MICROARTHROPOD FAUNA OF CULTIVATED SOIL

THESIS

By

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Submitted to

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Is there anything I
can say
anything I can give
or do for you?
Because all that I'm
all that I have
I owe to you..............

AFFECTIONATELY DEDICATED TO MY REVERED PARENTS

Who sacrificed their present to make my future

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CERTIFICATE – I

This is to certify that the thesis entitled **"Microarthropod fauna of Cultivated Soil"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Entomology** of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a bonafide research work carried out by **Ms Manpreet Kaur** daughter of **S. Dalbir Singh** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

(Y.S. Chandel)
Chairman,
Advisory Committee

Place : Palampur
Dated: July 26 , 2004

CERTIFICATE – II

This is to certify that the thesis entitled **"Microarthropod fauna of Cultivated Soil"** submitted by **Ms Manpreet Kaur** (Admission No. A-2002-30-18) daughter of **S. Dalbir Singh** to Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the subject of **Entomology**, has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Place : Palampur
Dated : 26/7/2004

Manpreet
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CONTENTS

LIST OF TABLES

Introduction

Chapter I

INTRODUCTION

Soil arthropods measuring upto 10 mm in length are considered to be microarthropods and are categorised as mesofauna of soil. These include Protura, Diplura and Collembola of class Insecta; Symphyla and Pauropoda of class Myriapoda; Tardigrada, Copepoda and Isopoda of class Crustacea; Pseudoscorpions, Spiders and Acari of the class Arachnida (Veeresh, 1988). Amongst these, Acari and Collembola are the most abundant (Singh and Pillai, 1981; Palacios-Vergas *et al.,* 2000) and constitute 72 to 97 per cent of the total arthropod fauna of Indian soil (Prabhoo, 1976; Singh and Pillai, 1976).

Arthropods comminute organic matter directly by feeding on detritus and indirectly by ingesting microbes and adhering detrital material. The result of comminution is an increase in the surface area of the organic matter for further microbial attack (Swift *et al.,* 1979). Microarthropods such as millipedes and isopods are important comminuter of detritus and some microarthropods skeletonize leaf material (Wallwork, 1970). Microarthropods can also passively transport bacteria, fungi, protozoa in the gut or on their cuticle across regions of soil that are impenetrable to the microbiota (Coleman, 1985). In this way microarthropods also act as catalysts. Behan and Hill (1978) reported that oribatid mites carried propagules from over 20 species of fungi.

Some soil microarthropods act as deterrents of plant disease e.g. *Folsomia hidakana* (Collembola) has been observed to suppress the damping off disease in Cabbage and Chinese Cabbage by *Rhizoctonia solani* (Shiraishi *et al.,* 2003). *Caloglyphus* mite feeds on various stages of a number of important plant parasitic nematodes (Sell, 1988).

The microarthropod population mainly varies from place to place depending upon factors like cultivation practices and changing environmental factors (Culik *et al.,* 2002; Ahmad *et al.,* 1999; Schrader *et al.,* 1997). Use of organic materials such as farm yard manure, crop residues and green manure were reported to have beneficial effect on the quality of soil which act as agents in improving soil organic matter content and thereby increase the stability of the soil structure. Intensive agricultural practices with high inputs such as application of inorganic fertilizers and pesticidal application against pests greatly disturb the natural soil biota (Rajagopal, 1998).

Although soil microarthropods have been intensively studied, many fundamental concepts concerning their ecological interactions are however, yet to be addressed. Hence, present investigations on "Microarthropod fauna of cultivated soil" were undertaken with emphasis on the following objectives :

- study the population fluctuation of soil microarthropods under maize-wheat cropping system.
- ascertain the impact of some commonly used soil insecticides on the population of soil microarthropods.

Review of Literature

Chapter II

REVIEW OF LITERATURE

The available review of literature in relation to the investigations reported in this thesis has been grouped under the following heads:

2.1 Survey for microarthropod fauna in agrosystem

2.2 Population fluctuation of microarthropods in agrosystem

2.3 Effect of pesticides on microarthropod fauna

2.4 Culturing of collembolans and mites

2.1 Survey for microarthropod fauna in agrosystem

Culik *et al.* (2002) carried out investigations on the biodiversity of collembola in agricultural soils in Brazil and found an average of 60600 collembola inhabiting/m^2.

The analysis of collembological structure of the population of soil microarthropods in Northern Spain revealed the association of 57 collembolan species (Arbea and Blasco-Zumeta, 2001).

Palacios-Vargas *et al.* (2000) carried out studies on the irrigated and rainfed plots in Mexico and collected a total of 45962 arthropods mainly Astigmata, Oribatida and Collembola.

The spring and summer abundance of soil living mites and collembola was investigated in organically grown field plots in Denmark which were incorporated in the soil shortly before sowing of spring barley with undersown clover grass. Microarthropods were extracted from 10 cm deep soil samples taken in May, June and August. The densities of both microarthropods were extremely high (upto 120000 collembola and 90000 mites/m^2). The highest densities of collembola were found in plots with fodder radish as a catch crop, and the most abundant were *Tullbergia* sp., *Isotoma notabilis* and *Folsomia fimetaria*. The mite fauna consisted mainly of mesostigmatid and prostigmatid mites and was more abundant in the catch crop plots than in the control plots in early June (Axelsen and Kristensen, 2000).

Vreeken-Buijs *et al.* (1998) carried out sampling for microarthropods analysis every 3 months for one year at 10 sites in the Northern Netherlands, varying in soil type and land use. The four quantitatively principal functional groups were observed to be cryptostigmatic mites, non-cryptostigmatic mites, predatory mites and omnivorous collembola. Microarthropod biomass was larger in sandy soil than in loamy and generally larger in meadows than in wheat fields.

Andre *et al.* (1994) investigated the diversity of soil fauna in 'fore dunes' in France. The density of microarthropods was found to be 3-10 times greater than those observed in other soil types. Thirty one species were identified, the majority being both undescribed and < 200 mum in size. It was suggested that the soil, including the deepest horizons and the rhizosphere, might have constituted a huge reservoir for diversity.

Microarthropod biomass-C dynamics in arable soil were observed in a two year sampling programme in a conventional and an integrated farming system in Netherlands. The most abundant functional groups were omnivorous collembola, omnivorous non-cryptostigmatic mites and predatory mites (Vreeken-Buijs *et al.,* 1994).

According to Vats and Narula (1990) population of soil arthropods ranged from 17 to 23253/m^2 in cereal fields and from 509 to 139436/m^2 in forest stand. The number of species was higher in forest stand than in cereal field. Acarina and Collembola comprised 52 and 55 per cent of the arthropods in cereal fields and 90.4 per cent in forest.

The effect of soil salinity and cultivation on soil mite (Acari) populations was studied in two small plots in India and data showed cryptostigmata to be predominant over mesostigmata and prostigmata (Sanyal, 1988).

Studies carried out on the vertical distribution of various organisms by Pelsmaeker de *et al.* (1985) revealed maximum density of carnivorous nematodes, collembola, insect larvae, Tardigrada, Acarina and Enchytraeida in the upper 10 cm of soil layer.

Kelly and Curry (1985) conducted studies on the arthropod fauna of a winter wheat crop and found maximum number of collembola (8,000 to 9,000/m^2) and Acari (6,000 to 7,000/m^2) as compared to others.

2.2 Population fluctuation of microarthropods in agrosystem

Culik *et al.* (2002) studied the biodiversity of Collembola in tropical agricultural environments of Brazil and found total collembolan density greater in September than in December. They also found total collembolan densities to be greater with no tillage versus conventional tillage and with mulch versus no mulch.

Studies were made on the population fluctuations of soil microarthropods in relation to changing environmental factors (temperature, gravity, relative humidity and light), at depth of 4 and 6 inches, between January and June in 1992 in India. The number of microarthropods was always more at 6 inches than at 4 inches in depth. The mean soil temperature range of 14.5-26.2°C was the most suitable for population growth. The maximum population density occurred in April (37.33 and 40.50 mean arthropods per soil sample at 4 and 6 inches, respectively), when the temperature ranged between 21.4 and 26.2°C. It was concluded that soil temperature and the geopositive and photonegative nature of microarthropods were the main factors influencing population fluctuations (Ahmad *et al.,* 1999).

Schrader *et al.* (1997) carried out studies on the influence of soil tillage and soil compaction on microarthropods in agricultural land. The population size of microarthropods decreased with increasing soil compaction. The total number of soil microarthropods increased from March to May. After this seasonal peak, abundance decreased until the last sampling date in August before harvest. Collembola were more sensitive to soil compaction than mites.

2.3 Effect of pesticides on microarthropod fauna

Cortet *et al.* (2002) evaluated the effect of two herbicides (atrazine and alachlor) and two insecticides (fipronil and carbofuran) on organic matter decomposition and soil mesofauna in a maize (*Zea mays)* field under normal agriculture conditions. The effects on soil microarthropods varied depending on both taxon and pesticides with fipronil having a particularly strong effect. Differences were also observed between treatments for organic matter decomposition parameters, especially with the use of alachlor.

A study was conducted in Brazil to determine the effects of organic and conventional agriculture on soil organisms on tomato *(Lycopersicum esculentum)* and maize *(Zea mays)* crops revealed that the number of earthworms was approximately ten times higher in the organic system. However, there was no difference in the decomposition rate of organic matter of the two systems (Bettiol *et al.,* 2002). The study further reflected that the number of microarthropods was always higher in the organic plots in relation to the conventional ones, reflecting on the Shannon index diversity. The highest insect population belonged to the order Collembola, and in the case of mites, to the super family Oribatuloidea.

In another study on the influences of organic and conventional management practices on microarthropod diversity, Doles *et al.* (2001) observed increased densities of microarthropods in organically managed orchards as compared to those found in conventionally managed orchards and natural sites.

