972, Gaur et al., 1972, Eberhardt and Pipes, 1974). Hence the mositure content, pH and organic matter content of the soil in the experimental field were estimated with a view to assessing the changes brought on these components as a result of the population fluctuations of beneficial soil organism caused by the insecticide treatments.

The data presented in para 3.8. showed that the variations in the moisture content in control and different treatments were very marginal and the lower or higher levels of moisture observed in different treatments had no relationship with the application of insecticides in the soil. The moisture content of the soil even during the rainy months (October/November Vide Appendix - 1) and summer months (January/February - Appendix - 1) also did not show significant difference. This may be due to the copious irrigation given to the crop as is being done by the farmers. The variations in pH also were limited and those of control plots remained on par with treatments. The data in Table 1 and Fig. 1 showed that the population of earthworms was generally low throughout the crop period and at that level significant alteration of soil pH would not be possible. The soil pH remained at the acidic level throughout the period of the experiment. The organic matter content in the control plots and those of treated plots were also on par throughout the crop period. This indicated that the treatments did not significantly influence the humification process in the banana ecosystem.

4.9. Correlation of soil parameters with the beneficial organisms of the soil

The results presented in para 3.9 showed that in the control plots there was significant negative correlation between the population of actinomycetes, soil pH and organic matter content, while in HCH treated plots positive correlation was noted between actinomycetes population and soil mositure as well as organic matter content. In carbofuran treated plot collembolans and mites and soil moisture were positively correlated, where as bacteria was negatively correlated with organic matter content. In the case of phorate positive correlation was noted between collembolans and mites with soil moisture, while positive correlation was noted between bacteria and soil pH. Bacterial population was negatively correlated with organic matter content. No definite trend was seen in the result indicating any shift in the association of soil organisms and soil parameters due to the introduction of insecticides in the banana ecosystem.

In general the application of HCH, carbofuran and phorate for the control of banana pests / diseases at the recommended doses, didnot cause significant adverse or stimulatory effects on the soil organisms so as to cause any persistent adverse or favourable effect in the banana ecosystem in Kerala.

SUMMARY

SUMMARY

Application of insecticides recommended for the control of major pests of banana in Kerala viz. rhizome weevil and nematodes and aphids, the sole vector of the dreaded bunch top disease of the crop, is likely to cause serious impact on the useful flora and fauna in the soil ecosystem. The present investigations were carried out to assess such effects if any.

A field experiment was conducted at College of Agriculture, Vellyani, during 1992 adopting a randomised block design using nendran variety of banana. The treatments were HCH 0.2 percent suspension used for dipping the suckers to control banana rhizome weevil incidence, carbofuran/1g ai/plant [7.5 kg ai/ha] applied at planting and at 105 DAP for the control of nematodes and phorate 2.5 g ai/plant [6.25 kg ai/ha] applied at 20, 75 and 165 DAP for the control of banana aphid.

Population of the soil organisms viz. earthworms, parasitic nematodes, non-parasitic nematodes, collembolans and mites, bacteria, actinomycetes and fungi were estimated in soil samples collected once prior to the planting and then at monthly intervals were assessed. Earthworms were counted by hand sorting method. Nematodes were extracted in the laboratory adopting cobb's sieving and decanting technique

and were counted under microscope. Collembolans and mites were separated by Berlese-Tullgren Funnel method and counted. Micro-organisms were estimated by serial dilution and plating technique. Moisture content, pH and organic matter content of the soil in the experimental field were also assessed at monthly intervals.

Even the small quantity of HCH introduced in the field through the dipped suckers reduced the earthworm population significantly. Within two months the population was restored. Immediately after the first and second application of carbofuran the population of earthworms declined significantly. Within two months after each treatment the population was restored and it came on par with control. In the case of phorate the first treatment caused significant reduction while the second and third treatments did not produce adverse effect on the earthworms. The population in plots treated with the heavy doses of carbofuran and phorate came on par with control, two months before the harvest.

Thus the insecticides were found to have no persistent deleterious effect in the banana ecosystem.

