

**DEVELOPMENT OF CONSERVATION
PRACTICES FOR BELOW GROUND
BIODIVERSITY IN SOYBEAN ECOSYSTEM**

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**DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
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BANGALORE-560065**

2011

**DEVELOPMENT OF CONSERVATION
PRACTICES FOR BELOW GROUND
BIODIVERSITY IN SOYBEAN ECOSYSTEM**

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Thesis submitted to the

*University of Agricultural Sciences, Bangalore
in partial fulfillment of the requirements
for the award of the Degree of*

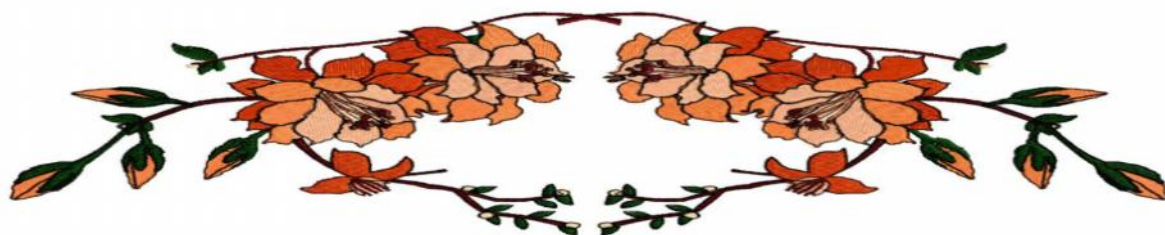
Master of Science (Agriculture)

IN

AGRICULTURAL ENTOMOLOGY

BANGALORE

JULY, 2011



AFFECTIONATELY DEDICATED

TO

MY BELOVED PARENTS

Smt. GURUMALLAMMA

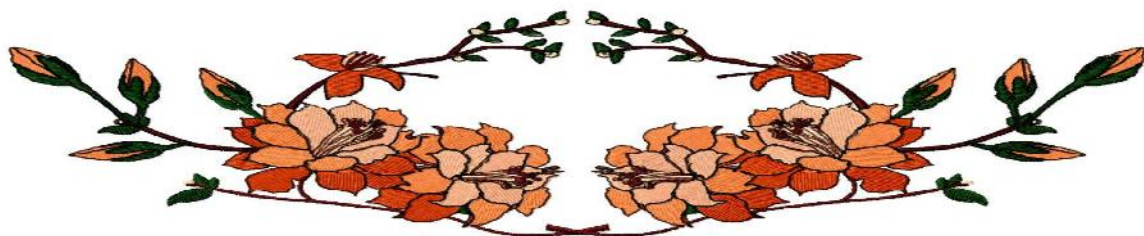
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Certificate

*This is to certify that the thesis entitled “**Development of conservation practices for below ground biodiversity in soybean ecosystem**” submitted by **Mr. VIRUPAKSHA, B. G., ID No. PAK 9106** for award of the degree of **MASTER OF SCIENCE (Agriculture)** in **AGRICULTURAL ENTOMOLOGY** of the University of Agricultural Sciences, Bangalore, is a record of bonafide research work carried out by him during the period of his study in this University, under my guidance and supervision, and that no part of the thesis has been submitted for the award of any degree, diploma, associate ship, fellowship or other similar titles.*

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(A. N. BALAKRISHNA)

ACKNOWLEDGEMENT

It is always a nostalgic feeling whenever one glances back to the days of hard work, tension and the need of the hour to excel. One would not achieve whatever he can, without the help, support, encouragement and the wishes of the near and dear ones. I owe them a lot and it is always a very difficult task expressing and putting into words the sense of gratitude I feel towards them. I wish to remember and acknowledge all who made this thesis possible.

*I am overwhelmed with heartfelt feelings of gratitude and profound indebtedness to the esteemed chairman of my Advisory Committee **Dr. N. G. Kumar**, Professor, Department of Agriculture Entomology, GKVK, Bangalore, for his abysmal guidance, constant fomenting, and punctilious and impeccable advice. Above all his affectionate way of dealing with the thing through the course of my investigation, helped me to consummate the research work,*

*I am very much grateful to my advisory committee members, **Dr. B. Mallik**, Dean (Agri.), College of Agriculture, GKVK, Bangalore, **Dr. C.T. Ashok Kumar**, Professor, Dept. of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bangalore, **Dr. C. A. Srinivasamurthy**, Professor and head, Dept. of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bangalore and **Dr. A. N. Balakrishna**, Professor, Department of Agricultural Microbiology, University of Agricultural Sciences, GKVK, Bangalore for their constant supervision, invaluable guidance and all the facilities extended during the course of this investigation.*

*I extend my sincere thanks to **Dr. A. K. Chakravarthy**, Professor and head, Department of Agricultural Entomology and other staff members of the Dept. of Agricultural Entomology for their help rendered in many ways.*

*It is an immense pleasure to express my sincere gratitude and heartfelt respect to **Dr. H. V. Nanjappa**, Dean (PGS), University of Agricultural Sciences, GKVK, Bangalore for his constant help in all aspects, criticism and helpful suggestions in carrying out this research work.*

*I remember fondly my parents **Smt. Gurumallamma, Sri. Guruswamy**, my lovely sister **Hema Mallesh** and all other family members for their love and affection, encouragement and all the support both morally and financially.*

*I wish to remember and never forget in my life the company of affectionate ever loving friends **Arun, Lohith, Ganesha², Nagraj, Mahendra, Lohith L.S., Sudhakar, Karthik** and my class mates **Chandra, Murali, Shashi, Subhash, Bhogeesh, Chethan, Akshay, Zeity, Loc, Shreedevi, Vinutha** whose hands were evident at each and every moment of tension, anxiety and achievements. I wish to express my heartfelt thanks to **Dr. Venkatesh Hosamani** for their enormous help and advice.*

*I am ever grateful to my senior friends **Byrappa, Veeranagappa, Naveen, Imran, Prashanth, Chandrashekaraiiah, Muthuraj, Nirmala, Anitha, Shivraj, Sudheer, Yashavanth, Shashank, Big B** and my junior friends **Prakash, Murali, Reddy, Prashanth, Vinayak, Vijay, Veeresh, BG, Rajshekar** for their love, support and encouragement.*

*My thanks equally to **Nagesh and Manu** for their immense help during my course of investigation.*

Finally I thank all those who are involved in helping me directly or indirectly to attain this stage.

Bangalore

July, 2011

(Virupaksha, B. G.)

DEVELOPMENT OF CONSERVATION PRACTICES FOR BELOW GROUND BIODIVERSITY IN SOYBEAN ECOSYSTEM

Virupaksha, B. G.

Abstract

The investigation on the development of conservation practices for below ground biodiversity in soybean ecosystem was carried out at the Zonal Agriculture Research Station, University of Agricultural Sciences, GKVK, Bangalore, during kharif season of 2010. Soil application of 20 tonnes of FYM/ha + introduction of native fauna recorded significantly higher soil invertebrates, soil total Acari, cryptostigmatids, other Acari and other invertebrates compared to other treatments during the cropping season. The highest population of total soil invertebrates was noticed 90 days after germination. The plots treated with FYM or FYM + fertilizer recorded significantly higher abundance of soil invertebrates compared to fertilizer alone treated plot during non-cropping season. The plot treated with 12.5t of FYM + 75% recommended fertilizer and 20t of FYM supported higher soil nematodes population. Application of 20t of FYM ha⁻¹ significantly increased the soil organic carbon content, available phosphorous, available potassium, exchangeable calcium, exchangeable magnesium and microbial biomass carbon in the soil compared to recommended fertilizer alone applied treatment. Higher production of leaf biomass and root biomass was observed in plots treated with 20 t of FYM followed by FYM + fertilizer compared to fertilizer alone applied plot. The soil invertebrates exhibited a significant positive relation with available phosphorus, available potassium, exchangeable calcium, exchangeable magnesium and microbial biomass C. Significant negative relationship existed between the abundance of soil invertebrates and maximum temperature of the atmosphere and soil temperature. Soil application of 20 t of FYM recorded higher grain yield compared to chemical fertilizers alone and package of practices followed treatments.

July, 2011
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(Major adviser)

**ಸೋಯಾ ಅವರೆಯ ಬೆಳೆ ಪದ್ಧತಿಯಲ್ಲಿ ಮಣ್ಣಿನ ಜೈವಿಕ ವೈವಿಧ್ಯತೆಯ
ಸಂರಕ್ಷಣಾ ಅಭ್ಯಾಸಗಳ ಅಭಿವೃದ್ಧಿ ಕ್ರಮಗಳು**

ವಿರುಪಾಕ್ಷ ಬಿ. ಜಿ
ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಸೋಯಾ ಅವರೆಯ ಬೆಳೆ ಪದ್ಧತಿಯಲ್ಲಿ ವಿವಿಧ ಮಣ್ಣಿನ ಜೀವವೈವಿಧ್ಯ ಸಂರಕ್ಷಣಾ ಪದ್ಧತಿಗಳ ಅಭಿವೃದ್ಧಿ ಬಗ್ಗೆ ವಲಯ ಕೃಷಿ ಸಂಶೋಧನಾ ಕೇಂದ್ರ ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಜಿ.ಕೆ.ವಿ.ಕೆ. ಬೆಂಗಳೂರು ೨೦೦೦ರ ಮುಂಗಾರಿನಲ್ಲಿ ಪರೀಕ್ಷಿಸಲಾಗಿದೆ. ಈ ಅಧ್ಯಯನದ ಪ್ರಕಾರ ಬೆಳೆ ಅವಧಿಯಲ್ಲಿ ಕೃಷಿ ಭೂಮಿಗೆ ೨೦ ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರವನ್ನು ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ ಮತ್ತು ಸ್ಥಳೀಯ ಮಣ್ಣು ಜೀವಿಗಳನ್ನು ಬಳಸಿಕೊಂಡಾಗ ಒಟ್ಟು ಸಂಧಿಪದಿಗಳ ಸಂಖ್ಯೆ ಹೆಚ್ಚಿ, ಗಣನೀಯವಾಗಿ ನುಸಿ, ಇತರೆ ನುಸಿ, ಕ್ರಿಪ್ಟೋಸ್ಪಿಗ್ಮಾಟಿಡ್ಸ್ ಮತ್ತು ಇತರೆ ಸಂಧಿಪದಿಗಳ ಸಂಖ್ಯೆಯು ಉಳಿದ ಉಪಚಾರಗಳಿಗೆ ಹೋಲಿಸಿದಾಗ ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯಲ್ಲಿ ಕಂಡು ಬಂದವು. ಅಧಿಕ ಸಂಧಿಪದಿಗಳ ಸಂಖ್ಯೆಯನ್ನು ೯೦ ದಿನಗಳ ಬೆಳೆ ಹಂತದಲ್ಲಿ ಗಮನಿಸಲಾಯಿತು. ಬೆಳೆ ಇಲ್ಲದ ಅವಧಿಯಲ್ಲಿಯೂ ಸಹ ಮಣ್ಣಿನ ಸಂಧಿಪದಿಗಳ ಸಂಖ್ಯೆಯು ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ ಅಥವಾ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ + ರಾಸಾಯನಿಕ ಗೊಬ್ಬರ ಉಪಚರಿಸಿದ ತಾಕುಗಳಲ್ಲಿ ಉಳಿದೆಲ್ಲಾ ಉಪಚಾರಗಳಿಗಿಂತ ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯಲ್ಲಿ ಕಂಡು ಬಂದಿತು. ಹೆಕ್ಟೇರಿಗೆ ೧೨.೫ ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ + ಶೇಕಡ ೭೫% ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಾಸಾಯನಿಕ ಗೊಬ್ಬರ ಮತ್ತು ೨೦ ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರವನ್ನು ಉಪಚರಿಸಿದ ತಾಕುಗಳಲ್ಲಿ ಮಣ್ಣಿನ ನೆಮಟೋಡ್‌ಗಳು ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯಲ್ಲಿ ಕಂಡು ಬಂದವು. ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ ಬಳಸುವುದರಿಂದ ಮಣ್ಣಿನ ಪೋಷಕಾಂಶಗಳ ಸ್ಥಿರತೆಯನ್ನು ಹೆಚ್ಚಿಸಿದೆ. ಹೆಕ್ಟೇರಿಗೆ ೨೦ ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರವನ್ನು ಬಳಸುವುದರಿಂದ ಸಾವಯವ ಇಂಗಾಲ, ಲಭ್ಯವಾಗುವ ರಂಜಕ, ಪೊಟ್ಯಾಷ್, ಕ್ಯಾಲ್ಸಿಯಂ, ಮೆಗ್ನೀಷಿಯಂ ಮತ್ತು ಸೂಕ್ಷ್ಮ ಜೀವಿಯ ಜೀವರಾಶಿ ಇಂಗಾಲದ ಸಂಖ್ಯೆಯು ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ ಮಾತ್ರ ಉಪಚಾರಕ್ಕೆ ಹೋಲಿಸಿದರೆ ಹೆಚ್ಚಾಯಿತು. ಎಲೆಗಳ ಜೀವರಾಶಿ ಮತ್ತು ಮೂಲ ಜೀವರಾಶಿಯ ಉತ್ಪಾದನೆ ರಸಗೊಬ್ಬರ ಅನ್ವಯಿಕ ಚಿಕಿತ್ಸೆಗೆ ಹೋಲಿಸಿದರೆ ೨೦ ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ ನಂತರ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ + ರಾಸಾಯನಿಕ ಗೊಬ್ಬರವನ್ನು ಉಪಚರಿಸಿದ ತಾಕುಗಳಲ್ಲಿ ಹೆಚ್ಚಾಗಿ ಕಂಡುಬಂದಿತು. ಮಣ್ಣಿನ ಸಂಧಿಪದಿಗಳು ಲಭ್ಯವಾಗುವ ರಂಜಕ, ಪೊಟ್ಯಾಷ್, ಕ್ಯಾಲ್ಸಿಯಂ, ಮೆಗ್ನೀಷಿಯಂ ಮತ್ತು ಸೂಕ್ಷ್ಮ ಜೀವಿಯ ಜೀವರಾಶಿಯ ನಡುವೆ ಧನಾತ್ಮಕ ಸಂಬಂಧ ಹೊಂದಿದೆ, ಹಾಗೆಯೇ ಮಣ್ಣಿನ ಸಂಧಿಪದಿಗಳ ಸಂಖ್ಯೆ ವಾತಾವರಣದ ಗರಿಷ್ಠ ಉಷ್ಣಾಂಶ ಮತ್ತು ಮಣ್ಣಿನ ಉಷ್ಣಾಂಶ ನಡುವೆ ಋಣಾತ್ಮಕ ಸಂಬಂಧವಿತ್ತು. ಮಣ್ಣಿಗೆ ೨೦ ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರವನ್ನು ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ ಬಳಸುವುದರಿಂದ ಧಾನ್ಯದ ಇಳುವರಿಯು ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಾಸಾಯನಿಕ ಗೊಬ್ಬರ ಮತ್ತು ಸುಧಾರಿತ ಬೇಸಾಯ ಕ್ರಮಗಳನ್ನು ಅನುಸರಿಸಿದ ಉಪಚಾರಗಳಿಗೆ ಹೋಲಿಸಿದಲ್ಲಿ ಹೆಚ್ಚಿಗೆ ದಾಖಲಾಗಿದೆ.