The short term effects of the herbicide, triasulfuron belonging to the chemical class of sulfonylureas on soil microarthropods were evaluated in two fields in Italy which had never been treated with sulfonylureas, and were cultivated with winter wheat. In particular, the effects of single application at rates corresponding to two-(rate 2) and six fold (rate 6) the recommended agricultural rates were analyzed and compared with controls. The changes in the population of main groups of microarthropods were evaluated. Rate 2 had very low effects, whereas rate 6 produced a significant decrease in the number of microarthropods, acarina and collembola in 0-7.5 cm surface layer (Rebecchi *et al.,* 2000).

Ellis *et al.* (1998) while evaluating the efficacy of chitin in the pots for the control of pests and diseases of sugarbeet seedlings found drastic reduction in the number of collembola in the treated soils.

The effects of insecticide, dimethoate and fungicide, benomyl, applied singly or together on soil organisms and plant growth were studied in microcosms containing agricultural soils and indigenous soil fauna together with introduced invertebrates and barley. Dimethoate reduced soil microarthropod population and the reduction was stronger in upper than in the lower soil layer. The collembola community structure was affected by both pesticides. Population of microarthropods in pesticides treated microcosms recovered during the experiment but the community structures remained differentiated (Martikainen *et al.,* 1998).

Pramanik *et al.* (1998) compared short term direct and residual toxicity of 5 different insecticides in soil medium using laboratory reared saprophytic microarthropod species. Based on the direct toxicity of highest recommended agricultural doses on several species, the insecticides were in the order heptachlor > endosulfan > methylparathion > phosphamidon > dichlorovos. Detailed LD_{50} (24 hour) studies and probit analysis showed *Cyphoderus javanus* (Collembola) to be the most sensitive species followed by *Archeqozetes longisetosus* (Cryptostigmata).

A refined microcosm technique was used to investigate the toxicity of copper, cadmium, malathion and polychlorinated biphenyl, aroclor 1254, to trophic groups of soil nematodes and to the microarthropod community of soil sample collected in an oak-beech forest in USA. Nematode abundance was reduced after exposure to copper at 100 fg/g with fungivore, bacterivore, and omnivore-predator nematodes being the most sensitive groups. Cadmium did not affect the nematode or microarthropod communities. Microarthropods were more sensitive to malathion than nematodes, and the total microarthropod abundance was lower than controls at 400 fg/g. Prostimatid mites and other arthropods were the most affected groups. Aroclor 1254 also had a greater negative impact on microarthropods than on nematodes. Total microarthropod abundance declined at 2500 fg/g, with prostimatid and oribatid mites exhibiting the highest susceptibility (Parmelee *et al.,* 1997).

Wiles and Frampton (1996) conducted field bioassays in UK to assess the toxicity of 3 insecticides (Chlorpyriphos, Cypermethrin and Pirimicarb) to 4 species of Collembola *(Isotoma viridis, Isotomurus palustris, Folsomia candida* and *Sminthurus viridis).* Cypermethrin and pirimicarb residues were of low toxicity, causing less than 10 per cent mortality whereas residues of chlorpyriphos were toxic to all 4 species of collembola.

Castro *et al.* (1996) studied the influence of three soil management system in Spanish olive orchards (tillage, no-tillage with bare soil and cereal cover crops with chemical mowing) and sunflower-wheat-leguminous rotation (tillage, minimum tillage and direct drilling) on the population of macro and microarthropods. The predominant microarthropods were Coleoptera and Hymenoptera, while the dominant microarthropods were the Collembola and Acari. A positive influence of plant residues on the abundance of soil arthropods was observed. The use of herbicides did not affect arthropod population.

The influence of dimethoate on the reproduction of two soil microarthropods, *Folsomia candida* and *F. fimetaria* was evaluated. Concentrations at approximately the recommended field dose had an adverse effect on the reproduction and survival of adults. *F. fimetaria* was more sensitive than *F. candida* (Krogh, 1995).

Application of phorate against jassid in cotton resulted in high toxicity to non target microarthropods with Collembola being most sensitive. However, foliar application of insecticides did not affect non target soil microarthropods (Singh and Gupta, 1994).

Field experiments were conducted in Georgia to evaluate the bactericides, oxytetracycline and sulfamethoxazole-penicillin, a nematicide-insecticide, carbofuran, and 3 insecticides, namely, carbaryl, naphthalene and aldicarb (Temik) for utilization in studies of the function of key organism groups. In these experiments, the ability of the pesticides to reduce target and non-target groups either directly or indirectly was assessed. Reduction in bacterial numbers after application of oxytetracycline or sulfamethoxazole-penicillin was limited, suggesting that these bactericides might be more effective when applied sequentially. Carbofuran, naphthalene, carbaryl and aldicarb had no significant effect on non-target bacteria, fungi and protozoa, nor on their target groups, nematodes or microarthropods. Naphthalene increased fungal activity and biomass, probably as an indirect effect of reducing number of fungal feeding nematodes and arthropods (Ingham *et al.,* 1994).

Vreeken-Buijs *et al.* (1994) observed microarthropod biomass-C dynamics in arable soil in a two year sampling programme in a conventional and an integrated farming system in Netherland. Management practices especially soil fumigation affected the short term dynamics of most groups but no effects were observed on the mean annual biomass of these groups.

According to Badejo and Adejuyigbe (1994) during the first 56 days after the pre-emergence application of hexazinone to a sandy loam alfisol, microarthropod population densities in the treated plots and untreated control plots were similar but lower than those in undisturbed forest plots.

In an annual (maize) and perennial (asparagus) cropping system the effects of the following methods of weed management : saw dust mulching, rotary cultivation at 3 week intervals; terbumeton/terbuthylazine at 5 kg/ha (in asparagus); bromacil at 1.6 kg (in asparagus); pre-emergence atrazine at 1.5 kg (in maize); post emergence rimsulfuron at 40 g/ha (in maize) on the detritus food web and below ground ecosystem was determined. Biota in the perennial system was more responsive to disturbance. The soil microflora was often strongly stimulated by mulching and caused large increase in top predatory, but not in most microbe-feeding nematodes. Micro and meso arthropod populations were generally most influenced by differences in plant residues and weed levels observed between treatments. Rotary cultivation and herbicide use did not exert consistent direct effects on any of the organisms considered (Wardle *et al.,* 1993).

Joy and Chakravorty (1991) evaluated the impact of insecticides on non-target microarthropod fauna in agricultural soil under laboratory and field condition in India. The density of total microarthropods and major groups (Acarina and Collembola) suffered a significant and persistent decline in aldrin 30 EC (0.25%) and endosulfan 35 EC (0.33%) treated soil in wheat fields. Dimethoate 30 EC (0.125%) and phosphamidon 85 EC (0.33%) applied in mustard fields produced only temporary decline. Laboratory studies showed that all the above insecticides and monocrotophos 36 EC (0.2%), parathion-methyl 50 EC (0.05%), chlordane 20 EC (0.125%) and carbaryl WP (0.625%) had a direct knockdown effect on *Cyphoderus* sp. but not *Xenilla* sp. Only endosulfan was toxic to the mite *Lancetoppia.* Toxicity was highest in a pure sand soil, followed by sandy loam, clay and organic soil. *Cyphoderus* sp. was shown to be a potential monitor for insecticide pollution in soil.

Casteels *et al.* (1990) tested the effect of 5 insecticides (parathion, dimethoate, pirmicarb, phosalone and fenvalerate) and 4 fungicides (benomyl, fenpropimorph, prochloraz and propic onazole) on predatory arthropods and Collembola in plot experiments in winter wheat during 1980-88. The insecticides parathion and dimethoate were very toxic towards Carabidae and Staphylinidae, reducing soil populations by 29 and 28 per cent, and by 67 and 31 per cent, respectively, and toxic towards Araneae (18 and 11 per cent population reductions). Fenvalerate reduced Araneae population by 30-33 per cent and phosalone reduced Collembola population by 44 per cent. The other pesticides mainly reduced arthropod by about 10 per cent, however, the insecticide pirimicarb and the fungicide benomyl had no toxic effects and Acari populations were unaffected by pesticide treatments. The toxic side effects varied between years, but were most apparent during the first week after application.

Under pot conditions, it was found that insecticides/acaricides i.e. formothion and malathion suppressed mites and collembola even at half the recommended dosages (Sreenivasa and Bagyaraj, 1989).

In India soil applications of aldicarb and phorate (at 0.5 and 1 kg a.i./ha) significantly reduced populations of soil collembola and mites for more than 114 and upto 60 days respectively, after treatment. Foliar application of dimethoate had no effect. Phorate was more toxic to Collembola than aldicarb. *The effect of phorate and aldicarb on soil organisms peaked on the 18th day* after treatment (Babu and Gupta, 1988).

Stinner *et al.* (1988) examined the influence of long term (20 years) tillage – mouldboard - ploughed, reduced-and no-tillage practices on-soil-inhabiting and canopy arthropod communities. Total number of microarthropods (mites and collembola) were lowest in the conventionally-(mouldboard-) ploughed treatments and highest in no-tillage treatments. Insecticide treatment significantly increased oribatid mite density, but consistently lowered (although not significantly) mesostigmatid mite populations. Insecticide application had little, if any, noticeable influence on collembolan (springtail) numbers.