Parasitic nematode population was not reduced by HCH treatment. In carbofuran treatments significant reduction was seen after the second application of insecticide. In the seventh month also significantly lower level of population was observed compared to control. The effect of the treatment was then not evident till harvest. The low population in field which was far below the economic threshold levels of different parasitic species, would have resulted in the lack of response to the toxicants recommended for the control of parasitic nematodes on banana.. In the case of phorate significant reduction was observed only after three consecutive application of the toxicant. The overall reduction of parasitic nematodes caused by phorate was not significant. Here also the low level of nematode population would have suppressed the manifestation of the nematicidal efficiency of the toxicants in the soil medium.

HCH treatment did not have any significant effect on non-parasitic nematodes. In the case of carbofuran and phorate treatments low population was observed throughout while significant reduction was noted for a short while after first application of the insecticides only.

Collembolan and mite population was not significantly reduced by HCH treatment. In carbofuran and phorate treatments two months after the first application and two months after the second application there were significant reductions compared to control.

The data on bacterial count in HCH showed significant differences during second, fifth and seventh months of observation and were low throughout the experiment. Since HCH application was not repeated the reduction could not be attributed to the insecticidal effect. Carbofuran significantly reduced the bacterial population though the population revived fully in two months time. Phorate suppressed the bacterial population after the first and second applications and after the third application slight stimulatory effect was observed. In all the treatments the population came on par with control from seven months after planting.

On actinomycetes HCH showed a suppressing effect during the fourth month and eighth month and a stimulatory effect was observed during the sixth month. No significant reduction was observed with carbofuran treatment upto three months and in subsequent observations a reduction was noted. The first and second application of phorate caused significant suppression of the population of actinomycetes and the population was then restored and remained unaffected till harvest.

The population of fungi were significantly lower during the third and fourth months after planting in HCH treatment. In carbofuran treatment slight suppression of soil fungi was noted at 90 days after the first application and 15 days after second application in treatments and control remained on par. In phorate slight suppression was noted after the second application of the toxicant and it was restored in the next month. The third application had no suppressive effect and higher levels of population compared to control were observed in the subsequent observations. The results indicated a tendency to boost the population of fungi with repeated application of the insecticide.

There was no impact of insecticidal treatments on soil moisture, soil pH and organic matter content in the banana ecosystem. The variations in pH and organic matter content in the control plots remained on par with the treatments indicating that the humification process in banana ecosystem mediated through different soil organisms was not affected by the insecticidal applications adopted for the control of banana pests.

Differences in the correlation of soil parameters with the beneficial organisms in the control and treatment plots did not show any definite trend. This may be attributed to the lack of high variability in the data on the population levels as well as the soil parameters.

The toxicants used for the control of the major pests/diseases of banana did not cause significant and persistent adverse/favourable effects on the soil fauna and flora in the banana ecosystem.

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* Orginal not seen

APPENDICES

APPENDIX - I

Weather parameters during the period of the experiment commencing from August 1992

Period of observation		Maximum temperature	Minimum temperature	Relative Humidity(%)	Total Rainfall (mm)
August	1st week	28.2	22.7	88	2.6
	2nd week	28.8	23.75	85	22.0
	3rd week	29.4	23.82	84	2.6
	4th week	29.4	23.3	82	2.6
September	1st week	28.3	22.9	84	32.5
	2nd week	28.9	23.9	83	23.6
	3rd week	29.9	23.6	80	Nil
	4th week	28.8	23.5	82	30.0
October	1st week	29.9	22.4	83	155.0
	2nd week	28.9	22.7	85	189.0
	3rd week	29.6	23.4	82	2.0
	4th week	28.5	23.5	82	5.6
November	1st week	28.3	22.8	81	2.9
	2nd week	28.3	23.0	82	151.9
	3rd week	29.1	22.0	81	103.9
	4th week	28.0	21.0	83	12.0
December	1st week	29.8	22.0	82	11.6
	2nd week	30.3	21.8	78	Nil
	3rd week	30.3	22.9	81	3.5
	4th week	30.8	19.12	70	Nil

Time of planting - July 1992.