ಕೃಷಿ ಕೀಟಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾಲಯ ಜಿ. ಕೆ. ವಿ. ಕೆ
ಬೆಂಗಳೂರು

ಡಾ|| ಎನ್. ಜಿ . ಕುಮಾರ
ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

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Introduction

I. INTRODUCTION

Historically, most of the efforts on biodiversity studies focused, especially on aboveground plant and animal species (Wardle, 2006). However, it is well recognized that in most terrestrial ecosystems, the belowground biota supports much greater diversity of organisms than does the aboveground biota, because soils are the central organizing entities in terrestrial ecosystems (Coleman and Whitman, 2005).

No component of ecosystems is potentially more important, both ecologically and economically than soils and their associated biodiversity (Giller *et al.*, 1997). History of soil fauna dates back to pre-historic period. Surprisingly, the study of belowground biological communities and their influence on ecosystem properties is a relatively new field of ecology. During the past 20 years, the importance of soil fauna in the functioning of soils has been recognized and continuously growing as an extension of terrestrial ecosystem (Decaens *et al.*, 2006). It is only during the past few decades that ecologists have begun to explore belowground communities and their functional significance for plant communities and plant ecosystem processes (Bardgett *et al.*, 2005a, b).

Soil organisms are essential components of agro ecosystems, making vital contributions to soil functions and soil processes. Without soil organisms, the soil would be a sterile medium that could not sustain crop production. Soil biota provides essential benefits for the functioning of agro ecosystems which are important for the long-term sustainability of agriculture. They support essential soil processes and play a key role in maintaining the soil quality that is necessary for crop productivity. Soil organisms help to create and maintain beneficial soil structure and decomposing crop residues so that valuable nutrients are released for

plant growth and contribute to soil carbon storage by mixing organic materials with mineral soil.

There are also many other reasons for measuring/monitoring soil biodiversity in agricultural land. Soil organisms are critical in determining the functioning of agro-ecosystems (Rossi *et al.*, 2006). It has long been known that soil organisms are integral to soil fertility and soil fauna play a multiple role in soil ecosystems *viz.*, decomposition, nutrient recycling and water infiltration (Hole, 1981).

Soil invertebrates are important components of a wide range of soil ecosystems. This diverse group of animals covers a range of taxa, the most important being protozoans, nematodes, oligochaete worms (earthworms and enchytraeids), mites, Collembola, millipedes, centipedes, and a range of insects whose larval stages complete their development in the soil (Wallwork, 1976). Soil invertebrates have important functions in soil, which influence the growth conditions of plants. Soil micro- and mesofauna (protozoans, nematodes, micro arthropods and enchytraeids) are grazers of bacteria and fungi, and are thought to stimulate microbial decomposition of dead organic matter, even though they may reduce the standing crop of microbial biomass (Ineson *et al.*, 1982; Seastedt, 1984; Didden, 1993). A number of examples show that soil animals can increase nitrogen mineralisation by 25.50% (Persson, 1983). Moreover, the soil meso- and micro fauna has an increased influence on decomposition processes. Soil micro arthropods are also important components of food webs.

Mesofauna comprising of enchytraeids, Collembola and mites plays a functional role for decomposition processes in the soil (Coleman and Crossley, 1996). Enchytraeids ingest microbes and labile organic matter and can affect soil structure through their burrowing activity and excrement production (Didden, 1993). In contrast, soil dwelling micro

arthropods have no burrowing activities, ingestion and assimilation of litter material plays a secondary role for most species (Schneider *et al.*, 2004). Micro arthropods instead fulfil primarily two functions in the soil food web: the first, as secondary decomposers that feed predominantly on fungi and in part litter, and the second, as strict carnivores or omnivores feeding on mixed fungal-carnivore diets.

Ingestion of the various food sources releases plant available N. Quantitatively, the release of N by the mesofauna has been found to be modest in comparison to the release of N by microbes and protozoa in particular (De Ruiter *et al.*, 1993). Direct quantitative measurements can improve the understanding of the role and function of these animals for N mineralization. It has been documented that Collembolan and earthworms excrete N in ammonia form (Sjursen and Holmstrup, 2004).

External agricultural inputs such as mineral fertilizers, organic amendments, microbial inoculants and pesticides are applied with the ultimate goal of maximizing productivity and economic returns, while side effects on soil organisms are often neglected. Agricultural inputs affect the amounts, activity and diversity of soil organisms. Mineral fertilizers have limited direct effects, but their application can enhance soil biological activity via increases in system productivity, crop residue return, and soil organic matter. Another important indirect effect especially of N fertilization is soil acidification, with considerable negative effects on soil organisms. Organic amendments such as manure, compost, bio-solids and humic substances provide a direct source of C for soil organisms as well as an indirect C source via increased plant growth and plant residue returns. Non-target effects of microbial inoculants appear to be small and transient. Among the pesticides, few significant effects of herbicides on soil organisms have been documented, whereas negative effects of insecticides and fungicides are more common.

Manures have been used for over millennia and inorganic fertilizers for century with great benefit in increased plant growth and better crop quality. At the same time, they also modify the physico-chemical properties of soils which, ultimately influence or affect the qualitative and quantitative composition of below ground arthropods. Therefore, the fertilizers and manures change the interrelationship among the organisms so that some species are favoured whereas others are affected adversely.

There is currently world-wide concern regarding the impact of modern farming practices on soil biological fertility due to loss of below ground biodiversity and water quality. Alternative management systems, such as organic and biodynamic farming, are being promoted on the basis that they are more environmentally benign and specifically enhance soil and water quality relative to conventional practices. Organic farming often increases diversity of soil organisms and soil fertility. Organic farming typically adds large amounts of organic matter and soil amendments, which, in turn, increases the biological activity in soil.

With this background, the present investigations were taken to enhance and reestablishment of the below ground biodiversity in already degraded agro ecosystem with the following objectives.

1. To study the impact of organic manures and chemical fertilizers on the abundance and diversity of soil arthropods.
2. To establish the relationship among soil arthropods, soil microbial biomass and soil fertility.
3. To establish the impact of abiotic factors on soil arthropods, soil microbial biomass and soil fertility.

Review of Literature

II. REVIEW OF LITERATURE

The literature on development of conservation practices for below ground biodiversity are presented in this chapter.

2.1 Population dynamics, distribution, abundance and diversity of soil fauna:

Gupta and Mukharji (1976) identified 35 genera and 37 species of Acari, 22 genera of Collembola and 16 genera of other soil arthropods. Among the Acari, Mesostigmata was represented by 13 genera and 13 species in cultivated and uncultivated soils. Cryptostigmata consisted of 13 genera and 15 species. The most abundant and widespread genera being *Epilohamannia* and *Scheloribates*, which inhabited mainly the upper layer of soil. Eight genera and eight species were recorded from Prostigmata, in which *Coccotydeus* and *Tydeus* were more common. The Astigmata was represented by genus *Tyrophagus*. Out of 22 genera of Collembola recorded, *Folsomia*, *Folsomides*, *Isotomides* and *Onychiurus* were predominant. Other soil arthropod genera included Diplura, Pauropoda, Symphyla, Palpigradi, Uropygi, Schizomida and Pseudoscorpionida.

Population fluctuation of Cryptostigmata and Collembola in a wasteland showed two peaks, a pronounced peak during post-monsoon period (September-October) and a less pronounced one during pre-monsoon period (May-June) (Bhattacharya and Raychaudhuri, 1979). Out of 30 species of cryptostigmatid mites collected from banana plantations, only 3 species viz., *Scheloribates albialatus*, *Oppia nodosa* and *Pilobatella berlesei* were dominant with a relative abundance of > 5 per cent. They showed a pronounced peak during post-monsoon period (October) and less pronounced peak during pre-monsoon (May or June) depending upon the onset of rains (Joy and Bhattacharya, 1981a).

Mahajan and Singh (1981) recorded higher Collembolan populations during monsoon months (July-September) when soil moisture was high and soil temperature was low. Further, declining trend was observed during summer months (April-May) with high soil temperature and low moisture content in arable fields where *Sorghum vulgare* and *Trifolium alexandrinum* were alternatively raised as fodder crops.

Singh and Pillai (1981) collected 71,513 micro-arthropods from 4 different fields for a period of 24 months. The ratio of Acari and Collembola in different fields viz., banana, citrus, fodder and fallow were 1.08: 1, 7.04: 1, 4.05: 1 and 3.52: 1, respectively. Acari and Collembola together constituted 77.88 to 88.04 per cent of total fauna in different habitats. Among Acari prostigmatid mites were most numerous in all fields followed by Cryptostigmata and Mesostigmata. Astigmata was very poor in distribution in all habitats.

The qualitative and quantitative composition of oribatid mites showed an irregular fluctuation. They were found to be higher in July-August, lower in May and more or less constant in December-January (Banerjee, 1982). Comparison of potato crop with winter wheat crop showed a significant increase in relative abundance of gamasid mites in the upper most soil layer (0-5 cm) and a corresponding decrease in 10-20 cm layer. The 5-10 cm layer didn't show much overall change. Maximum population was found immediately after the potato harvest. *Alliphis halleri* was much more abundant in potato than in winter wheat plots (Buhlmann, 1982).

Hazra (1982) collected 14 arthropod groups from Silent valley, Kerala. Acari were encountered in maximum number (35.31 %). Among the Collembolans *Idiomerus pallidus* formed the dominant group.

Maximum abundance of soil fauna was obtained from core area of the valley where the organic carbon and relative humidity was high.

Guru *et al.* (1988) reported six and five species of Collembola from cultivated and uncultivated sites, respectively. *Cryptopygus thermophilus* was the dominant species in both the sites. The population density of Collembola marked a significant decrease from uppermost to deeper layers. Two distinct population peaks were observed in both the sites in the months of November and February in crop field sites and October and February in the uncultivated site. The lowest density was marked during May in both the sites and there was no significant difference in the mean population of Collembola in two sites.

Soil samples taken from cultivated field revealed that the population was maximum in the spring season when moisture content and organic carbon was at optimum level in the soil and meager population was observed in summer season when the concentration of these factors was very low and soil temperature was high (Rather, 1988).

The population density of soil arthropods ranged from 17 to 23,253 / m² in cereal fields. Acari and Collembola comprised 52 and 55 per cent of the arthropods in the two habitats, respectively. Together, these two taxa made up 82.6 % in cereal fields (Vats and Narula, 1990a). The average population density of soil collembolans was 1082 / m² in a cereal field. Eight species representing 5 families were recorded in both soils. Hypogasturidae were dominant in forest and Entomobryidae in cereals (Vats and Narula, 1990b).

A comparison of the number of species of micro-arthropods obtained from cultivated and control (grassland) plots showed that the species diversity was less in cultivated plots. The nature of fluctuations of population of micro-arthropods suggests that each separate group

occurred almost simultaneously in the months when the edaphic factors were favourable (Sengupta and Sanyal, 1991).

Shweta and Gupta (1992) observed quantitative and qualitative variations of some Apterygota (Collembola, Diplura and Protura) inhabiting different types of soil. More than one of the abiotic factors (temperature, moisture, bicarbonate and nitrogen) appeared to control the qualitative abundance of the organisms. Banasco (1993) determined the number, consumption and distribution of Collembola in various Cuban soil types. The number ranged from 5.5 to 21.9 thousand per m² to a depth of 10 cm. Population density was 2.3 times higher in the rainy season than in the dry season and tended to be greater in the surface layers.

Soil samples from fields containing field crops, vegetable crops, ornamental plants, fruit trees and forest plantations showed that cryptostigmatid mites were the most frequent and abundant followed by mesostigmatids, prostigmatids and astigmatids. The relative densities of cryptostigmatids and mesostigmatids were almost similar in annual and perennial crops. Soil mites occurred most frequently in the upper 0-5cm. In terms of abundance, Prostigmata were more in the upper layer and Mesostigmata in the deeper layer (Walia and Mathur, 1994).

Narula *et al.*, (1995) collected 1999 individuals belonging to 59 species from cropland. Of all the groups, Acari were most dominant constituting 52.02% of total arthropods. Acari and Collembola together make up 82.63% of the total population. The population density ranged from 170 - 23,253/ m².

The garden soil had more population of non-insect fauna (234) namely mites, spiders, pseudoscorpions, millipedes, centipedes and earthworms in black soil (139) and red soil (83) (Hiremath, 1996a).

Regarding vertical distribution of mite, pseudoscorpions and centipedes were abundant in top soil (0-10 cm) whereas millipedes and earthworms were abundant only in lower layer (20-30 cm). The vertical distribution of these organisms has relation with feeding habit and moisture content of soil (Hiremath, 1996b).

Sanyal (1996) studied the composition and seasonal abundance of soil inhabiting arthropods of soil in banana and guava plantation. A total of 2235 arthropods belonging to 13 groups were extracted. Acari were most abundant followed by Collembola and Hymenoptera. The fauna of the banana ecosystem was rich compared to guava ecosystem. The arthropod population peaked in August at both the ecosystems.

The total soil arthropod population varied from a minimum of 2149 to 4417/m² in agricultural farm, 1328 to 5017/m² in crop field and 1485/m² in uncultivated field. Regarding the percentage composition of various arthropods, Acari have been most frequently occurring group in all the 3 fields followed by Collembola. The Coleoptera constituted 3-13% of the total arthropod fauna. One hundred and sixty six species of pterygotes have been recorded from uncultivated field, while 9 species were found in crop field. From agricultural fields, only 8 species of pterygotes were collected. Insect larvae mainly of Lepidoptera, Hymenoptera, Diptera and Coleoptera were observed (Shukla *et al.*, 1996).

A preliminary study of soil macro fauna bio-diversity in a set of ecosystems, from natural reserves to managed agro-ecosystems provides indications that species number, population density and biomass decrease from natural ecosystems to agro-ecosystems. The main reason for the decrease appears to be a lack of available organic matter and essential element supply in the agro-ecosystem soil. Maintaining biodiversity for a sustainable agriculture is connected with maintaining

available organic matter and essential nutrient sources in the soil (Pokarzhevskii and Krivolutskii, 1997).

The conservation practices (enriched with organic manures) helped to establish significantly higher soil invertebrate abundance (7.60) compared to recommended (no manures) method (4.87). Collembola were found to be relatively more abundant (44.9%) in conservation method where as acari, other minor insect and non-insect fauna were predominant in recommended practices. (Srinivas Reddy *et al.*, 1999).