The effect of some soil and foliar pesticides on the population density of different suborders of soil mites was investigated in cotton and soybean plots in Egypt. The herbicide oxadiazon (Ronstar 25 EC) had no effect on the population density of soil mites, under either cotton or soybean plants. A mixture of the fungicides carboxin and captan as 75 WP significantly reduced the numbers of cryptostigmatid mites under cotton plants. Soil application of carbofuran 10G (Furadan) or aldicarb 10G (Temik) at 6 and 12 kg/feddan, respectively, at the time of planting soybean seeds reduced the number of cryptostigmatid mites within 5 weeks following application, but mesostigmatid mites were not affected by either of these pesticides. Aldicarb also reduced the number of prostigmatid mites throughout the 5 weeks following application but neither aldicarb nor carbofuran altered the population density of any mite suborder within the later part of the 10 week period following treatment. Application of the foliar insecticides methomyl (Lannate 90 SP), Disa WP (of unstated composition) and SIR-8514 (triflumuron + tetradifon) 24.5 EC, binapacryl (Morocide 40 EC) and flubenzimine (cropotex 50 WP) and mixtures of methomyl with each acaricide to soybean plants had no effect on the population density of soil mites (Belal *et al.,* 1986).

Babu and Gupta (1986) reported that application of aldicarb and phorate at 0.5 and 1 kg/ha had a significant effect on mites and Collembola in the soil fauna. Foliar applications of dimethoate (0.2 and 0.4%) had no such effects. The toxicity of soil insecticides reached a peak, 18 days after application.

Kelly and Curry (1985) studied the effect of methiocarb (applied in various ways) for the control of slugs in winter wheat and found no adverse affect on predatory and decomposer fauna in single applications of methiocarb granules.

DDT application at the rate of 10 kg a.i./ha per growing season significantly reduced population of microarthropods. Acari were the dominant component of the fauna, prostigmata and mesostigmata being most affected by the pesticide. Collembola showed little response to DDT, though when maize straw was incorporated into the soil, higher populations occurred in DDT treated plots (Perfect *et al.,* 1981).

Gregoire (1981) applied 1 g aldicarb 10G (Temik) to 1 m^2 plots either in two line furrows (50 cm apart), in four lines (20 cm apart), or in a broadcast treatment. Microarthropods were collected after three weeks in pitfall traps (two per plot) and the numbers of each group were estimated. Collembola belonging to Sminthuridae and Isotomidae, were significantly reduced in number by the treatment, but the effect was less marked with furrow application, especially two line treatment, than with broadcasting. Number of mites (Eupodidae, Gamasida, Oribatida) were drastically reduced by the treatments. Collembola belonging to *Lepidocyrtus* sp. showed no reduction in numbers.

In France, studies on the effects of insecticidal treatments of cereal crops on beneficial insects were carried out. Analysis of catches before and after treatment with dimethoate and a combination of parathionmethyl and phosalone showed that the numbers of insects caught decreased by 60-70 per cent after the 1st treatment and by 70-80 per cent after the second. Pest population were very low on treatment dates. The insect groups most affected were carabidae, staphylinidae, collembola and hymenoptera (Chambon, 1982).

Heijbroek and Bund (1982) investigated the effect of Chloridazon on the microarthropod fauna. Lindane and aldicarb had a variable effect on the relative abundance of collembola.

Soil Acarina and Collembola were determined in sample taken from three orchards annually in October during 1969-74 to intensive orchard receiving a full spraying programme was compared with one in which insecticide spraying was stopped, and with an old orchard untreated for 10 years. Most soil inhabiting microarthropods were reduced by pesticides especially insecticides (Karg, 1978).

Thirumurthi and Lebrum (1977) found that carbofuran remained active in soil against insect for 10 weeks when applied to the soil at 2 kg toxicant/ha. Application rates of 10 or more kg/ha were shown to be very injurious to the soil fauna. In the case of *Folsomia candida,* the populations were reduced drastically.

2.4 Culturing of Collembolans and mites

Shiraishi *et al.* (2003) found doubling of the population of *Folsomia hidakana* (Collembola) in approximately 8.3 days while rearing this species in 'Koji' boiled rice on which *Aspergillus oryzae* flourished.

Sell (1988) observed yeast and hard boiled eggs to be suitable substrate for the mass culturing of mite, *Caloglyphus* sp.

Folsomia candida Willem (Collembola) was cultured from eggs in 5 cm diameter plastic petri dishes, part filled with Plaster of Paris containing different concentrations of activated plant charcoal. Three regimes comprising 0, 2.7 and 10% m/m charcoal in plaster were used. Animals reared on Plaster of Paris and 10% charcoal grew to a larger size, and moulted more frequently than those reared on the other two types of substrate. There were significant differences in fecundity between three populations. Those animals raised on the substrate with 10% charcoal laid a total of 5,879 eggs during the course of the experiment, more than double than those by the plaster of Paris only (Booth, 1983).

According to Shew and Beute (1979) laboratory cultures of mites of the genus *Caloglyphus* could be maintained for several months on *Pythium aphanidermatum* growing on potato-dextrose agar slant tubes.

Materials and Methods

MATERIALS AND METHODS

The studies were carried out in the laboratory and research farm of Department of Entomology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The detail of materials used and methods employed are described as below:

3.1 Analysis of microarthropod population

The microarthropods were extracted from soil by 'Tullgren funnel' (Veeresh, 1988). The population so obtained was counted under stereoscopic microscope and preserved in 70 per cent alcohol. The samples for identification of microarthropods have been sent to Dr. Jeffrey Battigelle, Earthworks Research Group, St. Albert, Alberta, Canada.

3.2 Determination of soil moisture

Moisture in the soil samples was determined following 'gravitational method' (Anonymous, 1997).

3.3 Survey studies for microarthropods

3.3.1 Analysis of soil for microarthropods in different localities

Soil samples from different localities of Himachal Pradesh were collected. For the collection of a sample from a locality, about 250 g of soil from the rhizosphere of four plants was taken and put in a polythene bag, mixed thoroughly and brought to the laboratory. From this composite sample, 250 cc soil was subjected to the analysis for assessing the population of microarthropods.

3.3.2 Analysis of plant rhizosphere *vis-à-vis* plant interspace soil for microarthropods

Twelve crops comprising agricultural, horticultural and plantation crops (Table 2) were selected for the comparative study of soil microarthropods in plant rhizosphere and plant interspaces at Palampur. From each crop, varying number of samples from the rhizosphere and plant interspaces were collected and analyzed as per methodology given above (3.3.1). The populations of both rhizosphere and interspaces were compared.

3.3.3 Microarthropods in vermicomposting

Study was conducted in the College of Basic Sciences of the University. The composting pit was filled with waste material and population of microarthropods (Collembola, mites and others) was assessed after 15, 30, 45, 60, 75, 90 and 105 days. For this, 100-150 g of decomposing material was drawn from four points in the pit at the depth of 15-20 cm, mixed thoroughly and designated as composite sample. From this composite sample, 250 cc of material was subjected to the analysis of microarthropods.

3.4 Population fluctuation

The population fluctuation of soil microarthropods was studied in the Research Farm of the Department of Entomology of the University. Maize and wheat crops were raised in 6 plots, each of 20 m^2 during kharif and rabi, 2003-04, respectively. From these plots, soil samples were collected at different depths of 0-15, 15-30 and 30-45 cm at an interval of one month for one year. For sampling, 50 x 50 cm area in each plot was selected and from this selected area, soil upto 45 cm depth was dug out. The soil of different horizons i.e. 0-15 cm, 15-30 cm and 30-45 cm was weighed and kept separately, mixed thoroughly and ultimately about 1 kg of sample from the soil of each depth was taken in a polythene bag and brought to laboratory for the analysis of microarthropods. From these samples, 250 g of soil of each sample was analysed for the microarthropods and expressed in per m^2.

3.5 Effect of insecticides on microarthropods

The study was carried out at the research farm of Department of Entomology at Palampur. The initial population (per m^2) of major microarthropods i.e. Collembolans and mites at 0-15 cm depth was determined in a field where maize-potato sequence was followed. For sampling, the procedure as detailed in Section 3.4 was followed. At the time of sowing of potato crop, in the last week of January, 2004 insecticides viz. phorate 10G (Thimet) @ 3 and 6 kg a.i./ha, carbofuran 3G (Furadan) @ 3 and 6 kg a.i./ha, chlorpyriphos 20 EC (Dursban) @ 400 and 800 g a.i./ha and quinalphos 25 EC (Ekalux) @ 400 and 800 g a.i./ha were applied. Microarthropods (Collembolans and mites) population was assessed again after 30 days of application & at harvest and compared with the pre-treatment counts. The per cent change (increase or decrease) in population of microarthropods was worked out by following the formula used by Henderson & Tilton (1955) as follows:

$$\% \text{ reduction in population} = \left\{ 1 - \left(\frac{T_a \times C_b}{T_b \times C_a} \right) \right\} \times 100$$

The above formula depicts per cent reduction in population. However, to fit in the present situation to obtain per cent increase or decrease in population over control, the formula was applied as given below:

$$\% \text{ change in population} = \left\{ \left(\frac{T_a \times C_b}{T_b \times C_a} \right) - 1 \right\} \times 100$$

where T_a = Population after treatment

T_b = Population before treatment

C_b = Population in control before treatment

C_a = Population after treatment in control

3.6 Multiplication of collembolans and mites

3.6.1 On soil with different substrates

The multiplication of Collembolans and mites was studied in plastic containers of 150 cc capacity. These containers were filled with 50 g autoclaved soil and each container was supplemented separately with equal chopped okra, potato, kinnow peel, pumpkin and cabbage after sterilizing in 0.01 per cent mercuric chloride followed by two washings in tap water. Thereafter, 50 individual each of collembolans and mites were released separately in each container. After 30, 45, 60 and 75 days of release, population counts of collembolans and mites were taken under stereoscopic microscope to know the multiplication potential of these organisms.