APPENDIX - I (Contd...)

Period of observation		Maximum temperature	Minimum temperature	Relative Humidity(%)	Total Rainfall (mm)
January	1st week	30.6	18.6	73	Nil
	2nd week	30.3	21.1	78	Nil
	3rd week	30.0	20.7	82	Nil
	4th week	30.6	21.6	76	Nil
February	1st week	31.4	19.4	60	Nil
	2nd week	30.8	20.4	75	Nil
	3rd week	29.4	23.2	80	Nil
	4th week	31.2	22.1	80	2.8
March	1st week	32.0	22.2	70	Nil
	2nd week	32.5	21.9	75	Nil
	3rd week	32.6	24.0	79	Nil
	4th week	32.3	23.9	75	39.9
April	1st week	32.7	24.2	79	3.5
	2nd week	32.1	24.3	81	9.2
	3rd week	32.6	24.2	80	12.5
	4th week	33.2	25.4	81	6.4
May	1st week	33.0	25.0	81	5.0
	2nd week	32.0	24.2	86	46.0
	3rd week	32.0	25.5	80	1.4
	4th week	31.0	23.1	86	87.6

ABSTRACT

Possible adverse effects of the insecticides recommended for the control of pests/diseases of banana in Kerala, on the useful soil organisms and the consequent impact on the banana ecosystem were studied in detail through a field experiment and follow up laboratory investigations. The results revealed:

[1] Earthworm population was adversely affected with HCH even in low doses upto two months after the treatment. With carbofuran soon after the first and second application the population declined but restored with in two months. In the case of phorate the first treatment alone caused significant adverse effect while the second and third did not cause any significant effect on the earthworms. Even in carbofuran and phorate treatments earthworm population came on par with control two months before the harvest.

[2] Parasitic nematodes were unaffected by HCH treatment. With carbofuran significant reduction in the population of parasitic nematode was noted after two applications of the insecticide. The nematicidal effect was seen lost throughout the period of observations from the eighth month. In phorate treatment significant

reduction was observed only after three consecutive applications of the toxicant. The overall reduction caused by phorate was not adequate. Carbofuran was hence better to control parasitic nematodes than phorate. In both the cases the low level of nematode population in soil may be attributed to the lack of response to the nematicides recommended for the control of the pest.

[3] HCH treatment was not at all toxic to non-parasitic nematodes. In the case of carbofuran and phorate low population was observed throughout, while significant reduction was observed for a short while after the first application of the insecticides only.

[4] Collembolan and mite population was not reduced by HCH treatment. Significant reduction was observed for two months after the first and second applications of carbofuran and phorate. Adverse effect was then lost and the population was maintained on par with control till harvest.

[5] The bacterial count was low throughout in HCH treatment. Though the carbofuran reduced the bacterial population it was revived in two months time. Phorate suppressed the bacterial population after first two applications, while with the third application slight enhancement was

observed on the population and it was restored on par with control before harvest of the crop.

[6] In fourth and eighth month a suppressing effect of HCH on actimycetes was noted and a stimulatory effect was observed during the sixth month. In carbofuran no significant reduction was observed upto three months and later on no reduction was noted. In phorate significant reduction was observed after the first and second application and the actinomycets population was then restored and remained unaffected till harvest.

[7] Significant reduction of fungi was observed during the third and fourth months after planting in HCH treatment. In carbofuran slight reduction was noted after first and second application. The population was then restored. In phorate slight reduction was noted after two applications and it was restored in the next month itself. The third application showed stimulatory effect and the population was higher than that observed in control in subsequent observations.

[8] The organic matter content in treatments and control remained on par and hence the humification process in banana ecosystem, through the activity of the soil organisms, was not seen affected by the application of insecticides. The variations in pH and moisture content of a soil in control plots and treatments also were not statistically significant.

[9] Changes in the correlation of soil parameters with the beneficial organisms in control and treatments also did not show any definite trend. This may be due to low variability in the data on the population levels as well as the soil parameters. In general the treatments did not alter the population of the soil fauna and flora in the ecosystem to cause any adverse persistent effect.