Application of organic manures or its combination with mineral fertilizer induces higher density of collembola than manured or unmanured soil. The treatments with different doses of organic manures increased the population of collembola compared to treatments with fertilizer alone. The population was higher during September and the density reduced during dry period. (Bandyopadhyaya, 2002).

A ten-year-old field experiment with potato and spring cereals in crop rotation under different fertilization were the main sampling area. The average quantity of Collembola varied within the range of 700-14300 and 0-600 individuals/m² for the edaphic and hemi-edaphic group, respectively. Application of organic manures and mineral nitrogen induced an increase in collembolan population but the difference between treatments remained insignificant. The abundance of Collembola under spring barely in September was several times higher than under potato (Kanal, 2004).

Soil animal communities in the five plant communities at different succession stages were investigated. A total of 13,381 individuals falling into 2 phyla, 8 classes and 20 orders were collected. The dominant groups were Acarina and Collembola, accounting for 94.24% of the total

individuals, with the number of Acarina individuals 7.66 times than that of Collembola (Lan *et al.*, 2006).

The composition and temporal changes of edaphic micro arthropods in both litter layer and soil were analyzed in a tropical dry forest ecosystem in Western Mexico. The total abundance of arthropods was 96,338 specimens, belonging to 33 taxa. Numerically dominant groups were Prostigmata, Cryptostigmata, Collembola and Mesostigmata, which constituted 92.6% of the total abundance (Palacios *et al.*, 2007).

The results of the effects of land reclamation and afforestation on soil arthropods in Iceland indicated that the reclamation changed soil animal group composition and significantly increased the density of soil arthropods. Soil arthropod density was significantly higher in birch and lupin reclamations than in grass reclamation. Soil arthropod density was found to be positively correlated with vascular plant species cover, the percentage of organic carbon, nitrogen, phosphorus and potassium, but negatively correlated with pH (Oddsdottir *et al.*, 2008).

Zhu-Xinyu *et al.* (2008) studied the structure and seasonal change of soil arthropod communities in the forest-steppe ecotone in northern Hebei, China. The group numbers and DG indices of the soil arthropod communities in autumn were the highest, while those in summer were lower and in spring were the lowest. At the same time, the seasonal changes of soil arthropod communities in different areas were affected by habitat conditions.

Shen-Yan *et al.* (2009) observed the difference in the soil faunal community structure between tea plantation and artificial plantation. The number of groups in the tea plantation was lower than that in artificial plantation. Most of the groups, individual numbers and the diversity indices were concentrated in the topsoil and decreased with the

increase of soil depth under the litter layer both in the tea plantation and the artificial plantation.

Lee-Ya-Fu *et al.* (2009) collected 7 classes and at least 17 orders of arthropods, with an estimated mean density of 13,982 individuals/m². The Collembola and Acari were the most common groups. The former dominated in abundance, comprising 8 families followed by the Acari (e.g., oribatids) with at least 37 families. The density and number of taxa of arthropod were highest in soil samples from vegetated areas. Soil samples beneath litter traps were in between, whereas the lowest taxon numbers and densities consistently occurred in soils from bare trails.

2.2 Effect of agrochemicals on the soil fauna and insect pests of soybean:

2.2.1 Soil application:

2.2.1.1 Effect of soil application of insecticides on soil fauna:

Before the application of chlorpyrifos most of the organisms (approximately 75%) were present in upper soil strata (0 - 5 cm). Chlorpyrifos applications changed the vertical distribution of soil micro-arthropods even after a 3-month period. Collembola and Acari were more sensitive to the pesticide than other insects. High concentrations of chlorpyrifos had much more severe effects on the micro fauna than low applications (Tadros and Carey, 1982).

In Kentucky blue grass turf, chlorpyrifos and isofenphos had the greatest impact on predacious arthropods with some taxa significantly reduced for at least 6 weeks. Effects of bendiocarb and trichlorfon were generally less severe and more temporary. Oribatid mite populations were apparently unaffected by the insecticides. Bendiocarb increased trap catches of ants for up to 2 weeks after application (Cockfield and Potter, 1983).

Kumar and Agarwal (1983) reported that aldicarb, carbofuran, disulfoton and phorate at 1.0 kg a.i. / ha were toxic to Collembola and other arthropods than mites. Disulfoton and phorate were found to be more toxic to Collembola and other arthropods than aldicarb and carbofuran. The mite population increased in disulfoton and phorate treated plots earlier than aldicarb and carbofuran because the former two insecticides were more toxic to predacious mites.

There was significant reduction in soil mite and Collembola population up to 8 weeks after application of soil insecticides *viz.* aldicarb and phorate (0.5 and 1.0 kg a.i. / ha) in cotton. Maximum decrease (64.8 %) in mite population was recorded on 18th day in plots treated with aldicarb (1.0 kg a.i. / ha). The maximum decrease (54.9 %) in mite population was noted in phorate treated plots at both the dosages. Significant reduction in the soil mite population was observed up to 60 and 53 days after the application of higher and lower dosages of soil insecticides, respectively. The mite population started building up from 60th day. Collembolans were most sensitive to soil insecticides and once its population dwindled, it never build-up again during the cropping season. Higher doses of both the soil insecticides had longer adverse effect on its population. Phorate at both the dosages proved to be more toxic to Collembola than aldicarb. Foliar application of dimethoate (0.02% or 0.04%) had no impact on non-target soil organisms (Sarathbabu and Gupta, 1986; Gupta, 1989 and 1996).

Studies of Khalil and Tadros (1988) revealed that higher concentrations of carbofuran (20 ml / 5 gal.) and Oxamyl (40 ml / 5 gal.) were very destructive to soil fauna of vegetable field (egg plant, pepper, tomato and water melon). The effect of isofenphos (oftanol) on non-target invertebrates in turf grass was determined by comparing population dynamics of 8 taxa sampled from treated versus untreated halves of

home lawns. Population of predacious Acari, Collembola, Diplura, Diplopoda and Staphylinidae were reduced in treated areas. Higher populations of Oribatida were found in treated areas. The time required for recovery ranged from several weeks to 8-10 months depending on the taxa, edaphic factors and predacious groups (Vavrek and Niemczyk, 1990).

According to Filser (1990), laboratory treated soil with endosulfan at field doses had distinct negative effects on the abundance and biomass of Collembola, especially in the adult stage. Eight newer granular insecticides including controlled release formulations applied to the soil at sowing for the control of groundnut leaf miner showed significant affect on non-target soil fauna that included mainly mites and Collembolans. Among these, chlorpyriphos 10G (4.0 kg a.i. / ha) were more toxic and reduced maximum soil fauna. The average per cent reduction of the soil fauna was highest in chlorpyriphos 10G (4.0 kg a.i. / ha) and lowest in isofenphos 5G (2.0 kg a.i. / ha) (Rajagopal *et al.*, 1990).

The soil micro-arthropod fauna consisting of Acari and Collembola was disturbed following a single application of isofenphos at 5 kg a.i. / ha. It greatly reduced numbers of all species. The least sensitive were euedaphic and epedaphic Collembola and Acari. Greatest pesticide effects were observed in sandy soils (Krogh, 1991).

An initial, single aldicarb application affected all soil mesofauna groups quantitatively and qualitatively. After one year, some populations did not recover from the intoxicification. For both mites and Collembola (arthropleona species) a negative effect of aldicarb was obvious (Koehler, 1991).

Field studies were conducted by Stark (1992) to determine the abundance of several groups of invertebrates inhabiting a turf grass system following the application of Margosan-O (MO) containing azadirachtin at 3.0 g / l a.i. and chlorpyrifos. MO was less detrimental than chlorpyrifos to most of the invertebrate's species. However, Oribatid mites were more sensitive to MO than chlorpyrifos. Sminthurid and non-sminthurid Collembola were also susceptible to MO, although less so than to chlorpyrifos.

Study conducted by Singh and Gupta (1993) revealed that insecticidal schedules in which soil insecticide phorate was applied during early stage of cotton crop growth against target pest also affected the population of soil arthropods adversely. The toxicity of phorate was at its peak on third day after its application in soil. Collembola was the most sensitive and once its population went down, it never exceeded over control even up to 5 months after its application. Its toxicity persisted up to 57-59 days against soil mites and thereafter it was lost.

The influence of chlorpyrifos application on the beneficial arthropods was assessed by Braman and Pandley (1993). Non-sminthurid Collembolans, ants, spiders and parasitic hymenoptera were adversely affected in the short term. Other taxa, notably oribatid Acari increased over time in response to insecticide application.

Field bioassays conducted by Wiles and Frampton (1996) indicated that Cypermethrin and pirimicarb residues were of low toxicity, causing less than 10% mortality, whereas residues of chlorpyrifos were toxic to all 4 species of Collembola on both soil types and in both exposed treatments. Interspecific differences in Collembolan susceptibility to chlorpyrifos residues gave the ranking. *Sminthurus viridis* > *Folsomia candida* > *Isotomurus palustris* > *I. Viridis*. Residues on the sandy soil were more toxic than those on the sandy clay loam.

Collembolan and mite population was not reduced by HCH treatment in banana ecosystem. Significant reduction was observed for 2 months after the first and second application of carbofuran and phorate. Adverse effect was then lost and the population was maintained on par with control till harvest (Alice *et al.*, 1999).

The result of the study conducted to assess the side-effects of chlorpyrifos on springtails, ants and oribatid mites associated with the soil surface of no-tillage cornfields indicated that principal components analysis detected no negative effect of insecticide chlorpyrifos on the assemblage of soil arthropods. Nonetheless, the activity of the ant *Solenopsis saevissima* (Fr. Smith) was lower 2 weeks after spraying but recovered afterwards, while the frequency of *Ectatomma brunneum* Fr. Smith, was significantly reduced only at the third week after spraying, and did not show any recovery until the end of the study. Chlorpyrifos did not decrease the overall abundance of Collembola. However, it had a significant impact on the members of the order Symphypleona, there being significantly lower captures of Sminthurides spp. There was no effect on oribatid mites (Michereff *et. al.*, 2004).

The broad-spectrum insecticides chlorpyrifos and cypermethrin and the selective insecticide pirimicarb were investigated in winter wheat fields in summer. Effects of chlorpyrifos on arthropod abundance and taxonomic richness were consistently negative whereas effects of cypermethrin were negative for predatory arthropods but positive for soil surface Collembola. Pirimicarb effects were marginal, primarily on aphids and their antagonists, with no effect on the Collembola community. Collembola-predator ratios were significantly higher following cypermethrin treatment, suggesting that cypermethrin-induced increases in collembolan abundance represent a classical resurgence. Observations in other studies suggest Collembola resurgences may be typical after

synthetic pyrethroid applications. Collembola responses to insecticides differed among species. Direct and indirect insecticide effects differ among closely-related arthropod taxa; resurgence of Collembola may occur widely after synthetic pyrethroid insecticide applications (Frampton and Brink, 2007).

Frampton (2002) reported from a 6-year study that the effects of two contrasting regimes of pesticide use on pitfall and suction catches of Collembola were monitored in an arable field under a rotation of grass and winter wheat. Current farm practice (CFP) represented conventional fungicide and herbicide use plus applications of organophosphorus (OP) insecticides, whereas reduced input approach (RIA) utilized minimum inputs of fungicides and herbicides and excluded any use of insecticides. Compared with RIA, the CFP regime caused a substantial decline in the abundance and diversity of Collembola in the field.

Chaudhary *et al.* (1981) reported that the application of mephosfolan 10G at 0.75 a.i./ha and aldicarb 10G, phorate 10G and carbofuran 3G at 1.0 Kg a.i./ha in furrows at the time of sowing were most effective against *M. sojae*.

According to Gain and Kundu (1988), phorate 10G, monocrotophos and quinalphos were effective against soybean stemfly. The highest yield of 19.09 q/ha was obtained by applying phorate @ 2.0 kg a.i./ha at sowing supplemented with two foliar sprays of monocrotophos at the rate of 0.05% at 15 and 31 days after sowing.

Singh and Singh (1989) observed that phorate @ 1.0 and 1.5 kg a.i./ha were found to be highly effective in reducing the stemfly and girdle beetle infestation when applied after 25 days of sowing.

Application of phorate 10G and carbofuran 3G at 1.5 kg a.i./ha, each have been found effective against the girdle beetle (*Obereopsis brevis*) and stem flies (*O. phaseoli* and *M. sojae*) (Singh and Singh, 1990).

Furrow application of phorate 10G at the rate of 15 kg/ha before sowing followed by one spray of monocrotophos (0.04%) on 20 days after germination or phorate 10G at sowing reduced the stem tunneling by stemfly and gave higher yield compared to untreated control (Kundu and Srivastava, 1991).

According to Kundu and Trimohan (1992) the soil application of phorate 10G at the rate of 1g/m + 3 sprays of endosulfan (0.07%) to soybean was the most effective treatment in reducing stem tunneling by *M. sojae* (37.67%) compared to the untreated control.

Soil application of isofenphos 5G (2 kg a.i. ha⁻¹), carbofuran 10G (4 kg a.i. ha⁻¹) and phorate 10G (4 kg a.i. ha⁻¹) at the time of sowing were significantly more effective in suppressing the groundnut leafminer, *A. modicella* infestation (Rajagopal and Gowda, 1992).

Significant reduction in stemfly infestation and nematode population was observed in phorate, quinalphos and mephosfolan applied plots. Further increase in the grain yield in the insecticidal treated plots was noticed compared to untreated plots (Kundu and Mishra, 1993).

According to Rajput *et al.* (1996), the soil application of phorate 10G @ 1.0 and 1.5 kg a.i. ha⁻¹ at 25 DAS gave a good control of stem fly up to 95 DAS. Pod damage by larvae of green semi-looper was lowest in plots treated with phorate 10G @ 1.5 kg a.i. ha⁻¹ at 25 DAS. Fewer plants were damaged by girdle beetle when treated with phorate 10G @ 1.5 kg a.i. ha⁻¹ and furrows application at the time of sowing.

Thiamethoxam 70 WS as a seed dress for soybean was highly effective in reducing the seedling borers like stemfly and girdle beetle infestation (7.90 and 5.85%) and increasing the seed yield (2328 kg/ha) compared to soil application of carbofuran, phorate and untreated check. The seed dress with thiamethoxam resulted in 742.50 kg/ha additional yield over untreated check, 15.76 per cent increase in seed yield over recommended practice of soil application of carbofuran granules (Patil and Kulkarni, 2004).

The fungicide Benomyl and the insecticide Chlorpyrifos application reduced the number of enchytraeids by 60 % and nematodes by 48 % at most. Mites were not affected (Roembke, 2009).