3.6.2 On wheat and paddy straws with different C:N ratio

Twenty g of wheat and paddy straw with different C:N ratios (Table 9 and 10) were filled in 150 cc plastic containers separately. Fifty ml of water was added to each container so as to make it just moist. After 10 days of adding water, 50 individuals each of collembola and mite were released separately. These containers were kept in the laboratory of the department of Entomology. After 60 days of release of collembola and mites, population counts of these arthropods were taken.

3.7 Statistical analysis

The data emanating on various parameters was subjected to statistical analysis as suggested by Gomez and Gomez (1984).

Results

Chapter IV

RESULTS

In the course of present investigations, studies on the survey of microarthropods in different localities of Himachal Pradesh, their population fluctuation and effect of insecticides on major microarthropods (mites and collembolans) were taken up. Besides an attempt to culture the mites and collembolans in laboratory was also made.

4.1 Survey studies

4.1.1 Analysis of soil samples for microarthropods in different localities

The study was aimed to know the abundance of two major microarthropods (Collembolans and mites) in different localities of Himachal Pradesh and ultimately to establish whether the prevailing abundance of these groups has any practical significance in agriculture. For this, 22 localities of 6 districts of Himachal Pradesh were surveyed as per procedure given in materials and methods under the head 3.3.1. The data observed are presented in Table 1. It can be revealed from the data that mites were found in the samples of 21 localities with population ranging from 1 to 55/250 cc of soil sample. On the other hand Collembolans were found in 13 localities only, with population ranging from 1 to 65/250 cc of soil sample. The sum total (locality wise) of all the microarthropods ranged between 1 to 137/250 cc of soil. No population of these microarthropods could be recorded in one locality at Bashing in district Kullu. From this study it appears that microarthropods are widely distributed in Himachal soils.

Table 1: Population density of microarthropods in different localities of Himachal Pradesh

District	Locality	Crop	Population/ 250 cc of soil			
			Collembola	Mite	Others	Total
Bilaspur	Berthin	Maize	65	36	0	101
	Nihari	Maize	40	28	0	68
Chamba	Ahala	Potato	0	4	0	4
Hamirpur	Kheri	Maize	0	2	2	4
Kangra	Baghru	Maize	1	15	1	17
	Berghatta	Maize	4	32	0	36
	Sujanpur Tira	Maize	5	10	0	15
Kullu	Aut	Potato	0	4	0	4
	Bagecha	Peas	0	7	0	7
	Bashing	Wheat	0	0	0	0
	Harabagh	Wheat	4	5	0	9
	Jhiri	Cabbage	0	1	0	1
	Kuteyangeh	Tomato	19	14	0	33
	Palsehar	Potato	0	3	0	3
	Panarsha	Tomato	1	8	0	9
	Patali Kuhal	Wheat	0	2	0	2
	Shamshi	Garlic	0	13	0	13
Mandi	Bardhan	Potato	12	2	0	14
	Barot	Potato	12	5	1	18
	Buching	Potato	56	10	0	66
	Janjehli	Apple	62	55	20	137
	Lohardi road	Potato	26	24	6	56

4.1.2 Analysis of plant rhizosphere *vis-à-vis* plant interspace soil samples for microarthropods

Twelve crops (Table 2) were selected for the purpose. A number of samples from the rhizosphere and interspaces were collected as per methodology described in materials and methods under the head 3.3.2. Sampling was done when the crop was about more than 45 days old. The population of all the crops/250 cc of soil was analyzed and compared. The data in Table 2 revealed the presence of both collembolans and mites in the rhizosphere as well as interspaces of all the crops. The total population of these organisms in rhizosphere and interspaces in different crops ranged from 6.00 to 30.17 and 1.67 to 26.67 individuals, respectively. Highest mean population of 30.17 (in rhizosphere) and 26.67 (plant interspaces) individuals/250 cc of soil sample were recorded in wheat crop. In general, more population of soil microarthropods was found in the rhizosphere as compared to inter plant spaces in all the crops.

The mean moisture (%) content in the soil samples ranged between 15.94 to 29.78 and 14.53 to 30.81 in the rhizosphere and plant interspace soil samples, respectively. No correlation between moisture content and total microarthropod population could be established.

The study shows that plant rhizosphere is more congenial environment for the multiplication of microarthropods as compared to plant interspaces.

4.1.3 Analysis of population of microarthropods in vermi-composting

The decomposing material was monitored for the population density of microarthropods at different intervals of vermicomposting. After 15 days of filling of the pit, the total population was observed to be 111.34

Table 2: Population status of microarthropods in rhizosphere *vis-à-vis* plant interspacing

Crops	No. of samples analysed	Population in rhizosphere/250 cc soil					Population in interspacing/250 cc soil				
		Collembola	Mite	Others	Total	Moisture (%)	Collembola	Mite	Others	Total	Moisture (%)
Potato	6	6.83 (0-11)	17.50 (1-57)	2.17 (0-4)	26.50	19.35 (7.24-25.40)	3.67 (0-6)	3.83 (2-8)	0.83 (0-4)	8.3	18.11 (6.32-19.97)
Cabbage	5	1.4 (1-2)	21.4 (9-43)	2.4 (1-51)	25.20	18.90 (11.57-24.96)	3.2 (1-6)	7.2 (2-13)	0.6 (0-2)	11.00	19.21 (12.50-25.2)
Bean	8	1.0 (0-2)	18.38 (6-37)	1.38 (0-3)	20.75	19.30 (8.0-24.1)	2.75 (0-10)	5.13 (1-17)	0.38 (0-1)	8.25	18.01 (7.80-23.2)
Soybean	3	2.5 (0-6)	2.0 (0-6)	4.0 (0-16)	8.5	23.32 (17.12-29.39)	1.16 (0-2)	2.5 (0-7)	0.66 (0-1)	4.0	21.43 (13.91-27.85)
Citrus	6	1.11 (0-2)	9.55 (5-20)	2.55 (0-6)	13.22	26.19 (18.39-32.23)	4.55 (0-10)	11.44 (2-21)	0.67 (0-3)	16.67	25.91 (18.33-31.78)
Brinjal	6	1.00 (0-2)	12.33 (7.25)	1.0 (0-2)	14.33	15.94 (8.33-21.97)	3.5 (0-8)	4.67 (1-10)	2.17 (0-5)	10.33	14.53 (7.01-21.08)
Mash	6	5.00 (2-7)	7.00 (1-21)	0.0 (0)	12.00	16.55 (9.3-22.63)	0.83 (0-4)	0.83 (0-2)	0.0 (0)	1.67	15.23 (7.71-22.58)
Maize	6	1.67 (1-3)	3.67 (2-6)	0.67 (0-1)	6.00	29.78 (27.7-31.60)	0.66 (0-1)	1.66 (1-2)	0.5 (0-1)	2.83	28.04 (15.56-30.45)
Kiwi	9	0.56 (0-3)	11.44 (4-24)	0.67 (0-2)	12.66	29.76 (14.5-32.2)	2.33 (0-10)	4.44 (0-19)	0.33 (0-1)	7.11	30.81 (23.25-38.29)
Wheat	6	1.83 (1-5)	28.33 (15-44)	0.0 (0)	30.17	28.99 (23.53-33.88)	1.33 (0-4)	25.0 (17-35)	0.33 (0-1)	26.67	28.78 (21.28-36.19)
Sarson	6	4.83 (1-12)	9.33 (2-15)	0.17 (0-1)	14.33	23.54 (16.12-29.68)	4.33 (1-11)	10.5 (2-17)	0.17 (0-1)	14.5	22.09 (15.45-28.57)
Tea	6	0.33 (0-2)	17.50 (5-36)	0.5 (0-2)	18.33	23.48 (15.96-30.2)	1.5 (0-5)	3.66 (0-11)	0.0 (0)	5.16	22.98 (15.39-28.47)
					(6.00-30.17)					(1.67-26.67)	

individuals/250 cc which increased with the increase of interval. The peak population of 1260.67 individuals was found at 75 days, after which decline in population was observed.

Table 3: Population of microarthropods in vermicomposting at different intervals

Intervals (Days)	Population of microarthropods/250 cc			
	Collembola	Mites	Other	Total
15	101.67	8.00	1.67	111.34
30	214.67	14.67	2.33	231.67
45	595.33	17.00	3.33	615.66
60	757.33	17.67	4.67	779.67
75	1235.67	19.00	6.00	1260.67
90	706.33	10.67	3.33	720.33
105	238.67	5.00	1.00	244.67

4.2 Population fluctuation of microarthropods

The population fluctuation of different microarthropods was studied from July, 2003 to June, 2004. The population data of various microarthropods recorded in different horizons of soil are presented in Table 4 and 5.