2.2.1.2 Effect of herbicides on soil fauna:

The herbicides caused changes in the abundance of micro-arthropods as well as its important groups *viz.*, Acari and Collembola in treated plots by either decreasing or increasing the population densities. An assessment of the over all impact of these herbicides upon soil micro-arthropods showed that TOK, E-25 significantly decreased the number of total micro-arthropods ($p < 0.05$) and Collembola ($p < 0.01$) in paddy field and of Mesostigmata ($p < 0.05$) in wheat fields whereas, STAM, F-34 reduced the number of Collembola ($p < 0.01$) and Mesostigmata ($p < 0.02$) significantly in paddy field. On the other hand, Banvel-D, 2, 4-D amine and 2,4-D sodium caused insignificant variation against soil fauna (Joy and Bhattacharya, 1981b).

Weed management using herbicide like terbutometon (terbuthylazine) at 5 kg / ha, bromocil at 1.6 kg in asparagus, post emergent primisulfuron at 30 g / ha, pre-emergent atrazine at 1.5 kg, post-emergent rimsulfuron at 40 g / ha in maize did not exert consistent direct effects on any soil organisms considered (Wardle *et al.*, 1993).

Weed management strategies *viz.*, saw dust mulching, repeated spring / summer cultivation, hand hoeing and 2 herbicides treatments terbumetan plus terbuthylazine (caragard) at 5.0 kg a.i. and bromocil (Hyvar) at 1.6 kg a.i. / ha in maize and asparagus exerted significant indirect effects on the soil arthropod fauna, probably by modifying the quality of their habitat (Wardle *et al.*, 1993).

During the first 56 days after the pre-emergence application of hexazinone to a sandy loam alfisols, micro-arthropod population densities in the treated plots and untreated control plots were similar but lower than those in undisturbed forest soil. Thereafter, soil micro-arthropod densities were lower in the treated plots. The vertical distribution of soil micro-arthropods were also affected in the treated plots (Badejo and Adejuyigbe, 1994).

Reduction or elimination of tillage (made possible by herbicides) can preserve some of the characteristics of natural ecosystems. It may result in increased invertebrate diversity. At normal use rates, most herbicides appear to have little direct impact on soil inhabiting invertebrates (Fawcett, 1996).

The recovery of collembolan species from the genera *Cryptopygus*, *Dicranocentrus* and *Rhodanella* from the deleterious effects of pre-cultivation clearing, ploughing and harrowing of soil did not occur in the galex (metobromuron + metolachlor) plots during the vegetative growth of cowpeas. The activities of litter Collembola that survived the precultivation activities were further reduced in the galex and hoe-weeded plot in the pod-ripening phase of cowpea development. Hand pulling of weeds and the cover provided by weeds in the weedy control were more conducive to Collembola activity than hoe weeding and the pre-emergence application of galex (Badejo *et. al.*, 1997).

The short-term effects on soil microarthropods of the herbicide triasulfuron, belonging to the chemical class of sulfonylureas, were evaluated in two fields which had never been treated with sulfonylureas, and were cultivated with winter wheat. In particular, the effects of single applications at rates corresponding to two and six fold the recommended agricultural rate (7.5g active ingredient ha⁻¹) were analysed and compared with controls. The changes in the populations of the main groups of microarthropods were evaluated. Rate two fold had very low effects, whereas six fold produced a significant decrease in the number of microarthropods, Acarina and Collembola (Rebecchi *et al.*, 2000).

The demography of *Paronychiurus kimi* (Lee), a dominant springtail in the paddy fields was studied under the influence of glufosinate-ammonium (GA), a herbicide, on two different substrates: plaster-charcoal and artificial soil. On plaster-charcoal substrate with brewer's yeast provided as food, survival rate of eggs, juveniles and adults, and life table statistics of *P. kimi* did not reveal any significant influence of GA except at an extremely high concentration (1572.70g/cm²). The EC₅₀ of GA for reproduction of *P. kimi* was estimated to be 446.21g/cm². In artificial soil with brewer's yeast, *P. kimi* was susceptible to GA. Reproduction of *P. kimi* was significantly reduced at 0.5 mg/kg and the adult survival rate decreased at 50 mg/kg. The life table statistics showed significant influences of GA even at low concentration, and the EC₅₀ was estimated to be 0.039 mg/kg. (Kang *et al.*, 2001)

Lins *et al.* (2007) noticed both the type of herbicide and the time of data sampling influenced the Collembola population fluctuation. Further, they noticed the treatments with atrazine and 2, 4-D caused the most reduction of the population of Collembola compared to glyphosate and nicosulfuron depending on the time of application.

2.3 Effect of manures on soil fauna and insect pests:

Fresh heaps of organic matter contain very few or no animals but as the heaps age, there is a succession of animals paralleling the chemical changes during decomposition (Muller, 1957). Typical manure animals are replaced by compost animals, which in turn are displaced by typical soil fauna (Cernova, 1971). In leaf compost, mites may initially predominate but are later surpassed by Collembolans (Ghilarov, 1965). Among the Collembolans, certain species are shown to be regularly eliminated by aging of the compost (Mrohs, 1961).

In compost-earth, the animals increased to a maximum at the start of decomposition, then decreased markedly, unless fresh decomposable material was added. In 1 kg of air-dry young compost, 4,16,000 animals declined to 32,000, 26,000 and 4,000 in 6 months, 2 years and 4 years, respectively. There was decrease in the number of taxa, from 17 at the beginning to 3, four years later. It was concluded that well rotted compost, 3 years old, might not contain a greater metazoic fauna than grassland or arable soils (Stockli, 1964).

Tischler (1955) pointed out that the number of species in manure might be small but the number of individuals and biomass was greater than in the soil. There were 3, 00,000 mites, 1, 50,000 enchytraeids, 1, 30,000 Collembolans, 30,000 insects and 300 earthworms per m² for a 10 cm depth (Gunhold, 1952; Graff, 1953). Mrohs (1961) listed the order of abundance in compost as mites, Collembolans, bundling earthworms and enchytraeids.

Two to three weeks after manure applications, the manure faunal population begins to decrease but the total faunal counts usually remain higher than in undunged fields (Leuthold, 1961). Herbke (1962) demonstrated that diplopod population densities were 180% higher in

treated plots than controls, even 10 years after the last manure application. Greater species diversity was also evident in manured plots.

Manures are generally very effective in increasing soil Collembola (Christiansen, 1964). Holler-Land (1962) compared to total Collembolan population in agricultural fields, half of which received fertilizers alone, the remainder inorganic fertilizers plus manure. In fields under truck crops (potatoes, turnips, cabbage etc.) the annual average number in the unmanured plots was only half of that in the manured plots 3 years after the last application of manure. Gisin (1955) concluded that farmyard manure temporarily stimulated certain Collembola but did not depress true soil forms. Other insects particularly Coleoptera, Hymenoptera, Diptera and Thysanoptera usually increased following organic amendments.

Primavesi and Covolo (1968) suggested that mites did not respond favourably to manure because of their aversion to nitrogen. Different Acari groups predominate at different times following manuring. Holler-Land (1962) found that three and half years after manuring truck-crop fields, the Mesostigmata and Prostigmata were twice as numerous in manured plots compared to unmanured controls. In contrast to Mesostigmata, the *Cryptostigmata* decreased slightly in manured plots.

Marshall (1977) reviewed that various farmyard manures increased enchytraeid number by providing food and better moisture conditions during dry periods. The application of complete or nitrogenous chemical fertilizers reduced the number of enchytraeid population mainly caused by the increase in electrical conductivity of the soil solution.

Application of 2 tonnes of farmyard manure per ten acres of clay soils increased the mesofaunal population. Twenty-seven enchytraeids

and 29 springtails were counted in one g. clod (Watanable and Ogawa, 1990).

The largest biomass of Collembola occurred in the oilseed rape green manured sandy soil, whereas individual numbers were greatest under sandy loam soil (Filser, 1995). Compost application significantly increased the Collembola and Acari (Oribatid, Gamasina) (Chacon *et al.*, 1997).

Wu *et al.* (2002) found that densities of collembola were four times higher in the organic than those in the conventional agro ecosystem and also total population of Acarina was higher in the organic than that in the conventional agro ecosystem. And they reported that the subfamilies of Acarina- Mesostigmata and Prostigmata were found in greater number in the organic than those in the conventional agro ecosystem because they are mainly omnivores and predators. Where, Astigmata and Cryptostigmata are predominant in conventional ecosystem because they are usually fungivores, mycophages or detritivores.

The organically manured treatments like FYM, neem cake and vermicompost plot recorded lowest pest population compared to straight fertilizer treatments. The plant received organic manures recorded low nitrogen and high levels of phenols and tannins whereas the straight fertilizer treatment recorded vice versa. Thus phenols and tannins induced the resistance in pest control (Rajashekararao, 2005).

Ayuke *et al.* (2004) revealed that addition of organic residues increased faunal biomass substantially over the fertilized and unfertilised controls. Whereas, green manures like senna and tithonia increased total faunal biomass by 45 % and 49 % over the fertilized and unfertilized controls, respectively. They found significant variation in faunal biomass over time between green manure, fertilizer and no input control.

Effect of manures and inorganic fertilizers on soil fauna is presented in table 1.

2.4 Effect of fertilizers on the soil fauna:

Single formulations, particularly of nitrogen and calcium, increased number of species and individuals (Ghilarov, 1971), but the highest rates of increases have come from complete and mixed fertilizers (Hryniuk, 1966) especially when calcium accompanied these fertilizers (Themlitz, 1963).

Continuous fertilization over 50 years did not adversely affect the fauna (Edwards and Lofty, 1969) and fertilizers may benefit the fauna in the short term (Table 1). Franz (1953) noticed a positive effect for enchytraeids, Collembolans and mites 10 years after application of NPK.

Most of the workers have recorded springtail increase in forest soils from various nitrogenous formulations. Even among nitrogenous formulations there were differential responses. Weetman *et al.* (1972) recorded a 0.9, 1.8 and 2.4 fold increase over controls in springtail population, 2 years after fertilizing a black spruce stand, with 448 Kg N/ha of ammonium nitrate, calcium nitrate and urea, respectively. Fertilizers that neutralise soil reaction can be expected to favour directly Collembolans (Christiansen, 1964).

Collembolan populations have generally increased following application of phosphorus alone or in combination with other elements (Mayer-Krapoll, 1963). Carey *et al.* (1971) noted a 5% decrease in Collembolan population from controls 5 years after application of 448 Kg K / ha as potassium chloride to a red pine plantation. Insects other than Collembolans also increased following fertilization.

Table 1: Effect of manures and manures plus inorganic fertilizers on soil fauna.

Treatment	Habitat	Diplopods	Symphylids	Insects	Collembolans	Mites	Spider	Reference
Manure	Arable	329	-	695	344	246	-	Morris, 1922
Manure	Arable	948	387	253	417	700	65	Morris, 1927
Manure	Arable	221	-	552	144	342	243	Russel, 1961
Manure	Arable	-	358	200	206	129	75	Hryniuk, 1962
Manure	Arable	186	-	115	236	191	-	Saurlandt and Trappman, 1962
Manure	Arable	-	-	-	232	203	-	Edwards and Lofty, 1969
Manure	Grassland	-	-	-	190	129	-	Franz, 1953*
Manure	Grassland	-	-	-	640	66	-	Franz, 1953**
Manure + NH ₄ Salts	Arable	378	575	898	537	300	135	Morris, 1927
Manure + Ca (H ₂ PO ₄) ₂ +NH ₄ Salts	Arable	1075	387	221	413	548	135	Morris, 1927
Manure + NPK	Grassland	-	-	-	168	86	-	Franz, 1953*
Manure + NPK	Grassland	-	-	-	315	116	-	Franz, 1953**

* One year after application

** Ten years after application

Most authors have reported increase in Acari population following fertilization under agricultural and forestry conditions. Although most of the nitrogenous fertilizers increased mite populations in agricultural (Muller, 1957) and in forest soils (Mayer-Krapoll, 1963), response varied with formulations.

Four months after application of 224 kg N / ha as urea, the species composition remained constant, but the relative abundance of certain orders and species of mites changed. There was a 2 and 3 fold increase in Mesostigmata and Astigmata, respectively over the control. The Cryptostigmata decreased slightly in the fertilized plots (Behan, 1972).

With fertilizers, the Oribatei tend to respond less rapidly than the other Acari orders. This is probably because of their long life cycle and saprophagous feeding habits, where as the Mesostigmata and Prostigmata are primarily predators with relatively short periods between generations. The Astigmata are mainly saprophagous with short life cycles and like the Mesostigmata and Prostigmata, could quickly take advantage of favourable conditions induced by fertilization (Marshall, 1977).

In forest soils, phosphorus alone or combined with other elements stimulated Acari population (Mayer-Krapoll, 1963). Five years after fertilizing a red pine plantation with 448 kg K / ha of potassium chloride, the 4 major orders of mites (Astigmata, Mesostigmata, Cryptostigmata and Prostigmata) increased by 59, 25, 12 and 35 %, respectively over control. However, the total number of families decreased in the fertilized plots, indicating a differential response by families and possible species (Carey *et al.*, 1971).

Potter *et al.* (1985) conducted a study to determine the influence of prolonged N fertilization on populations of Collembola and Acari involved in decomposition process in Kentucky blue grass (*Poa pratensis* L.). Six rates of ammonium nitrate fertilizer ranging from 0 to 25 kg N m⁻² were applied annually for 7 years. Collembola were more abundant at an intermediate fertilizer rate, where as Acarinae were unaffected by N fertilization.

Collembolans like *Onychiurus furcifer*, *Folsomia quadrioculata* and *Isotoma natabilis* were positively correlated with the concentrations of potassium and to a certain extent phosphorus but *O. quadricellatus* and *Isotomiella minor* were negatively correlated with the content of basic cations or pH values. The number of species increased with content of potassium (Geissen *et al.*, 1997). The population of Collembola and Acari were greatest in mineral fertilizer + mulch than NPK fertilizer + organic fertilizer or NPK fertilizer + without mulch (Sautter *et al.*, 1998).

2.5 Impact of application of organic manure along with chemical fertilizers on the chemical properties of soil:

2.5.1 Soil organic carbon:

A significant increase in the organic carbon content of soil till 52 days after application due to application of FYM at all the levels was observed by Gupta *et al.* (1988) and thereafter it decreased.

Subramanian and Kumaraswamy (1989) observed increased organic carbon status of soil due to addition of either FYM alone or in combination with fertilizers and attributed it to increase in root biomass added to soil.

Incorporation of sorghum stubbles, safflower stalks and FYM significantly increase the infiltration rate, bulk density, water holding

capacity, organic carbon, available nitrogen and available phosphorus as compared with the fertilizer treatment (Badanur *et al.*, 1990).

Bhandari *et al.* (1992) observed significant increase in organic carbon content of soil with the application of 100 per cent recommended dose of fertilizer plus organic manures. Shinde and Gowade (1992) noticed increase in organic carbon content from 0.43 in case of control to 0.58 per cent due to addition of 10 t of FYM per ha.

Pattar *et al.* (1998) noticed that the application of FYM @ 10 t/ha resulted in higher organic carbon content in addition to available NPK content of soil. Sharma (1999) reported that application of FYM and crop residue alone or in combination with reduced level of fertilizer was effective in building up of soil fertility with respect to organic carbon, nitrogen, phosphorus and potassium content of the soil in long run. Badole and More (2000) concluded from an incubation study that organic carbon content was relatively higher when organic sources were added (FYM, neem cake and glyricidia) than with inorganic sources.

Devaraja (2005), Prasanna (2006), Girish (2006) and Satish (2009) reported significantly higher soil organic carbon in the treatments applied with double doses of recommended FYM.

In long-term manuring and fertilization in maize - wheat - cowpea cropping system, the application of graded doses of NPK from 50% (130 kg N, 35 kg P and 41.5 kg K ha⁻¹) to 150% (390 kg N, 105 kg P and 124 kg K ha⁻¹) in the cropping system significantly enhanced soil organic carbon, the increase in the soil organic C fractions was greater when farmyard manure (FYM) was applied conjointly with 100% NPK (Purakayastha *et al.*, 2008).

2.5.2 Available nitrogen:

Acharya and Rajagopalan (1956) and Biswas *et al.* (1967) reported that organic carbon and available nitrogen in soil increased with the application of FYM and the fertility status also improved.

Biswas and Khosla (1971) and Maurya and Ghosh (1972) showed that long-term application of manures improved the organic carbon content, levels of nitrogen and available nutrients.

Singh *et al.* (1980) reported that increased application of FYM increases the available nitrogen content in the soil over the years. However, significant difference was not found among the treatments.

Continues organic manure application or in combination with inorganic fertilizers significantly influenced the uptake of nutrients, organic carbon, available N, P and K in soil, Microbial biomass C, Microbial biomass N, Microbial biomass P, Microbial biomass S over the 100% NPK (Mishra *et al.*, 2008).

The long-term effect of organic and inorganic fertilizers (NPK) on nutrient build-up and their relationship with microbial properties in a rice-wheat cropping sequence were studied in surface (0-15 cm) and subsurface (15-30 cm) soil samples by Bedi and Dubey, (2009). The substitution of 25 and 50% nitrogen through organic fertilizers proved to be better than inorganic fertilizers alone. Amongst the organic sources, the substitution of FYM resulted in higher organic carbon, total and available nitrogen, phosphorus and sulfur than green manure or wheat straw. The substitution of 50% nitrogen through organic fertilizer was more effective than the substitution of 25% nitrogen. Further the total pool of nutrients showed a high, positive, significant relationship with the total microbial count, biomass carbon, respiration, and the

dehydrogenase and phosphatase [phosphoric monoester hydrolases] enzymes.

2.5.3 Available phosphorus:

Organic acid produced during the decomposition of green leaf manures and FYM are known to have beneficial effect in increasing the availability of phosphorus to crops when easily decomposable organic materials are added to soil as they were effective in increasing the availability of soil phosphorus (Dalton *et al.*, 1952).

Farmyard manure itself is known to contain considerable amount of phosphorus and its contribution to the available phosphorus pool upon mineralization has been well documented (Mandal and Mandal, 1973).

Farmyard manure application reduced the loss of nutrients through leaching and provided a significant amount of plant nutrients, which created a balancing effect on supply of nitrogen, phosphorus and potassium (Singh *et al.*, 1979).

Available P content of the surface and sub surface soil increased significantly with increase in farmyard manure application (Gupta *et al.*, 1988). Organic manure application at 15 t/ha had a significant influence on the available phosphorus from the native and applied sources (Krishnaswamy *et al.*, 1984).

Bhanavase *et al.* (1992) noticed significant increase in available P content of soil due to addition of FYM + Urea N, crop residue + Urea N compared to control and crop residue alone. Gupta *et al.* (2000) reported that the available P and K content of soil decreased with successive rise in levels of N addition through Urea, where as the status of these

nutrients increased in the plots, which received combined application of urea and manures.

Kale *et al.* (1992) reported that application of vermicompost in combination with NPK fertilizer resulted in higher content of P as compared to FYM in combination with NPK fertilizer or control.

Devaraja (2005), Prasanna (2006), Girish (2006) and Satish (2009) reported significantly higher available phosphorus from plots treated with 20 t of recommended FYM.

2.5.4 Available potassium:

Nimje and Seth (1988) found that FYM application at 15 t / ha increased the NPK concentration in the soil as well as uptake by plant in addition to increase in residual NPK in soil. Sharma and Arora (1988) observed that application of Potassic fertilizer and FYM significantly increased available potassium content in sandy loam soil of Jalandhar (Punjab).

Sud *et al.* (1980) reported that application of FYM increased the soil organic carbon and available NPK content of soil. Amount of available K in soil depends upon the clay content besides other factors.

Shinde and Gowade (1992) observed an increase in the available K content of soil due to addition of FYM (15 t/ha) from 235 Kg /ha in control to 258 Kg/ha.

Devaraja (2005) documented that the plots treated with 20t of recommended FYM recorded significantly higher available potassium.

Prasanna (2006), Girish (2006) and Satish (2009) reported significantly higher available potassium in the plot treated with double doses of FYM.

The effect of 30 years of continuous cropping, fertilization and manuring on potassium balance and availability in a sandy loam was investigated under a rain fed soybean-wheat cropping. It found that continuous application of NPK + 10 t FYM annually to soybean resulted in build up of available K (Bhattacharyya *et al.*, 2008).

2.5.5 Exchangeable calcium and magnesium:

Naik and Ballal (1968) observed an increase in Ca and Mg content of medium black soils at all levels of organic matter application.

Singh *et al.* (1980) reported a build up of exchangeable Mg with the addition of FYM. Das *et al.* (1991) observed that application of poultry manures and FYM increased the exchangeable calcium content gradually up to 36 days of incubation.

Sureshlal and Mathur (1988) observed that the application of NPK fertilizer had decreased the exchangeable calcium and magnesium content of soil but there was a decrease and increase in the exchangeable calcium and magnesium content, respectively due to addition of farmyard manure.

Basumatary and Talukdar (1999) reported that integrated treatments receiving chemical fertilizer along with 50 and 25 per cent of organic N through FYM resulted in significantly higher content of exchangeable calcium and magnesium. At the end of seven years of cropping both exchangeable and total Ca and Mg depleted over initial value, except a slight increase in Ca in 50 per cent organic matter substituted treatments.

Devaraja (2005), Prasanna (2006), Girish (2006) and Satish (2009) reported that application of 20t of recommended FYM significantly

enhanced the exchangeable calcium and magnesium content of soil compared to chemical fertilizer alone-applied treatments.

2.5.6 Soil pH:

Singh and Singh (1974) observed the reduction in pH with incorporation of sunhemp and FYM when compared to control. The decrease in soil pH by about one unit from initial value could be related to decomposition and mineralization of organic matter (Singh *et al.*, 1980). They also found slight depression in soil pH with the increased application levels of phosphorus.

Increased use of N fertilizers during past 20 years has been accompanied by a growing concern about their possible negative influence on soil properties. This cause increase in micronutrients, decrease in soil pH and exchangeable bases significantly compared to no N fertilizer plots (Darusman *et al.*, 1991).

Long term use of fertilizers of various combination *viz*, control, N, NP, NPK were evaluated and revealed application of fertilizers lowered the soil pH and significantly improved soil physical properties (Chawla and Chhabra, 1991).

2.6 Effect on soil microbial biomass C:

The soil microbial biomass comprising 2-3% of the total organic carbon in soil is a relatively liable fraction of soil organic matter; it is therefore a more important repository of plant nutrients than its small size might indicate. Microbial biomass has been recognized both as transforming agent and as a source and sink for various nutrients.

The soil microbial biomass itself is a part of soil organic matter, typically about 2 per cent of the total organic carbon; soil microbial biomass is defined as the living microbial component of the soil that

includes bacteria, *Actinomycetes*, fungi, algae and micro fauna (Alexander, 1977). The soil microbial biomass is also referred to as active soil organic matter pool (Parten *et al.*, 1987) and related to quantity, type and placement of organic residue addition (Sanchez *et al.*, 1989).

The microbial biomass is an essential component of organic turnover (Jenkinson, 1990; Duxbury *et al.*, 1989). The microbial biomass is influenced to variable extent by macroclimate (Insam *et al.*, 1989) and soil type (Sparling, 1991). But in particular is responsive to land use and agricultural practices. The interaction among these, results in a system, which oscillates between nutrient mineralization and immobilization (Mazzarino *et al.*, 1991).

Asha (2003) noticed significantly higher soil microbial biomass in wetland compared to dry land, further there was a significant increase in microbial biomass up to 30 days of incubation but decreased after 45 days after application of fertilizers to these soils.

An incubation study with different organic amendments in an alfisol showed maximum microbial biomass C and N on 30th day and a suddenly decreased 45th day followed by a sudden increase in both microbial biomass C and N by 60th day (Snehalatha *et al.*, 2003).

Field experiment were carried out to find out the effect of endosulfan, monocrotophos and Farm yard manure (FYM) on soil microflora, microbial biomass carbon. Adverse effect of endosulfan and monocrotophos was seen on microflora in absence of FYM. Addition of FYM @ 20t ha⁻¹ increased the microbial population and improved soil properties compared to that of untreated plots (Shashi *et al.*, 2007).

2.7 Impact of abiotic factors on soil fauna:

Convey *et al.* (2002) reported the consequences on the soil micro arthropod community of a four-year, multivariate, climate-manipulation experiment carried out over vegetation near Palmer Station, Anvers Island, western Antarctic Peninsula found by raising temperatures and reduce ultraviolet (UV)-B (280–320 nm) treatments. And found that by increasing temperature micro arthropods (particularly Collembola) population decreased in numbers, while water amendment increased numbers of micro arthropod. The negative impact of UV (-A or -B) on arthropod heterotroph and detritivore populations in the Antarctic terrestrial food web is likely to be a secondary consequence of UV impact on vegetation characteristics.

Precipitation and temperature were significantly correlated with Collembola and Mesostigmata densities and also with total arthropod. The seasonal variation in the amount of litter fall was also significantly related to the abundance of arthropod in the litter layer biotope (Palacios *et al.*, 2007).

Geissen *et al.* (2007) investigated the relationships between soil chemical properties, humus form and feeding activity in eight forest sites in Northrhine-Westphalia, Germany. All study sites were very acid with pH (CaCl₂) values in the Ah horizon between 2.8 and 4.0. The five other sites varied significantly due to their soil chemical parameters (pH in Ah: 2.8-4.0). Forest types and climatic conditions were not related to activity of soil fauna. Feeding activity and thickness of the O layer were strongly negatively correlated, whereas the activity was strongly positively correlated to soil pH in the five study sites with a wide range of soil chemical parameters.

The relationship between soil fauna and various abiotic factors *viz.*, temperature, relative humidity, rainfall, soil moisture, soil temperature, nitrate, phosphate, calcium carbonate, organic carbon and pH are presented in table 2.

Table 2: Correlation studies between soil fauna and abiotic factors.

[illegible]

<i>Azadirachta indica</i>	Micro-arthropod			+ve	+ve							Reddy, 1992
<i>Dipteryx odorata</i>	Soil invertebrates		-ve								-ve	Harada and Bandeira, 1994
<i>Quassia Simarouba</i>	Soil invertebrates		+ve									
Crop land	Acari and Collembola	+ve			-ve							Narula <i>et al.</i> , 1995
Forest	Acari	-ve			+ve		+ve			+ve	-ve	Banerjee, 1996
Rubber	Collembola				+ve							Chakraborti and Bhattacharya, 1996
Dalbergia sisso	Mites	-ve			+ve		+ve			+ve	-ve	Marnta Singh <i>et al.</i> , 1996
	Soil insects				+ve	-ve						Shukla <i>et al.</i> , 1996
Cultivated soils	Collembola						+ve	+ve		+ve		Kovac, <i>et. al.</i> , 1997
Agro-forestry	Collembola	-ve			+ve							Badejo <i>et al.</i> , 1998
Tropical decidous forest	Collembola	+ve		+ve								Palacios <i>et al.</i> , 1998

Temp. : Temperature

RH: Relative humidity

RF: Rainfall

SM: Soil moisture

ST: Soil Temperature

NO₃ : Nitrate

Po₄ : Phosphate

CaCO₃ : Calcium carbonate

OC: Organic carbon

Material and Methods

III. MATERIAL AND METHODS

The studies on development of conservation practices for below ground biodiversity in soybean ecosystem were conducted at Gandhi Krishi Vignana Kendra campus of the University of Agricultural Sciences, Bangalore during *kharif* season of 2009-10 under rainfed conditions. The experimental site is located at 13° 01' North latitude and 77° 35' East longitude and at an altitude of 930 m above mean sea level (MSL). The soil belongs to Vijayapur series and is classified as Oxic Haplustalf. According to FAO classification, the soil is Ferric Luvisols. Soil is reddish brown, lateritic derived from granite gneiss under subtropical semiarid climate. This was the long-term experiment initiated nine years back and the same was continued for tenth year (August to December, 2010) with the initial soil chemical properties (organic carbon 0.34%), available phosphorus (11.69 kg/ha), available potassium (120.50 kg/ha), exchangeable calcium (6.6 meq/100g.), exchangeable magnesium (3.62 meq/100g.) and pH (5.92) during 2001 to know the effect of organic manures and chemical fertilizers on abundance of arthropods in soybean cropping system. The materials used and methods followed to carry out the experiments are presented in this chapter.

3.1 Impact of different doses of organic manures on below ground biodiversity:

3.1.1 To study the impact of organic manure and chemical fertilizers on the abundance of soil arthropods:

The field experiment was laid out in a randomized complete block design with the following treatments. Each treatment was replicated three times.

Treatments:

1. Recommended fertilizers (25:60:25 NPK Kg per ha) + Recommended FYM (10 tonnes per ha) + Phorate 10 G @ 1 kg *a.i.* per ha + herbicide (Lasso 50 EC @ 2.5 lit per ha) + fungicide seed treatment (Thiram + Bavistin- each 2g/kg of seeds).
2. 12.5 tonnes of FYM + 75 per cent of recommended fertilizer.
3. 15.0 tonnes of FYM + 50 per cent of recommended fertilizer.
4. 17.5 tonnes of FYM + 25 per cent of recommended fertilizer.
5. 20.0 tonnes of FYM.
6. 10.0 tonnes of FYM.
7. Recommended FYM (partially decomposed).
8. Recommended FYM + mulching (Glyricidia 2 tonnes per ha.).
9. Recommended fertilizer alone.
10. 50 per cent of recommended FYM.