It can be seen from the Table 5 that mite fauna dominated in all the depths. At 0-15 cm depth, population of collembolans & mites and rest of the soil microarthropods during different months of the year ranged from 1595.3 to 5252.8, 3658.3 to 15849.5 and 371.3 to 1853.8 individuals/m^2, respectively (Table 5). At this depth, maximum population (22956.2 individuals) of total microarthropods was observed in May, 2004 (Table 4). The data also revealed

Table 4: Population of microarthropods* at different depths during different months

Months	Total population/m^2 in different depths (cm)				% share in different depths (cm)		
	0-15	15-30	30-45	Mean	0-15	15-30	30-45
July, 2003	7409.7 (8.83)	2383.2 (7.74)	574.3 (6.35)	3455.7 (7.64)	71.47	22.99	5.54
August, 2003	5912.5 (8.62)	1675.3 (7.41)	518.0 (6.22)	2701.9 (7.42)	72.94	20.67	6.39
September, 2003	7300.2 (8.87)	3126.8 (8.04)	738.5 (6.55)	3721.8 (7.82)	65.38	28.00	6.61
October, 2003	8951.3 (9.06)	4450.7 (8.40)	720.2 (6.56)	4707.4 (8.00)	63.38	31.51	5.10
November, 2003	6840.0 (8.80)	3066.0 (8.02)	676.8 (6.51)	3527.6 (7.77)	64.63	28.97	6.39
December, 2003	6703.8 (8.79)	2880.8 (7.96)	726.5 (6.57)	3437.0 (7.78)	65.01	27.94	7.04
January, 2004	8873.2 (9.06)	2950.0 (7.98)	735.0 (6.59)	4186.1 (7.88)	70.66	23.49	5.85
February, 2004	11978.8 (9.37)	4078.5 (8.30)	1175.5 (7.05)	5744.3 (8.24)	69.51	23.67	6.82
March, 2004	14880.7 (9.59)	4602.5 (8.42)	893.8 (6.76)	6792.3 (8.26)	73.02	22.59	4.39
April, 2004	15867.3 (9.64)	5131.5 (8.52)	964.7 (6.86)	7321.2 (8.34)	72.24	23.36	4.39
May, 2004	22956.2 (10.02)	8143.5 (8.99)	972.0 (6.86)	10690.6 (8.62)	71.58	25.39	3.03
June, 2004	6739.0 (8.81)	2822.8 (7.93)	1973.8 (7.55)	3845.2 (8.10)	58.42	24.47	17.11
Mean	10367.7 (9.12)	3775.9 (8.14)	889.1 (6.70)		68.19	25.25	6.55

*Includes collembolans, mites plus other than these two groups
Figures in parentheses are log transformed values

CD (P = 0.05) Months (A) = 0.15
Depths (B) = 0.08
A x B = 0.26

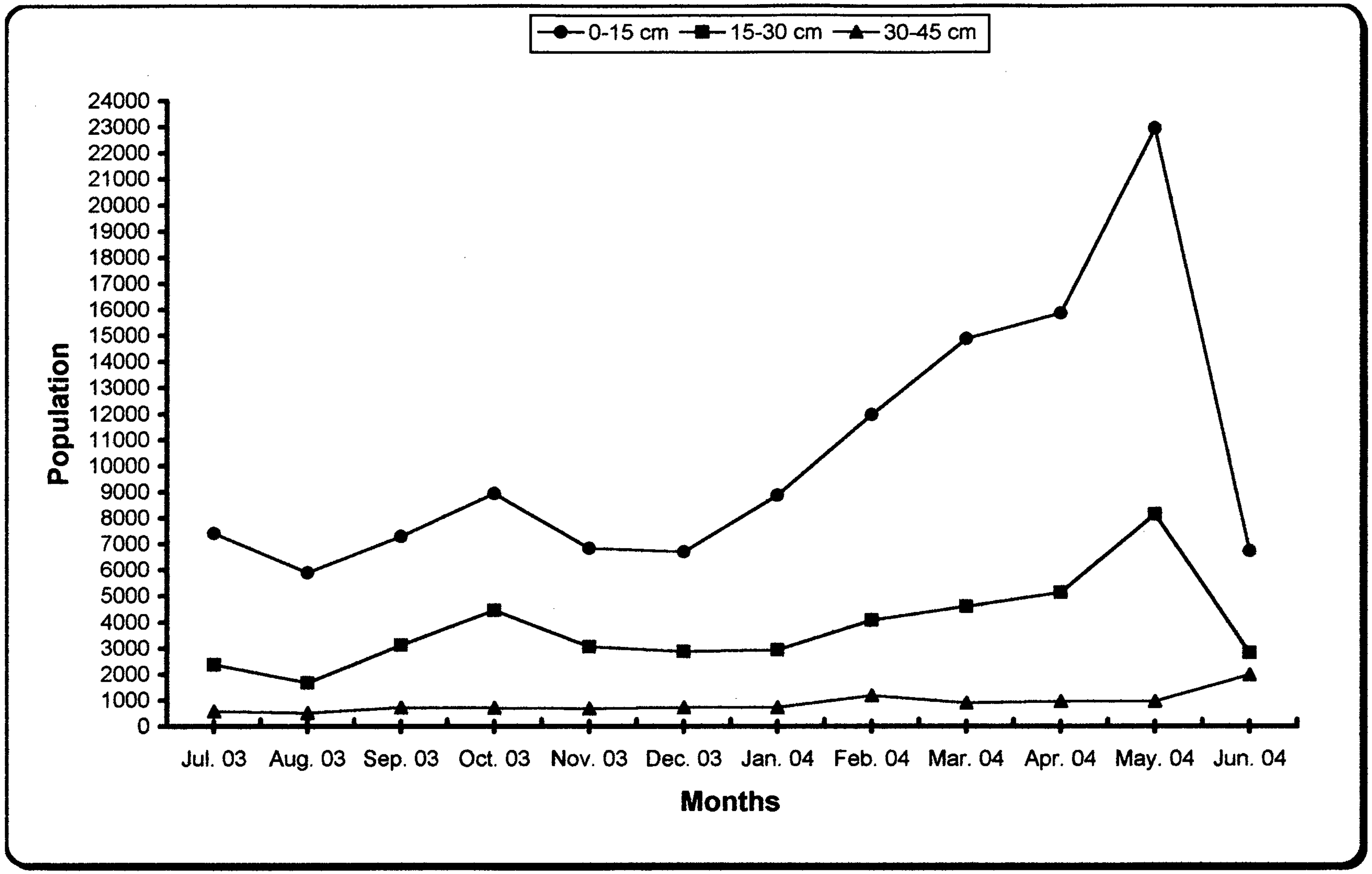

Fig. 1: Population fluctuation of microarthropods at different depths during different months

Table 5: Population of microarthropods (per 250 cc soil sample) in maize-wheat cropping system at Palampur

Months	0-15 cm			15-30 cm			30-45 cm		
	Collembolans	Mites	Others	Collembolans	Mites	Others	Collembolans	Mites	Others
July, 2003	1988.5 (7.45)	3777.5 (8.11)	1643.7 (7.26)	1150.8 (7.02)	959.0 (6.77)	273.3 (5.55)	152.5 (5.01)	304.5 (5.71)	117.3 (4.76)
August, 2003	1595.3 (7.34)	3658.3 (8.06)	658.8 (6.40)	581.2 (6.35)	940.0 (6.83)	154.2 (5.01)	165.0 (5.06)	225.5 (5.39)	127.5 (4.83)
September, 2003	2067.8 (7.62)	4578.5 (8.38)	653.8 (6.36)	740.8 (6.58)	1807.2 (7.49)	578.8 (6.35)	245.5 (5.34)	297.0 (5.60)	196.0 (5.04)
October, 2003	2986.5 (7.92)	5089.2 (8.49)	875.7 (6.75)	1547.3 (7.32)	2079.2 (7.63)	824.2 (6.70)	240.5 (5.44)	313.5 (5.73)	166.2 (5.11)
November, 2003	1695.0 (7.38)	4140.0 (8.20)	1005.7 (6.92)	782.8 (6.65)	1724.7 (7.44)	558.5 (6.32)	244.0 (5.49)	274.3 (5.61)	158.5 (5.04)
December, 2003	1892.2 (7.51)	3926.7 (8.24)	885.0 (6.78)	772.3 (6.63)	1601.7 (7.37)	506.8 (6.21)	232.8 (5.44)	325.0 (5.76)	168.7 (5.09)
January, 2004	2162.3 (7.52)	5936.0 (8.67)	774.8 (6.60)	813.5 (6.68)	1614.5 (7.38)	522.0 (6.25)	233.2 (5.45)	330.3 (5.78)	171.5 (5.11)
February, 2004	3496.8 (8.14)	7925.8 (8.94)	556.2 (6.25)	1531.7 (7.32)	2249.7 (7.70)	297.2 (5.67)	452.3 (6.09)	554.5 (6.30)	168.7 (5.10)
March, 2004	4821.8 (8.35)	9213.7 (9.12)	845.2 (6.72)	1558.3 (7.33)	2778.8 (7.90)	265.3 (5.53)	326.7 (5.73)	407.5 (5.97)	159.7 (5.05)
April, 2004	5214.2 (8.54)	10282.1 (9.19)	371.0 (5.87)	1189.5 (7.07)	3694.7 (8.18)	247.3 (5.49)	343.7 (5.83)	431.2 (6.05)	189.8 (5.23)
May, 2004	5252.8 (8.55)	15849.5 (9.64)	1853.8 (7.50)	1983.5 (7.56)	5078.3 (8.52)	1081.7 (6.98)	345.3 (5.83)	473.0 (6.14)	153.7 (4.98)
June, 2004	1993.0 (7.59)	3827.8 (8.24)	918.2 (6.82)	870.7 (6.76)	1344.0 (7.17)	608.2 (6.40)	610.7 (6.39)	1040.8 (6.90)	322.3 (5.75)
$\bar{X}$ (range)	2930.5 (1595.3-5252.8)	6517.1 (3658.3-15849.5)	920.1 (371.3-1853.8)	1126.9 (581.2-1983.5)	2155.9 (940.0-5078.3)	493.1 (154.2-1081.7)	299.3 (152.5-610.7)	414.7 (225.5-1040.8)	174.9 (117.3-322.3)

Maize crop sowing = 2nd week of June, 2003; Wheat crop sowing = 2nd week of November, 2003

Sampling time = First week of every month; Figures in parentheses are log transformed values

CD (P=0.05)	Months (A) =	0.11	Depths (B) =	0.05
	Microarthropods (C) =	0.05	A x B =	0.19
	A x C =	0.19	B x C =	0.09
	A x B x C =	0.33		

that total microarthropod population peaked twice during the study period i.e. October, 2003 (8951.3 individuals) and May, 2004 (22956.2 individuals) (Table 4 & Fig. 1). At 15-30 cm depth, the mean population/m^2 was observed to be 581.2 to 1983.5, 940.0 to 5078.3 and 154.2 to 1081.7 individuals of collembolans, mites and rest of the microarthropods (Table 5). Like uppermost zone, two distinct peaks of the population were also observed at soil depth of 15-30 cm during the same months as in 0-15 cm layer of the soil i.e. October 2003 (4450.7 individuals) and May 2004 (8143.5 individuals) (Table 4 & Fig. 1). Observations recorded on the population of microarthropods at soil depth of 30-45 cm reflected substantial decline in their population. The mean population of collembolans, mites & other microarthropods was observed to be in the range of 152.5 to 610.7, 225.5 to 1040.8 and 117.3 to 322.3 individuals, respectively (Table 5). At this depth (30-45 cm) population remained almost static and clear cut peaks could not be observed (Table 4 & Fig. 1). The top layer (0-15 cm) shared 68.19 per cent population followed by 25.25 and 6.55 per cent at 15-30 cm and 30-45 cm, respectively (Table 4).