FYM was applied to the respective plots about one week before sowing. Chemical fertilizers N, P, K were applied with recommended doses to particular treatments at the time of sowing in furrows. Soil insecticide (phorate) was applied in the furrows at the time of sowing. Seed treatment with fungicide (Thiram + Bavistin - 2g each per kg) was done before sowing. Herbicide (Lasso) treatment was given to the soil on the day of sowing as pre-emergent application. *Rhizobium* seed treatment (500g/ha) was done at the time of sowing to enhance nodulation. Phosphorous solubilising bacteria (500g/ha) were treated with seeds at the time of sowing to enhance the phosphorous content in the soil. Soil from grassland was applied (1 kg/subplot) to introduce native faunal diversity into the crop field.



Plate 1: General view of experimental plot

The soybean variety Hardee was sown with a spacing of 30×10 cm in 6×3.6 m sub plot on 9th August 2010. Crop was raised under rainfed condition. Need based plant protection measures were taken at 23rd, 45th and 60th (Spinosad @ 0.25 ml/l) days after germination (DAG) in order to manage foliar insect pest population.

3.1.1.1 Seed treatment with fungicide (Thiram + Bavistin):

Required quantity of chemical was mixed with 20 ml of water plus gum arabica solution (2 ml) and this slurry were mixed thoroughly with one kilogram of seeds. Treated seeds were dried under shade and used for sowing.

3.1.1.2 Estimation of the population of below ground arthropods:

3.1.1.2.1 Sampling method:

The soil samples were collected before imposition of treatments and on 10, 20, 30, 45, 60, 90 and 105 days after germination in each treatment. The samples were also collected at 15 days interval during non-cropping season. The samples were collected using the circular core sampler measuring 12 cm diameter and 10 cm height. The core sampler was placed on the soil surface and pressed downwards and turned in clockwise direction to a depth of 10 cm. The quantity of soil samples taken was 400 g on dry weight basis. Such collected samples were immediately transferred to aluminium cans (15 cm height and 6 cm diameter) and labels were placed into each can and closed with lid.

3.1.1.2.2 Extraction technique:

The fauna was extracted from the soil samples using Rothamsted modified MacFadyen high gradient funnel apparatus situated in the soil biology laboratory. Soil samples were placed carefully along with the labels in canisters. The electric bulbs (25 W) fixed at the top in the baffle

board served as the source of light and heat energy. The apparatus was run for 48 hours. The invertebrates including earthworms passing through 2×2 mm sieve of the sample holder were collected in vials containing 70% ethyl alcohol fixed to the lower end of the funnel. These vials were periodically checked to keep the alcohol at desired levels. Labels were kept intact both in soil sample and fauna extracted vial.

3.1.1.2.3 Sorting procedure:

A stereo binocular microscope (35 X magnification) was used for sorting out the extracted soil invertebrates. They were separated into different taxonomic groups.

3.1.1.2.4 Preservation of soil invertebrates:

Taxonomic groups encountered during the study period were preserved in vials containing 75% ethyl alcohol and labelled (date of collection, treatment etc.,) for further taxonomic identification.

3.1.1.3 Extraction of soil nematodes by Baermann's funnel method:

The soil samples were collected 60, 90 and 120 days after germination in each treatment. The samples were collected using the circular core sampler measuring 12 cm diameter and 10 cm height. The quantity of soil samples taken was 75 g on dry weight basis. Such collected samples were immediately brought to the laboratory for soil nematodes extraction.

Procedure

1. A glass funnel of 10 cm diameter attached with a short rubber tube to the stem and closed at the other end with a Hoffman's clip was taken and places the funnel on a suitable support.
2. The funnel assembly was filled with water carefully.

3. Water was added in such a way that the lower surface of the wire gauze touched the water.
4. Double layers of tissue paper were placed over wire gauze (mesh) and placed it on the funnel.
5. The soil sample was placed over the double layers of tissue paper.
6. The nematode suspension was collected carefully after 48 hours by releasing the Hoffman's clip.

3.2 To establish the relationship among soil arthropods, soil microbial biomass C and soil fertility:

3.2.1 Soil analysis:

To compare the fertility status of each treatment, soil samples were collected just before imposing the treatment, 45 DAG and at the time of harvesting to a depth of 15 cm. Then the collected samples were dried under shade. The samples were crushed into a powder and passed through 2 mm sieve. Such samples were preserved in polythene bags for analytical work in the laboratory.

3.2.1.1 Organic carbon (OC):

Finely ground (0.2 mm sieved) soil was used for the estimation of the organic carbon by wet oxidation method using potassium dichromate and sulphuric acid for oxidation of organic carbon and expressed in percentage (Walkley and Black, 1934).

3.2.1.2 Available nitrogen:

The available nitrogen in the soil was estimated by alkaline potassium permanganate method by taking 20g of soil sample and distilled (Subbiah and Asiza, 1956) and expressed in Kg/ha.

3.2.1.3 Available phosphorus (P_2O_5):

The available phosphorus in the soil was estimated by taking 5g of soil sample extracted with Brays I reagent. The extracted phosphorus was then estimated by ascorbic acid method. The intensity of the colour was read in spectrophotometer as described by Jackson (1973) and expressed in kg/ha.

3.2.1.4 Available potassium (K_2O):

The available potassium in the soil was estimated by taking 5 g of soil sample extracted with neutral normal ammonium acetate solution using flame photometer (Jackson, 1973) and expressed in kg/ha.

3.2.1.5 Exchangeable calcium (Ca) and magnesium (Mg):

Calcium content of soil was estimated by Versenate titration method using sodium hydroxide and Erichrome black-T (EBT) indicator after extraction with neutral normal ammonium acetate. Calcium + magnesium in the ammonium acetate was measured by Versenate titration method using buffer complex + EBT indicator. Magnesium content in soil was calculated by subtracting exchangeable calcium content from exchangeable calcium + magnesium content of soil and the same was expressed in milli equivalent (meq) per 100g (Jackson, 1973).

3.2.2 Microbial biomass C and N:

Microbial biomass C and N were estimated following fumigation and extraction as proposed by Carter (1991). Ninhydrin reactive nitrogen released during the fumigation of soil was determined by using Ninhydrin reagent and was used as a measure of microbial biomass.

Each soil sample was divided into two sets. One set of a moist soil sample (10 g soil on oven dry basis) was fumigated with ethanol-free chloroform for five days in screw-capped bottles. Then the caps were

removed and kept in an oven at 40 °C for over night to remove all the chloroform and was extracted with 2M KCl by placing these bottles on a reciprocal shaker for 30 min. The suspension was filtered using Whatman No.42 filter paper. In a similar manner unfumigated set of the same soil sample was extracted.

To a known aliquot of soil extract, 4 ml of freshly prepared ninhydrin reagent was added and the mixture was boiled in a water bath for 20 min. The contents were allowed to cool and the volume was made up to 10 ml using a 1:1 mixture of methoxy ethanol and distilled water. The intensity of purple colour developed was recorded using a Bosch and Lamb spectrophotometer at 570 nm wavelength. A standard curve was developed using 5 different concentrations of L-Leucine N (3.5 to 16.8µg N ml⁻¹) dissolved in 2M KCl. Absorbance values were compared with a standard curve and microbial biomass C and N were calculated using the following formula.

$$\text{Biomass C} \begin{matrix} \text{g-1 soil} \end{matrix} = \frac{\begin{matrix} \text{Ninhydrin reactive -N} \\ \text{in fumigated soil} \end{matrix} - \begin{matrix} \text{Ninhydrin reactive -N} \\ \text{in unfumigated soil} \end{matrix}}{\text{Weight of the sample}} \times 24$$

$$\text{Biomass N} \begin{matrix} \text{g-1 soil} \end{matrix} = \frac{\begin{matrix} \text{Ninhydrin reactive -N} \\ \text{in fumigated soil} \end{matrix} - \begin{matrix} \text{Ninhydrin reactive -N} \\ \text{in unfumigated soil} \end{matrix}}{\text{Weight of the sample}} \times 2.8$$

3.3 To establish the impact of abiotic factors on soil arthropods, soil microbial biomass C and soil fertility:

3.3.1 Estimation of soil moisture:

During the time of each soil sampling, some quantity of soil was collected in stainless steel moisture can for estimation of soil moisture. Fresh weight was taken using electronic balance. Then it was dried in a hot air oven at 102 °C in the laboratory. After 24 hours, dry weight of the

soil samples was recorded. The moisture percentage was calculated using the following formula.

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

3.3.2 Estimation of soil temperature:

Soil temperature was recorded by inserting a soil thermometer into the soil to a depth of 10 cm at the time of each sampling period and readings were noted down.

Abiotic factors *viz.*, atmospheric temperature (max and min), relative humidity (max and min), sunshine hours and rainfall of the experimental location were collected.

3.4 Statistical analysis:

The data were transformed using arcsine and $\sqrt{X+0.5}$ transformations, wherever necessary and statistically analyzed by adopting analysis of variance (Sundararaj *et al.*, 1972).

3.4.1 Abundance:

The total number of individuals of all arthropods species, which appeared at the time of observation in each treatment, was taken. The data were transformed using $\sqrt{X+0.5}$ transformations before statistical analysis (Sundararaj *et al.*, 1972).

3.4.2 Relative abundance:

$$\text{Relative abundance (\%)} = \frac{\text{No. of individuals in particular group}}{\text{Total no. of individuals of all groups}} \times 100$$

3.4.3 Correlation between faunal population and soil fertility level

The correlation coefficients were worked out by adopting multiple correlation analysis to find out the relationship between the abundance of arthropods population at different soil fertility levels and weather parameters (soil temperature, soil moisture, rainfall etc.).

3.5 Pitfall trap for collection of soil macrofauna:

The trap consisted of plastic cups, 5 cm in diameter and 7 cm in height. The traps were placed in the ground with their rim levelled with the soil surface. Each cup was filled 25 ml of 75% ethyl alcohol as killing agent and few drops of glycerol as attractant. Each pitfall trap was placed in all the treatment which were replicated thrice, pitfall traps were placed on the day of soil sampling. The cups were left for two days before they were collected. The specimen from the trap were emptied and preserved for further taxonomic classification.

Experimental Results

IV. EXPERIMENTAL RESULTS

Results of the studies on the development of conservation practices for below ground biodiversity in soybean ecosystem are presented in this chapter.

4.1 Impact of organic manures and chemical fertilizers on the abundance of below ground invertebrates in soybean ecosystem:

4.1.1 Impact of different doses of organic manure along with chemical fertilizers on the abundance of soil invertebrates during cropping season:

The result regarding the impact of FYM, chemical fertilizers and their interaction on the abundance of soil invertebrates in soybean ecosystem are presented in the table 3.

4.1.1.1 Treatment effect:

There was a significant difference in abundance of soil invertebrates among the treatments. Significantly higher soil invertebrates abundance was recorded in 20 tonnes of FYM applied treatment (37.92 invertebrates 400 g⁻¹ of soil). Further, T₄ (22.38) showed on par in soil invertebrates with T₃ (21.92), T₂ (19.83) and T₇ (18.38). Soil application of recommended dose of fertilizer alone recorded least soil invertebrates abundance (12.75 invertebrates 400 g⁻¹ of soil) which was on par with T₆ (15.21), T₁₀ (14.83), T₁ (16.13) and T₈ (15.50).

4.1.1.2 Duration effect:

Abundance of soil invertebrates in soybean crop differed significantly among the intervals. It varied from 5.77 at before application of treatments to 40.27 at 90 DAG. The soil invertebrate's population was

Table 3: Impact of organic manure and fertilizers on the abundance of soil invertebrates in soybean ecosystem during cropping season.

Treatments	Number of soil invertebrates / 400g of soil at days after germination								
	BAT	10	20	30	45	60	90	105	Mean
T1	7.33 (2.73)	7.00 (2.69)	3.33 (1.78)	9.67 (3.18)	14.00 (3.78)	24.00 (4.86)	31.33 (5.63)	32.33 (5.65)	16.13 (3.79) ^{de}
T2	4.00 (2.11)	9.33 (3.10)	8.00 (2.78)	13.33 (3.69)	19.00 (4.16)	21.33 (4.47)	43.00 (6.56)	40.67 (6.41)	19.83 (4.16) ^{bcd}
T3	5.33 (2.40)	5.67 (2.46)	9.33 (3.13)	18.00 (4.24)	17.67 (4.21)	13.33 (3.61)	57.00 (7.48)	49.00 (7.03)	21.92 (4.32) ^{bc}
T4	4.00 (2.08)	5.67 (2.46)	7.33 (2.68)	16.33 (4.07)	28.33 (5.28)	23.33 (4.72)	52.33 (7.20)	41.67 (6.45)	22.38 (4.37) ^b
T5	7.67 (2.78)	14.33 (3.83)	13.33 (3.63)	40.33 (6.32)	42.67 (6.47)	37.67 (5.88)	75.67 (8.66)	71.67 (8.47)	37.92 (5.75) ^a
T6	3.33 (1.93)	3.67 (1.97)	7.67 (2.83)	13.67 (3.76)	19.67 (4.38)	12.33 (3.45)	23.33 (4.85)	38.00 (6.14)	15.21 (3.66) ^{de}
T7	4.33 (2.19)	4.00 (2.01)	9.33 (2.98)	11.33 (3.36)	14.67 (3.86)	31.00 (5.49)	43.33 (6.57)	29.00 (5.37)	18.38 (3.98) ^{bcd}
T8	8.33 (2.93)	8.00 (2.82)	15.67 (3.89)	16.00 (4.01)	7.00 (2.67)	20.67 (4.37)	20.33 (4.52)	28.00 (5.32)	15.50 (3.82) ^{cde}
T9	4.67 (2.14)	7.67 (2.71)	6.33 (2.59)	8.67 (3.02)	9.00 (2.84)	13.33 (3.68)	25.33 (5.07)	27.00 (5.21)	12.75 (3.41) ^e
T10	8.67 (2.80)	6.33 (2.61)	10.67 (3.23)	9.33 (3.09)	7.33 (2.79)	15.00 (3.91)	31.00 (5.54)	30.33 (5.50)	14.83 (3.68) ^{de}
Mean	5.77 (2.41)	7.17 (2.67)	9.10 (2.95)	15.67 (3.87)	17.93 (4.04)	21.20 (4.44)	40.27 (6.21)	38.77 (6.15)	
								S.Em±	CD@5%
Treatment								0.189	0.53
Days								0.169	0.47
Interaction								0.535	1.49

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values, BAT = Before application of treatments



Plate 2: Cryptostigmatid mite



Plate 3: Other soil mite



Plate 4: Collembola



Plate 5: Diplura



Plate 6: Termite



Plate 7: Pseudo scorpion



Plate 8: Ant



Plate 9: Earwig



Plate 10: Fly



Plate 11: Wood lice



Plate 12: Grub



Plate 13: Centipede



Plate 14: Spider



Plate 15: Staphilinid beetle



Plate 16: Beetle



Plate 17: Caterpillar



Plate 18: Aphid



Plate 19: Psocid

significantly high at 90 DAG (40.27) compared to other sampling periods except 105 DAG (38.77).

4.1.1.3 Interaction effect:

There was no significant variation in the soil invertebrate's population among the treatments at before application of treatment. However, the invertebrates population varied from 3.33 (T₆) to 8.67 (T₁₀) soil invertebrates 400 g⁻¹ of soil.

There was a significant difference among the treatments at 10 DAG. Significantly maximum soil invertebrate's abundance was recorded in T₅ (14.33). However, it was on par with rest of the treatments except T₇ (4.00) and T₆ (3.67).

The abundance of soil invertebrates was significantly higher in T₅ (40.33) compared to rest of the treatments at 30 DAG. Further all other treatments were on par with each other and least number of invertebrates recorded in T₉ (8.67).

Soil application of 20 tonnes of FYM per ha recorded significantly higher soil invertebrates abundance (75.67) compared to other treatments except T₃ (57.00) and T₄ (52.33) at peak population stage (90 DAG). However, latter two treatments were on par with T₇ and T₂. The least soil invertebrate's abundance was recorded in T₈ (20.33).

Soil invertebrates abundance was significantly high in T₅ (71.67) compared to rest of the treatments except T₃ (49.00) at 105 DAG (at harvesting stage). Recommended dose of fertilizer alone treatment showed significantly least number of soil invertebrates (27.00). However, it was on par with other treatments except T₅ and T₃.

4.1.2 Impact of different doses of organic manure along with chemical fertilizers on the abundance of soil total Acari during cropping season:

Data pertaining to the impact of FYM, chemical fertilizers on the abundance of soil total Acari are presented in the table 4.

4.1.2.1 Treatment effect:

Significant difference in abundance of soil total Acari was noticed among the treatments. Significantly higher soil total Acari abundance was recorded in the plot treated with 20 tonnes of FYM (25.79 total Acari / 400 g of soil) than rest of the treatments. Soil application of 17.5 t of FYM/ha + 25% of recommended fertilizer harboured 15.17 total Acari /400 g of soil and was on par with rest of the treatments except T₈, T₁₀ and T₉. The latter two treatments i.e., 50% of recommended FYM and recommended fertilizer alone treated plots recorded lower total Acari (8.67 total Acari/ 400g soil) and (8.04 total Acari/ 400g soil), respectively compared to other treatments.

4.1.2.2 Duration effect:

There was significant difference in abundance of soil total Acari among the intervals in soybean ecosystem. Significantly high soil total Acari population was recorded at 105 DAG (30.73) compared to rest of the duration except at 90 DAG (29.63). Soil total Acari were significantly least at before application of treatments (1.87).

4.1.2.3 Interaction effect:

There was no significant difference in soil Acari population among the treatments at before application of treatments. However, highest soil total Acari abundance was recorded in T₁₀ (4.33) and least soil total Acari recorded in T₈ (1.00).

Table 4: Impact of organic manure and fertilizers on the abundance of soil total Acari in soybean ecosystem during cropping season.

Treatments	Number of soil total Acari / 400g of soil at days after germination								
	BAT	10	20	30	45	60	90	105	Mean
T ₁	2.33 (1.56)	4.67 (2.24)	1.00 (1.17)	3.33 (1.93)	8.00 (2.87)	15.33 (3.94)	22.00 (4.71)	26.67 (5.11)	10.42 (3.24) ^{bcd}
T ₂	1.67 (1.46)	5.67 (2.33)	5.67 (2.32)	6.00 (2.54)	14.67 (3.51)	14.00 (3.71)	36.00 (6.03)	36.00 (6.03)	14.96 (3.48) ^{bc}
T ₃	2.67 (1.77)	3.00 (1.85)	5.33 (2.40)	5.33 (2.38)	9.00 (3.05)	9.33 (3.09)	39.00 (6.19)	38.67 (6.25)	14.04 (3.37) ^{bc}
T ₄	1.00 (1.17)	3.33 (1.89)	3.00 (1.83)	7.33 (2.79)	16.00 (3.97)	15.00 (3.84)	40.67 (6.31)	35.00 (5.92)	15.17 (3.56) ^b
T ₅	2.00 (1.56)	8.33 (2.94)	9.00 (3.02)	25.00 (4.94)	27.33 (5.02)	22.67 (4.50)	52.67 (7.23)	59.33 (7.68)	25.79 (5.10) ^a
T ₆	1.00 (1.17)	1.00 (1.17)	4.33 (2.12)	7.33 (2.79)	15.67 (3.88)	7.33 (2.78)	18.00 (4.25)	29.67 (5.44)	10.54 (3.25) ^{bc}
T ₇	1.67 (1.38)	2.67 (1.71)	3.67 (1.85)	7.33 (2.67)	7.00 (2.65)	16.67 (4.09)	35.00 (5.91)	22.00 (4.71)	12.00 (3.33) ^{bc}
T ₈	1.00 (1.09)	4.67 (2.17)	8.67 (2.86)	8.67 (3.01)	4.33 (2.14)	13.33 (3.61)	14.00 (3.78)	20.00 (4.52)	9.33 (3.01) ^{cde}
T ₉	1.00 (1.17)	4.33 (2.08)	2.67 (1.77)	6.00 (2.54)	6.00 (2.40)	6.00 (2.53)	17.33 (4.20)	21.00 (4.59)	8.04 (2.66) ^e
T ₁₀	4.33 (1.94)	2.67 (1.76)	4.00 (2.03)	5.67 (2.43)	5.33 (2.40)	6.67 (2.64)	21.67 (4.59)	19.00 (4.32)	8.67 (2.77) ^{de}
Mean	1.87 (1.43)	4.03 (2.02)	4.73 (2.14)	8.20 (2.81)	11.33 (3.19)	12.33 (3.48)	29.63 (5.32)	30.73 (5.46)	
								S.Em±	CD @ 5%
Treatment								0.16	0.48
Days								0.14	0.43
Interaction								0.48	1.36

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values, BAT = Before application of treatments

Higher abundance of soil total Acari (8.33) was recorded in 20 tonnes of FYM treated plot at 10 DAG but there was no significant difference among the treatments except T₆ (1.00).

Significantly higher abundance of soil total Acari was recorded in T₅ (25.00) at 30 DAG. There was no significant difference in soil total Acari population among rest of the treatments. However, least soil total Acari abundance was recorded in T₁ (3.33).

Significant difference in total Acari population was observed among treatments at 90 DAG. Significantly higher soil total Acari abundance was found in T₅ (52.67) compared to other treatments except T₄, T₃, T₂ and T₇. However, rest of the treatments were on par in Acari population with T₉ (17.33).

Significantly higher abundance of soil total Acari was recorded in T₅ (59.33) at 105 DAG compared to rest of the treatments. Least abundance of soil total Acari was in T₁₀ (19.00).

4.1.3 Impact of different doses of organic manure along with chemical fertilizers on the abundance of soil cryptostigmatids during cropping season:

The results of the impact of FYM and chemical fertilizers on the abundance of soil cryptostigmatids in soybean ecosystem are presented in the table 5.

4.1.3.1 Treatment effect:

Significant difference in abundance of soil cryptostigmatids was noticed among the treatments. Higher soil cryptostigmatids abundance was recorded in 20 tonnes of FYM (13.25 cryptostigmatids / 400 g of soil) applied treatment. Significantly least soil cryptostigmatids was noticed in the plot treated with the recommended fertilizer alone (3.5

cryptostigmatids / 400g of soil) which was on par with remaining treatments except T₃, T₄ and T₂.

4.1.3.2 Duration effect:

There was a significant difference in abundance of soil cryptostigmatids in soybean ecosystem among the intervals. Soil cryptostigmatids population was significantly high at 45 DAG (9.33) which was on par with 90 (7.77 cryptostigmatids / 400g of soil), 60 (7.60 cryptostigmatids / 400g of soil) and 105 DAG (7.23 cryptostigmatids / 400g of soil). Significantly least cryptostigmatids population were recorded at before application of treatments (1.70 cryptostigmatids / 400g of soil).

4.1.3.3 Interaction effect:

There was no significant difference among the treatments at before application of treatment. However, higher soil cryptostigmatids abundance was recorded in T₁₀ (3.67 cryptostigmatids / 400g of soil) and least cryptostigmatids abundance was noticed in 12.5 t of FYM + 75 % recommended fertilizer treated plot (0.67 cryptostigmatids / 400g of soil).

There was a significant difference among the treatments at 10 DAG. Significantly higher abundance of soil cryptostigmatids was recorded in T₅ (6.00 cryptostigmatids / 400g of soil) which was on par with the rest of the treatments except the plot treated with recommended FYM (1.00 cryptostigmatids / 400g of soil).

Higher soil cryptostigmatids abundance was recorded in T₅ (19.33 cryptostigmatids / 400g of soil) at 30 DAG and significantly least population was found in recommended package of practices followed plot (3.33) which was on par with rest of the treatments except T₅.

Table 5: Impact of organic manure and fertilizers on the abundance of Cryptostigmatids in soybean ecosystem during cropping season.

Treatments	Number of Cryptostigmatids / 400g of soil at days after germination								
	BAT	10	20	30	45	60	90	105	Mean
T ₁	2.33 (1.56)	3.33 (1.77)	1.00 (1.17)	3.33 (1.93)	7.00 (2.70)	8.33 (2.95)	6.33 (2.58)	7.00 (2.65)	4.83 (2.16) ^{bc}
T ₂	0.67 (1.05)	5.33 (2.28)	5.33 (2.27)	6.00 (2.54)	13.00 (2.35)	9.00 (3.01)	5.33 (2.28)	7.67 (2.85)	6.54 (2.45) ^b
T ₃	2.33 (1.67)	2.67 (1.77)	3.33 (1.95)	4.33 (2.18)	7.67 (2.83)	6.00 (2.53)	8.33 (2.93)	9.00 (3.06)	5.46 (2.36) ^b
T ₄	1.33 (1.26)	3.00 (1.72)	2.67 (1.76)	5.00 (2.34)	10.00 (3.22)	8.00 (2.85)	14.00 (3.73)	4.00 (2.08)	6.00 (2.38) ^b
T ₅	2.00 (1.55)	6.00 (2.51)	8.00 (2.80)	19.33 (4.39)	25.67 (4.87)	14.00 (3.63)	17.00 (4.01)	14.00 (3.77)	13.25 (3.44) ^a
T ₆	1.00 (1.17)	1.00 (1.17)	4.00 (2.02)	5.33 (2.41)	13.00 (3.50)	5.00 (2.31)	4.67 (2.17)	6.33 (2.54)	5.04 (2.16) ^{bc}
T ₇	1.67 (1.38)	2.33 (1.64)	3.00 (1.72)	5.67 (2.32)	4.67 (2.22)	9.33 (3.10)	6.67 (2.61)	6.00 (2.53)	4.92 (2.19) ^{bc}
T ₈	1.00 (1.09)	4.33 (2.08)	8.00 (2.73)	6.00 (2.54)	3.00 (1.85)	8.33 (2.91)	5.67 (2.46)	5.67 (2.43)	5.25 (2.26) ^{bc}
T ₉	1.00 (1.17)	2.67 (1.66)	1.33 (1.28)	4.67 (2.26)	5.00 (2.22)	4.00 (2.11)	3.67 (2.01)	5.67 (2.38)	3.50 (1.89) ^c
T ₁₀	3.67 (1.84)	2.67 (1.76)	2.00 (1.46)	4.00 (2.09)	4.33 (2.19)	4.00 (2.08)	6.00 (2.45)	7.00 (2.68)	4.21 (2.07) ^{bc}
Mean	1.70 (1.37)	3.33 (1.83)	3.87 (1.92)	6.37 (2.50)	9.33 (2.89)	7.60 (2.75)	7.77 (2.72)	7.23 (2.70)	
								S.Em±	CD @ 5%
Treatment								0.14	0.41
Days								0.12	0.36
Interaction								0.41	1.16

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values, BAT = Before application of treatments

There was a significant difference in cryptostigmatids population among treatments at 45 DAG. Higher soil cryptostigmatids abundance was recorded T₅ (25.67 cryptostigmatids / 400g of soil). The least cryptostigmatids population were recorded in T₈ (3.00) which was on par with remaining treatments except T₃, T₄ and T₆.

Significantly higher soil cryptostigmatids abundance was recorded in T₅ (14.00) at 105 DAG. Least abundance was observed in T₄ (4.00) followed by recommended dose of fertilizer applied plot (5.67) which were on par with the rest of the treatments except T₅.

4.1.4 Impact of different doses of organic manure along with chemical fertilizers on the abundance of soil other Acari during cropping season:

Data regarding the effect of FYM and chemical fertilizers on the abundance of soil other Acari in soybean ecosystem are presented in the table 6.

4.1.4.1 Treatments effect:

Significant difference in abundance of soil other Acari was noticed among the treatments. Higher soil other Acari abundance was recorded in 20 t of FYM treated plot (12.58 other Acari / 400 g of soil) followed by T₄ (9.21 other Acari / 400 g of soil). Least soil other Acari were noticed in T₈ (4.08 other Acari / 400g of soil) which was on par with remaining treatments except T₂, T₄ and T₅.

4.1.4.2 Duration effect:

There was a significant difference in abundance of soil other Acari among the intervals in soybean ecosystem. It varied from 0.23 at BAT to 23.50 at 105 DAG. Soil other Acari population was significantly high at 105 DAG followed by 90 DAG (22.03). Significantly least other Acari was

observed in before application of treatment (0.23) which was on par with 10 (0.67) and 20 DAG (0.83).

4.1.4.3 Interaction effect:

There was no significant difference among the treatments at BAT. However, highest soil other Acari abundance was recorded in T₂ (1.00) and no activity of other acari was noticed in T₉, T₈, T₇, T₆, T₄ and T₁.

At 10 DAG, soil other Acari abundance showed no significant difference. However, higher soil other Acari abundance was documented in T₅ (2.33) and other acari population was not found in T₁₀ and T₆.

There was a significant difference in the other Acari abundance among the treatments at 45 DAG. Significantly higher soil other Acari abundance was recorded in T₄ (6.00) and rests of the treatments were on par with each other with least abundance in T₁₀, T₉ and T₁ (1.00 each).

Significantly higher abundance of soil other Acari was recorded in T₅ (45.33) at 105 DAG. Treatment with 50 % of recommended FYM treatment showed least soil other Acari (12.00) followed by T₈ (14.33) and T₉ (15.33).

4.1.5 Impact of different doses of organic manure along with chemical fertilizers on the abundance of soil other invertebrates during cropping season:

Data regarding the effect of FYM and chemical fertilizers on the abundance of soil other invertebrates in soybean ecosystem are presented in the table 7.

4.1.5.1 Treatments effect:

Significant difference in abundance of soil other invertebrates was noticed among the treatments. Significantly higher soil other

Table 6: Impact of organic manure and fertilizer on the abundance of other Acari in soybean ecosystem during cropping season.