The interaction effect of population during different months of the year and different soil depths is given in Table 5(a). It can be seen from the table that there were significant differences between the mean population of different months at all the depths. The sum total of microarthropod population between 0-45 cm during different months varied significantly with highest during the month of May (3563.5). The interaction of different months to the microarthropods in Table 5(b) revealed maximum mean population of mites (3029.3 individuals) which varied significantly from other groups. Another interaction analysis between depths and microarthropods in Table 5(c) show maximum mean population of 3455.9 at 0-15 cm which declined significantly with the increase in depth. Maximum mean population (at 0-45 cm depth) of mites (3029.2) was recorded which varied significantly from other groups.

Table 5(a): Interaction between months and depths (A x B)

Months \ Depths (cm)	0-15	15-30	30-45	Mean
July, 2003	2469.9 (7.61)	794.4 (6.45)	191.4 (5.16)	1151.9 (6.41)
August, 2003	1970.8 (7.27)	558.4 (6.06)	172.7 (5.09)	900.6 (6.14)
September, 2003	2433.4 (7.45)	1042.3 (6.81)	246.2 (5.33)	1240.6 (6.53)
October, 2003	2983.8 (7.72)	1483.6 (7.22)	240.1 (5.43)	1569.2 (6.79)
November, 2003	2280.0 (7.50)	1022.0 (6.80)	225.6 (5.38)	1175.9 (6.56)
December, 2003	2234.6 (7.51)	960.3 (6.74)	242.2 (5.43)	1145.7 (6.56)
January, 2004	2957.7 (7.60)	983.3 (6.77)	245.0 (5.45)	1395.3 (6.61)
February, 2004	3992.9 (7.78)	1359.5 (6.90)	391.8 (5.83)	1914.7 (6.84)
March, 2004	4960.2 (8.06)	1534.2 (6.92)	297.9 (5.58)	2264.1 (6.85)
April, 2004	5289.1 (7.87)	1710.5 (6.91)	321.6 (5.70)	2440.4 (6.83)
May, 2004	7652.1 (8.56)	2714.5 (7.69)	324.0 (5.65)	3563.5 (7.30)
June, 2004	2246.3 (7.55)	940.9 (6.78)	657.9 (6.35)	1281.7 (6.89)
Mean	3455.9 (7.71)	1258.6 (6.84)	296.4 (5.53)	

CD (P=0.05)
Mean (A) = 0.11
Depth (B) = 0.05
A x B = 0.19

Table 5(b): Interaction between months and different micro-arthropods (A x C)

Micro-arthropods / Months	Collembolans	Mites	Others	Mean
July, 2003	1097.3 (6.49)	1680.3 (6.86)	678.1 (5.86)	1151.9 (6.40)
August, 2003	780.5 (6.25)	1607.9 (6.76)	313.5 (5.41)	900.6 (6.14)
September, 2003	1018.0 (6.51)	2227.6 (7.16)	476.2 (5.92)	1240.6 (6.53)
October, 2003	1591.4 (6.89)	2493.9 (7.28)	622.0 (6.19)	1569.1 (6.79)
November, 2003	907.3 (6.51)	2046.3 (7.08)	574.2 (6.09)	1175.9 (6.56)
December, 2003	965.8 (6.53)	1951.1 (7.12)	520.2 (6.03)	1145.7 (6.56)
January, 2004	1069.7 (6.55)	2626.9 (7.28)	489.4 (5.99)	1395.3 (6.61)
February, 2004	1826.9 (7.18)	3576.7 (7.65)	340.7 (5.67)	1914.8 (6.83)
March, 2004	2235.6 (7.14)	4133.3 (7.66)	423.4 (5.77)	2264.1 (6.86)
April, 2004	2249.1 (7.15)	4802.7 (7.81)	269.4 (5.53)	2440.4 (6.83)
May, 2004	2527.2 (7.31)	7133.6 (8.10)	1029.7 (6.49)	3563.5 (7.30)
June, 2004	1158.1 (6.91)	2070.9 (7.44)	616.2 (6.32)	1281.7 (6.89)
Mean	1452.2 (6.78)	3029.3 (7.35)	529.4 (5.94)	

CD (P=0.05)	Month (A)	=	0.11
	Microarthropods (C)	=	0.05
	A x C	=	0.19

Table 5(c): Interaction between depths and different microarthropods (B x C)

Depths (cm) / Microarthropods	0-15	15-30	30-45	Mean
Collembola	2930.5 (7.82)	1126.9 (6.94)	299.3 (5.59)	1452.2 (6.78)
Mites	6517.1 (8.61)	2155.9 (7.53)	414.7 (5.91)	3029.2 (7.35)
Others	920.1 (6.68)	493.1 (6.04)	174.9 (5.09)	529.4 (5.94)
Mean	3455.9 (7.70)	1258.6 (6.84)	296.3 (5.53)	

CD (P=0.05) Depth (B) = 0.05
Microarthropods(C) = 0.05
B x C = 0.09

4.3 *Effect of insecticides on soil microarthropods*

The test insecticides (Table 6) were applied at the time of sowing. The population of two microarthropods, namely, Collembola & mite was estimated just before sowing and at 30 days of insecticidal application and near crop harvest. The results obtained are given in Table 6. It can be seen from the table that observation recorded 30 days after application of various insecticides showed the population reduction of Collembolans ranging between 41.09 (quinalphos @ 400 g a.i./ha) and 100 per cent (phorate @ 6 kg a.i. and carbofuran @ 6 kg a.i./ha). However, observations near crop harvest reflected cent per cent reduction of Collembolans in all the treatments except carbofuran 3 kg a.i./ha where decline to the tune of 83.65 per cent was observed.

Table 6: Effect of insecticides on soil microarthropods (Collembolans and mites)

Insecticides	Dosage/ ha (a.i.)	Population of microarthropods/m^2						Per cent change in population over control			
		Before application		30 days after application		Near harvest		30 days after application		Near harvest	
		Collembolans	Mites	Collembolans	Mites	Collembolans	Mites	Collembolans	Mites	Collembolans	Mites
Phorate 10G	3 kg	1829 (7.47)	4651 (8.44)	271 (5.48)	5191 (8.52)	0 (0.00)	11209 (9.32)	-89.54	+6.38	-100.00	+115.72
Phorate 10G	6 kg	1369 (7.22)	8200 (9.01)	0 (0.00)	10389 (9.17)	0 (0.00)	5479 (8.60)	-100.00	+20.76	-100.00	-40.19
Carbofuran 3G	3 kg	1091 (6.99)	12849 (9.46)	369 (5.89)	13480 (9.50)	271 (5.60)	13410 (9.49)	-76.13	-0.001	-83.65	-6.58
Carbofuran 3G	6 kg	1640 (7.39)	15031 (9.61)	0 (0.00)	6560 (8.75)	0 (0.00)	11751 (9.36)	-100.00	-58.40	-100.00	-30.02
Chlorpyriphos 20 EC	400 g	1731 (7.41)	3951 (8.28)	820 (6.68)	4920 (8.46)	0 (0.00)	6560 (8.78)	-66.57	+18.69	-100.00	+48.62
Chlorpyriphos 20 EC	800 g	1640 (7.39)	13120 (9.48)	820 (6.68)	8749 (9.07)	0 (0.00)	9100 (9.11)	-64.72	-36.44	-100.00	-37.91
Quinalphos 25 EC	400 g	1640 (7.40)	6289 (8.73)	1369 (7.22)	6831 (8.79)	0 (0.00)	8190 (9.01)	-41.09	+3.53	-100.00	+16.57
Quinalphos 25 EC	800 g	1540 (7.30)	5469 (8.60)	191 (5.18)	6191 (8.70)	0 (0.00)	7731 (8.93)	-91.25	+7.90	-100.00	+26.53
Control	-	1369 (7.21)	19951 (9.89)	1940 (7.57)	20931 (9.94)	2080 (7.63)	22289 (10.01)	+41.71	+4.91	+51.94	+11.72
CD (P=0.05)		NS	NS	(0.53)	(0.46)	(0.11)	(0.16)				

Figures in parentheses are log (x + 1) transferred values ; + = increase in population; - = decrease in population

In case of mites, carbofuran (3 and 6 kg a.i./ha) and chlorpyriphos (800 g a.i./ha) revealed the population decline of 0.001, 58.40 and 36.44 per cent at 30 days after insecticidal application. In rest of the treatments, population increased variably. Near the crop harvest, population decline of 40.19, 6.58, 30.02 and 37.91 per cent was found in phorate @ 6 kg, carbofuran @ 3 & 6 kg and chlorpyriphos @ 800 g/ha, respectively. In rest of the treatments, population increase ranging from 16.57 to 115.72 was noticed. While comparing different treatments among themselves it was observed that at 30 days after treatment, population of collembolans was totally eliminated in phorate @ 6 kg a.i./ha and carbofuran @ 6 kg a.i./ha treated plots. The minimum population of 191 was recorded in quinalphos (800 g a.i./ha) which was at par with phorate (3 kg a.i./ha). Near the crop harvest, no population of Collembolans was observed in any of the treatments except in plots where carbofuran 3 kg a.i./ha was applied (271 individuals as compared to 2080 in control).

At both the observation periods, mite population was observed to vary significantly within treatments. At 30 days, significantly highest population of 13480 mite individuals were found where carbofuran (3 kg a.i./ha) was applied which was at par with phorate (6 kg a.i./ha) and chlorpyriphos (800 g a.i./ha) as compared to 20931 mites in control plots. Near the crop harvest, highest population of 13410 mites was recorded in carbofuran (3 kg a.i./ha) treated plots which was at par with higher test dosage of this insecticide. In rest of the treatments, population ranging from 7731 to 11209 mite individuals/m^2 were found as compared to 22289 in control plots. It is, therefore, concluded that all the test chemicals proved highly detrimental to the collembolans whereas the harmful effects on mite population could be observed in phorate @ 6 kg, carbofuran @ 3 & 6 kg and chlorpyriphos @ 800 g/ha only.

4.4 Culturing of Collembolans and mites

This aspect was undertaken in order to obtain sufficient population of these organisms which can be used for further laboratory studies.

4.4.1 On different substrates

Studies on the multiplication of collembolans and mites were undertaken on five substrates, namely, okra, potato tubers, kinnow peel, pumpkin and cabbage. The population multiplication of both of these organisms was observed after 30, 45 60 and 75 days of release of the initial populations. It is evident from the data presented in Table 7 that on okra and potato, the population of collembolans increased with the increase in time (after the release of population). However, on okra the collembolan population

Table 7: Multiplication of Collembola on different substrates

Days after release of Collembolans	Multiplication on					
	Okra	Potato	Cabbage	Kinnow peel	Pumpkin	Mean
30	45.66 (6.83)	64.67 (8.09)	12.67 (3.69)	5.33 (2.45)	8.00 (2.98)	27.27 (4.81)
45	77.00 (8.82)	93.00 (9.67)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	34.00 (4.30)
60	87.33 (9.37)	107.00 (10.39)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	38.87 (4.55)
75	169.33 (13.04)	171.67 (12.94)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	68.2 (5.79)
Mean	94.83 (9.51)	109.08 (10.27)	3.17 (1.67)	1.33 (1.36)	2.00 (1.49)	

Figures in parentheses are square root transformed values

CD (P=0.05)	Substrates (A)	=	0.62
	Days (B)	=	0.56
	A x B	=	1.24

at 30 days after release (45.66) was observed to be less than even the initially released population (50.00). But this population increased significantly at later dates at each observation period i.e. 77.00, 87.33 and 169.33 after 45, 60 and 75 days, respectively.

Similarly, on potato, the collembola population increased with the increase of time. At 30 days, a population of 64.67 individuals were recorded which further increased to 93.00, 107.00 and 171.67 individuals at 45, 60 and 75 days. The collembolan population on potato differed significantly at each observation period. Other substrates viz. cabbage, kinnow peel and pumpkin, though reflected very low populations of 12.67, 5.33 and 8.00 at 30 days observation period, no population was recorded at subsequent intervals. The mean maximum and minimum temperature during the period of study varied from 32.5 to 16.1°C and 28.7 to 11.8°C.

Interaction data of substrate x days, revealed maximum population on potato which differed significantly from the population multiplication on okra.

Multiplication of mites like collembolans was observed only on okra and potato and their population also increased with the increase of time after the initial release of these organisms (Table 8). However, mite population was observed to be more in comparison to the collembolans (Table 7 & 8). The population of mites on okra was found to be 52.67 individuals after 30 days of release which increased significantly to 234.33 at 75 days. At 30 days, the mite population on potato was 279.33 which peaked upto 348.33 at 75 days of data recording. There were significant differences between the mite populations recorded at all the intervals. The interaction analysis revealed highly significant differences between the total population recorded on okra and potato.

Table 8: Multiplication of mites on different substrates

Days after release of Mites	Multiplication on					
	Okra	Potato	Cabbage	Kinnow peel	Pumpkin	Mean
30	52.67 (7.27)	279.33 (16.74)	22.67 (4.85)	15.67 (4.08)	17.33 (4.28)	77.53 (7.44)
45	150.00 (12.28)	281.00 (16.79)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	86.20 (6.41)
60	199.00 (14.13)	303.33 (17.44)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	100.47 (6.91)
75	234.33 (15.34)	348.33 (18.68)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	116.53 (7.40)
Mean	159.00 (12.25)	302.99 (17.41)	5.67 (1.96)	3.92 (1.77)	4.33 (1.82)	

Figures in parentheses are square root transformed values

CD (P=0.05)	Substrates (A)	=	0.35
	Days (B)	=	0.31
	A x B	=	0.70

Hence, amongst the evaluated substrates potato appears to be best for maintaining the populations of collembolans and mites followed by okra.

4.4.2 On wheat and paddy straw with different C:N ratio

Fifty individuals each of collembolans and mites were released separately in containers having wheat and paddy straw with varying C:N ratios. After 60 days of release of these organisms, population counts were taken and the data so obtained has been presented in Table 9 and 10.

On wheat straw at C:N ratio of 79.0:1, 132 individuals of collembolans were recorded as compared to 115.00 of mites (Table 9). At C:N ratio of 39.26:1 and 19.63:1, no collembolan were observed, whereas the mite population increased to 146.33 and 146.67 respectively, being statistically at par with each other. In the treatment where only collembolans were released for the multiplication, 60.67, 50.33 and 44.67 individuals of mites were also found at C:N ratios of 79.0:1, 39.26:1 & 19.63:1, respectively. The interaction analysis revealed highly significant differences between mites and collembolans population build up at different C:N ratio.

Table 9: Multiplication of microarthropods (Collembolans and mites) on wheat straw at different C:N ratios

C:N ratio	Population after 60 days of release		
	Collembolans	Mites	Mean
79.0:1	132.00 (11.51)	115.00 (10.75)	123.5 (11.13)
39.26:1	0.00 (1.00)	146.33 (12.13)	73.16 (6.57)
19.63:1	0.00 (1.00)	146.67 (12.14)	73.33 (6.57)
Mean	44.00 (4.50)	136.00 (11.67)	

Figures in parentheses are square root transformed values
Number of individuals released initially = 50

CD (P=0.05)	C:N ratio (A)	=	0.697
	Microarthropods (B)	=	0.569
	A x B	=	0.986

The multiplication of Collembolans and mites in paddy straw at different C:N ratios (Table 10) indicated more reduction of the initially released population. In Collembolans at the natural C:N ratios of 99.0:1, there was more than 50 per cent reduction in population. No population of collembolans could be recorded at the remaining two C:N ratios. In case of mites, 27.67, 39.33 and 20.00 individuals were recorded at different C:N ratios of 99.0:1,

Table 10: Multiplication of microarthropods (Collembolans and mites) on paddy straw at different C:N ratios

C:N ratio	Population after 60 days of release		
	Collembolans	Mites	Mean
99.0:1	20.67 (4.60)	27.67 (5.32)	24.17 (4.96)
49.6:1	0.00 (1.00)	39.33 (6.34)	19.66 (3.67)
24.8:1	0.00 (1.00)	20.00 (4.57)	10.00 (2.79)
Mean	6.89 (2.20)	29.00 (5.41)	

Figures in parentheses are square root transformed values
Number of individuals released initially = 50

CD (P=0.05) C:N ratio (A) = 0.65
Microarthropods (B) = 0.53
A x B = 0.93

49.6:1 and 24.8:1, respectively. In treatments where collembolans were solely released, 41.67, 40.33 & 34.33 individuals of mites were also recorded in C:N ratios of 99.0:1, 49.6:1 & 24.8:1, respectively. In interaction analysis, significant differences between collembolans and mites population were found. From these studies, it was concluded that wheat substrate at different C:N ratios appears to be more suitable for the multiplication of collembolans and mites as compared to different C:N ratios of paddy.

Discussion

Chapter V

DISCUSSION

The results of studies undertaken on various aspects of soil microarthropods, namely, survey in Himachal Pradesh, population fluctuation during different months under specified cropping scheme, effect of insecticides on major soil microarthropods and standardisation of rearing techniques of major microarthropods are discussed here as under:

The survey studies revealed the presence of mites in 21 out of 22 surveyed localities with population of 1 to 55/250 cc soil sample whereas the prevalence of collembolans was observed only in 13 localities. However, density of Collembolans was found to be more than mites and ranged between 1 to 65. The sum total of all kinds of microarthropods (locality wise) was found between 1 to 137/250 cc of soil sample. There are variable reports on the prevalence of microarthropods in soil. Culik *et al.* (2002) reported an average of 60600 Collembola inhabiting/m^2. Vats and Narula (1990) recorded the population of soil arthropods ranging from 17 to 23253/m^2 in cereal fields and from 509 to 139436/m^2 in forest stand. Axelsen and Kristensen (2000), however, observed upto 120000 and 90000 individuals/ m^2 of Collembolans and mites, respectively. The low microarthropod population encountered in present investigations can be attributed to the difference in climatic conditions, soil conditions, crop sequence, organic matter content etc.

Survey for microarthropods in plant rhizosphere *vis-à-vis* interplant spaces showed that plant rhizosphere harboured high population of microarthropods as compared to interplant spaces in all the crops. The mean population of 30.17/250 cc soil of all kinds of microarthropods was found in the rhizosphere as compared to 26.67 in interspaces of plants/crops. There is no report of this type of study in the literature in respect of soil microarthropods. These results find considerable support from the facts that greater number of bacteria, fungi and actinomycetes are present in the rhizosphere than in non rhizosphere soil. One of the most important factor responsible for the rhizosphere effect (overall influence of plant roots on soil microorganisms) is the availability of great variety of organic substances in the root zone by way of exudates from roots, which in turn directly or indirectly influence the quality and quantity of microorganisms in the root region. The substances exuded by plant roots include amino acids, sugars, organic acids, vitamins, nucleotides and many other unidentified compounds. Further, the nature and amount of substances thus exuded by roots are dependent on the plant species, plant age and environmental conditions under which the plant grow (Rao, 1977).

While studying the population status of microarthropods in vermi-composting, it was found that population (per 250 cc) of these creatures which was 111.34 at 15 days, increased with an increase in intervals and reached upto 1260.67 individuals after 75 days, followed by sharp population decline. No such information on microarthropods in vermicomposting is available in the literature. For this, further studies on different factors especially temperature and pH are required to find out the appropriate reasoning.

Mite fauna was more abundant as compared to other types of microarthropods at different soil depths. The population of microarthropods fluctuated during different months and two peaks at depths 0-15 and 15-30 cm were observed whereas population remained almost static at 30-45 cm depth. The density of microarthropods decreased with the increase in depths. The top layer (0-15 cm) harboured 68.19 per cent microarthropods, followed by 25.25

and 6.55 per cent at 15-30 cm and 30-45 cm, respectively. The findings of Ahmad *et al.* (1999) regarding the presence of more number of microarthropods at 6 inches than at 4 inches depth are however, contrary to the present studies. The greater density of microarthropods at 0-15 cm soil depth may be because of the reason that in this particular region the soil has more organic matter which is favourable for the multiplication of micro-arthropods. Variable reports on the seasonal fluctuation are available in the literature which can be attributed to varying climatic conditions, soil conditions, agronomic practices etc. Culik *et al.* (2002) observed greater density of total Collembolans in September than in December and also found greater density of these insects with no tillage versus conventional tillage and with mulch versus no mulch.

Presently, use of chemicals for the management of pests, diseases and weeds is most popular. Although large quantities of chemicals are applied to crops, only a small percentage of the applied pesticides reach the target pests and this is estimated to be less than 0.1 per cent (Pimental and Levitan, 1986). Thus, more than 99 per cent of applied pesticides go off into the environment and affect the non-target biota. In general, the toxicity of pesticides is related to the environmental hazards. Insecticides are generally most hazardous to the environment, followed by fungicides and herbicides. In the present studies, four insecticides (chlorpyriphos, quinalphos, phorate and carbofuran) at their recommended and double the recommended dosages eliminated the population of collembolans completely except carbofuran (3 kg a.i./ha) where population declined by 83.65 per cent. The harmful effect on mite population were observed in phorate (6 kg/ha), carbofuran (3 & 6 kg/ha) and chlorpyriphos (800 g/ha) only. There are mixed reports in literature on the effect of carbofuran, chlorpyriphos and phorate on soil microarthropods. In field bioassay in U.K., chlorpyriphos has been found toxic to four species of Collembola *(Isotoma viridis, Isotomurus palustris, Folsomia candida* and *Sminthurus viridis)* (Wiles and Frampton, 1996). Application of phorate against jassid in cotton resulted in high toxicity to non-target microarthropods with Collembola being the most sensitive (Singh and Gupta, 1994). Ingham *et al.* (1994), however, observed no significant effect of carbofuran on microarthropods. Soil application of phorate @ 1 kg a.i./ha significantly reduced the populations of collembolans and mites upto 60 days after treatment. Soil application of carbofuran (Furadan) and aldicarb (Temik) resulted in reduction of cryptostigmatid mites within 5 weeks of application. Mesostigmatid mites, however, were not affected by either of these pesticides (Belal *et al.*, 1986). They further observed that aldicarb also reduced the number of prostigmatid mites throughout 5 weeks following application but neither aldicarb nor carbofuran altered the population density of any mite suborder within the later part of the 10 week period following treatment. The effect of agricultural chemicals on microarthropods have been ascertained by many workers (Cortet *et al.,* 2002; Rebecchi *et al.,* 2000; Martikainen *et al.,* 1998; Pramanik *et al.,* 1998; Parmelee *et al.,* 1997; Krogh, 1995; Sreenivasa and Bagyaraj, 1989; Chambon, 1982; Karg, 1978).

Attempts were made on *in vitro* rearing of collembolans and mites on different substrates so as to find out some simple, easily practicable method to obtain sufficient number of these organisms for various studies. Amongst the five substrates evaluated, only potato and okra were observed to be the suitable. Fungal growth was observed on the surface of these substrates. It is not clear currently whether these organisms (collembolans and mites) feed on the fungi growing on these substrates or on their nutrients and need further experimentation. There is no such information in the literature, however, there are reports of multiplication of microarthropods on fungi. Shew and Beute (1979) maintained cultures of mites of the genus *Caloglyphus* for several months on *Pythium aphanidermatum* growing on potato dextrose agar slants. Shiraishi *et al.* (2003) found doubling of the population of *Folsomia hidakana* (Collembola) in approximately 8.3 days while rearing the species in 'Koji' boiled rice on which *Aspergillus oryzae* flourished.

Two substrates i.e. wheat and paddy (collected from stores) were taken and were provided for the multiplication of both collembolans and mites at their natural C:N ratios and further two altered ratios. Collembolans multiplied more than 2.5 times, at the natural C:N ratio of 79.0:1 on wheat, whereas on paddy, the population of these organisms declined nearly by 2.5 times. No multiplication of collembolans could be observed in rest of the altered C:N ratios either on wheat or paddy. In case of mites, maximum multiplication (nearly three times of the initial number) was in wheat C:N ratio of 19.63:1. In case of paddy, though mites were recorded at all C:N ratios, population was even less than that of released number. Thus wheat was found to be more suitable substrate, though multiplication rate was not so good. It was interesting to note that in the treatments (irrespective of substrates), where collembolans were released, population of mites was also encountered at 60 days of their release. Since both wheat and paddy straw has been collected from their stores, the mites must be perpetuating on these substrates in the form of some dormant stage.

The above discussion reveals some of the preliminary information on microarthropods in agriculture. There is need to understand the importance of microarthropods in soil processes. For this, identification of different types of microarthropods is required. Finally, the interactions of microarthropods and other soil organisms must be explored.

Summary

Chapter VI

SUMMARY

The present investigations on, "Microarthropod fauna of cultivated soil" were undertaken during 2003-2004.

Microarthropods are widely distributed in the soils of Himachal Pradesh. In all, 22 localities of 6 districts of the state were surveyed. Mites (population ranging from 1 to 55/250 cc) were observed in 21 localities, whereas collembolans (population ranging from 1 to 65/250 cc of soil) were found in 13 localities. The occurrence of mites was more frequent than other microarthropods. The abundance of microarthropods was observed to be more in rhizosphere as compared to the soil of plant interspaces. The population of these organisms in rhizosphere and interspaces in different crops ranged from 6.00 to 30.17 and 1.67 to 26.67, respectively. Samples analysed from vermi-composting pit at different intervals revealed a population of 111.34 to 1260.67 microarthropods/250 cc material.

Vertical distribution of various microarthropods was studied at different soil depths, i.e. 0-15 cm, 15-30 cm and 30-45 cm at an interval of one month for one year. The mean populations (per m^2) of all types of microarthropods during different months of the year were found to be 10367.7, 3775.9 and 889.1 individuals at 0-15, 15-30 and 30-45 cm, respectively. Top 0-15 cm of soil inhabited 68.19 per cent population of microarthropods followed by 25.25 per cent at 15-30 cm and only 6.55 per cent at 30-45 cm.

Effect of insecticides (quinalphos 25 EC, chlorpyriphos 20 EC, phorate 10G, carbofuran 3G) was studied on the population of two dominant microarthropods, namely, collembolans and mites. The collembolans population declined ranging between 41.09 (quinalphos @ 400 g a.i./ha) and 100 per cent (phorate @ 6 kg a.i./ha and carbofuran @ 6 kg a.i./ha) when the population was assessed at 30 days of the application of insecticides. Near harvest of the crop, population of these organisms got reduced by 100 per cent in all the treatments except carbofuran @ 3 kg a.i./ha where decline to the tune of 83.65 per cent was observed. Treatments, namely, carbofuran (3 and 6 kg a.i./ha) and chlorpyriphos (800 g a.i./ha) revealed a decline of 0.001, 58.40 and 36.44 per cent in mite population, 30 days after insecticidal application and 6.58, 30.02 and 37.91 per cent near crop harvest. In case of phorate (6 kg/ha) treated plots, at 30 days though population increase was there, found to decline by 40.19 per cent near harvest.

Five substrates, namely, okra, potato tubers, kinnow peel, pumpkin and cabbage were evaluated for their suitability for the multiplication of collembolans and mites. Multiplication of these microarthropods was observed only on potato and okra.

The population multiplication of microarthropods on wheat and paddy straw at different C:N ratios was studied. On wheat, collembolans multiplied more than 2.5 times at the natural C:N ratio (79.0:1) whereas no population of these organisms could be recorded at the remaining two C:N ratios. However, mite population of 115.00, 146.33 and 146.67 was recorded at the C:N ratios of 79.0:1, 39.26:1 and 19.63:1, respectively. In paddy substrate, either low population (even less than that of released) or no population of Collembola/mite was be recorded at different C:N ratios. Therefore, wheat substrate was found to be comparatively better for microarthropods development as compared to paddy straw.

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