Treatments	Number of other Acari / 400g of soil at days after germination								
	BAT	10	20	30	45	60	90	105	Mean
T ₁	0.00 (0.70)	1.33 (1.26)	0.00 (0.70)	0.00 (0.70)	1.00 (1.17)	7.00 (2.67)	15.67 (3.97)	19.67 (4.41)	5.58 (2.15) ^{cd}
T ₂	1.00 (1.17)	0.33 (0.87)	0.33 (0.87)	0.00 (0.70)	1.67 (1.25)	5.00 (2.28)	31.67 (5.51)	28.33 (5.36)	8.54 (2.49) ^c
T ₃	0.33 (0.87)	0.33 (0.87)	1.33 (1.18)	1.00 (1.17)	1.33 (1.34)	3.33 (1.90)	30.67 (5.50)	29.67 (5.48)	8.50 (2.35) ^{cd}
T ₄	0.00 (0.70)	0.33 (0.87)	0.33 (0.87)	2.33 (1.67)	6.00 (2.34)	7.00 (2.65)	26.67 (5.07)	31.00 (5.59)	9.21 (3.01) ^b
T ₅	0.33 (0.87)	2.33 (1.49)	1.00 (1.17)	5.67 (2.32)	1.67 (1.38)	8.67 (2.74)	35.67 (5.94)	45.33 (6.72)	12.58 (3.43) ^a
T ₆	0.00 (0.70)	0.00 (0.70)	0.33 (0.87)	2.00 (1.55)	2.67 (1.61)	2.33 (1.67)	13.33 (3.53)	23.33 (4.85)	5.50 (2.14) ^{cd}
T ₇	0.00 (0.70)	0.33 (0.87)	1.00 (1.17)	1.67 (1.46)	2.33 (1.59)	7.33 (2.75)	28.33 (5.33)	16.00 (4.01)	7.13 (2.24) ^{cd}
T ₈	0.00 (0.70)	0.33 (0.87)	0.67 (1.05)	2.67 (1.76)	1.33 (1.26)	5.00 (2.21)	8.33 (2.95)	14.33 (3.83)	4.08 (2.01) ^d
T ₉	0.00 (0.70)	1.33 (1.26)	1.33 (1.26)	1.33 (1.26)	1.00 (1.17)	2.00 (1.55)	13.67 (3.71)	15.33 (3.95)	4.50 (2.08) ^d
T ₁₀	0.67 (0.99)	0.00 (0.70)	2.00 (1.52)	1.67 (1.38)	1.00 (1.17)	2.67 (1.73)	16.33 (3.98)	12.00 (3.46)	4.54 (2.09) ^d
Mean	0.23 (0.81)	0.67 (0.98)	0.83 (1.07)	1.83 (1.41)	2.00 (1.43)	5.03 (2.22)	22.03 (4.55)	23.50 (4.77)	
								S.Em±	CD @ 5%
Treatment								0.13	0.37
Days								0.12	0.33
Interaction								0.38	1.06

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values, BAT = Before application of treatments

invertebrates abundance was recorded in T₅ (12.17 soil other invertebrates / 400 g of soil) compared to other treatments. Least soil other invertebrates were noticed in T₉ (4.70 soil other invertebrates / 400g of soil) which was on par with rest of the treatments except T₄, T₃ and T₅.

4.1.5.2 Duration effect:

Abundance of soil other invertebrates in soybean crop differs significantly among the intervals. It varied from 2.87 (BAT) to 10.23 (90 DAG). Soil other invertebrates population was significantly high at 90 DAG compared to other intervals. Least population of other invertebrates was observed at BAT and was on par with 10 and 20 DAG.

4.1.5.3 Interaction effect:

There was a significant difference among the treatments at BAT. Highest soil other invertebrates abundance was recorded in T₈ (6.33) and was on par with remaining treatments except T₂ and T₆ (1.33 each). Recommended dose of FYM treated plot and T₂ harboured least soil other invertebrate's abundance.

Significant difference in other invertebrate population was noticed among the treatment at 10 DAG. Higher abundance of soil other invertebrates was recorded in T₅ (6.00) which was on par with rest of the treatments except T₇ (1.33) which harboured least number of other invertebrate population.

At 30 DAG, soil other invertebrates abundance showed significant difference among the treatments. Significantly higher other invertebrates abundance was recorded in T₅ (19.00) followed by T₃ (12.33) which was on par with rest of the treatments except T₇ (4.00), T₁₀ (3.67) and recommended fertilizer alone applied plot (2.33).

Table 7: Impact of organic manure and fertilizers on the abundance of other invertebrates in soybean ecosystem during cropping season.

Treatments	Number of other invertebrates / 400g of soil at days after germination								
	BAT	10	20	30	45	60	90	105	Mean
T ₁	4.00 (2.11)	2.33 (1.64)	2.33 (1.49)	6.33 (2.61)	6.00 (2.53)	8.67 (2.88)	9.33 (3.10)	5.67 (2.48)	5.71 (2.38) ^{bcd}
T ₂	1.33 (1.26)	3.67 (2.02)	2.33 (1.59)	7.33 (2.71)	4.33 (2.16)	7.33 (1.49)	6.00 (2.38)	4.67 (2.25)	4.70 (2.16) ^d
T ₃	1.67 (1.38)	2.67 (1.73)	4.00 (2.11)	12.33 (3.54)	8.67 (2.96)	4.00 (1.96)	18.00 (4.17)	10.00 (3.23)	7.79 (2.68) ^b
T ₄	1.67 (1.38)	2.33 (1.67)	4.33 (1.97)	9.00 (3.01)	12.33 (3.55)	8.33 (2.75)	11.67 (3.43)	6.67 (2.64)	7.17 (2.59) ^{bc}
T ₅	4.67 (2.22)	6.00 (2.54)	4.33 (2.12)	19.00 (4.35)	15.33 (3.96)	15.00 (3.83)	19.67 (4.25)	12.33 (3.53)	12.17 (3.36) ^a
T ₆	1.33 (1.26)	2.67 (1.73)	3.67 (2.03)	6.33 (2.60)	4.00 (2.11)	5.00 (2.04)	5.33 (2.35)	8.33 (2.83)	4.71 (2.17) ^{cd}
T ₇	1.67 (1.38)	1.33 (1.26)	5.33 (2.31)	4.00 (2.11)	7.67 (2.84)	14.33 (3.70)	8.33 (2.93)	7.00 (2.66)	6.33 (2.45) ^{bcd}
T ₈	6.33 (2.60)	3.33 (1.89)	7.00 (2.65)	7.33 (2.72)	2.67 (1.73)	7.33 (2.49)	6.33 (2.56)	8.00 (2.87)	6.17 (2.43) ^{bcd}
T ₉	2.67 (1.73)	3.67 (1.96)	3.67 (1.96)	2.33 (1.67)	3.00 (1.70)	7.33 (2.75)	8.33 (2.91)	6.00 (2.54)	4.70 (2.16) ^d
T ₁₀	3.33 (1.90)	3.67 (2.01)	6.67 (2.60)	3.67 (2.02)	2.00 (1.55)	8.33 (2.96)	9.33 (3.13)	11.67 (3.47)	6.21 (2.48) ^{bcd}
Mean	2.87 (1.81)	3.17 (1.85)	4.37 (2.08)	7.77 (2.73)	6.60 (2.51)	8.57 (2.78)	10.23 (3.11)	8.03 (2.85)	
								S.Em±	CD @ 5%
Treatment								0.14	0.42
Days								0.13	0.38
Interaction								0.42	1.20

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values, BAT = Before application of treatments

Soil other invertebrates abundance was significantly different among the treatments at 90 DAG. The higher soil other invertebrates abundance was recorded in T₅ (19.67) followed by T₃ (18.00). Least soil other invertebrates abundance was documented in T₆ (5.33) which was on par with remaining treatments except T₃ and T₅.

4.1.6 Impact of different doses of organic manure and chemical fertilizers on the abundance of soil invertebrates during non-cropping season:

The data on the impact of organic manure and chemical fertilizers on the abundance of soil invertebrates during non-cropping season are presented in the table 8.

4.1.6.1 Treatments effect:

Significantly higher soil invertebrates abundance was recorded in T₃ (11.96 invertebrates / 400g of soil) followed by T₆ (invertebrates / 400g of soil 11.69) which was on par with remaining treatments except T₄ (9.63) and T₉ (8.75) during non-cropping season. Significantly least abundance was recorded in recommended dose of fertilizer alone treated plot (8.75 invertebrates / 400g of soil).

4.1.6.2 Duration effect:

Abundance of soil invertebrates differs significantly among the intervals. Significantly higher soil invertebrates abundance was recorded at 120 DAG (39.03 invertebrates / 400g of soil) compared to rest of the treatments. It was followed by 150 DAG (14.86) and 135 DAG (15.03). Least abundance of soil invertebrates was recorded at 225 DAG (4.00).

4.1.6.3 Interaction effect:

Significantly higher soil invertebrates abundance was observed in T₅ (50.67 invertebrates / 400g of soil) at 120 DAG. Least abundance was

Table 8: Impact of organic manure and fertilizers on the abundance of soil invertebrates in soybean ecosystem during non-cropping season.

Treatments	Number of soil invertebrates / 400g of soil at days after germination											
	120	135	150	165	180	195	210	225	240	255	270	Mean
T ₁	39.67 (6.32)	16.33 (4.04)	15.33 (3.91)	13.00 (3.63)	6.00 (2.52)	3.00 (1.85)	4.00 (2.11)	7.67 (2.83)	5.67 (2.46)	3.00 (1.82)	8.33 (2.91)	11.09 (3.40) ^{abc}
T ₂	38.00 (6.18)	13.33 (3.65)	12.33 (3.52)	6.33 (2.61)	11.67 (3.44)	2.33 (1.64)	2.33 (1.64)	3.00 (1.78)	5.33 (2.40)	2.00 (1.55)	10.67 (3.29)	9.75 (3.20) ^{bcd}
T ₃	41.00 (6.42)	17.67 (4.20)	24.33 (4.96)	18.33 (4.29)	4.00 (2.08)	8.33 (2.95)	2.67 (1.73)	3.33 (1.93)	3.00 (1.61)	7.67 (2.85)	1.33 (1.28)	11.96 (3.52) ^a
T ₄	36.33 (6.05)	7.00 (2.72)	12.67 (3.59)	6.67 (2.65)	7.67 (2.84)	9.33 (3.07)	7.33 (2.77)	4.00 (2.08)	2.67 (1.64)	8.67 (3.00)	3.67 (1.79)	9.63 (3.18) ^{cd}
T ₅	50.67 (7.12)	15.33 (3.92)	18.33 (4.20)	7.33 (2.74)	3.33 (1.95)	5.33 (2.41)	7.00 (2.72)	1.67 (1.44)	4.00 (2.08)	1.67 (1.35)	9.33 (3.10)	11.27 (3.43) ^{ab}
T ₆	44.00 (6.65)	26.67 (5.17)	19.33 (4.38)	12.67 (3.57)	3.00 (1.85)	3.67 (2.00)	3.00 (1.81)	3.00 (1.81)	4.33 (2.18)	5.00 (2.28)	4.00 (2.08)	11.69 (3.49) ^{ab}
T ₇	39.33 (6.25)	18.67 (4.35)	8.67 (3.00)	9.67 (3.11)	9.33 (3.12)	7.00 (2.72)	3.67 (2.01)	3.67 (1.96)	9.67 (3.14)	3.33 (1.94)	5.67 (2.44)	10.78 (3.35) ^{abc}
T ₈	34.33 (5.88)	16.67 (4.09)	15.00 (3.91)	15.67 (4.00)	10.33 (3.25)	6.33 (2.59)	1.67 (1.46)	3.33 (1.90)	4.33 (1.98)	5.00 (2.32)	5.33 (2.16)	10.72 (3.34) ^{abcd}
T ₉	29.33 (5.43)	9.33 (3.10)	11.00 (3.38)	9.67 (3.10)	7.67 (2.80)	2.67 (1.77)	3.33 (1.93)	6.67 (2.65)	8.33 (2.91)	2.67 (1.61)	5.67 (2.47)	8.75 (3.04) ^d
T ₁₀	37.67 (6.16)	9.33 (3.01)	11.67 (3.46)	12.33 (3.52)	10.00 (3.23)	8.67 (3.00)	5.33 (2.24)	3.67 (2.00)	4.00 (2.09)	4.67 (2.22)	6.33 (2.60)	10.33 (3.29) ^{abcd}
Mean	39.03 (6.25)	15.03 (3.82)	14.86 (3.83)	11.16 (3.32)	7.30 (2.71)	5.67 (2.40)	4.03 (2.04)	4.00 (2.04)	5.13 (2.25)	4.36 (2.09)	6.03 (2.41)	
											S.Em±	CD @ 5%
Treatment											0.10	0.30
Days											0.11	0.31
Interaction											0.35	1.00

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values

noticed in T₉ (29.33) which was on par with rest of the treatments except T₆ (44.00) and T₅ (50.67).

Abundance of soil invertebrates differs significantly among the treatments at 150 DAG. Significantly higher abundance was observed in T₃ (24.33 invertebrates / 400g of soil) which was on par with T₆ (19.33) and T₅ (18.33). Remaining treatments were on par with recommended fertilizer alone applied plot (11.00).

There was significant difference in soil invertebrate's population among the treatment at 210 DAG. Soil invertebrate's abundance was significantly higher in T₄ (7.33). Least Soil invertebrate's population was noticed in T₈ (1.67).

At 240 DAG, soil invertebrate's abundance showed significance difference among the treatments. Significantly higher soil invertebrates abundance was observed in T₇ (9.67 invertebrates / 400g of soil) and least number was found in T₃ (3.00).

T₂ (10.67 invertebrates / 400g of soil) recorded significantly higher soil invertebrates abundance at 270 DAG. Least abundance of soil invertebrates was observed in T₃ (1.33) which was on par with T₄ (3.67), T₆ (4.00) and T₈ (5.33).

4.1.7 Impact of different doses of organic manure and chemical fertilizers on the abundance of soil macro-arthropods during cropping season:

The data on the impact of different doses of organic manure on the activity of soil macro-arthropods is given in the Table 9.

4.1.7.1 Treatments effect:

There was no significant difference among the treatments for soil macro-arthropods population. However, higher soil macro-arthropods abundance was recorded in plot treated with recommended doses FYM + mulching of glyricidia, 2t per ha (6.37) and least population was observed in T₁₀ and T₄ (5.25 each).

4.1.7.2 Duration effect:

The macro-arthropods were significantly high at 90 DAG (7.63) followed by 60 DAG (7.30) and significantly least activity of macro-arthropods was recorded at BAT (2.63).

4.1.7.3 Interaction effect:

There was no significant difference in macro-arthropods population among the treatments at BAT. However, the population ranged from 1.00 to 4.67 in T₃ and recommended fertilizer alone applied treatments, respectively.

Soil macro-arthropods population showed no significant difference among the treatments at 10 DAG. However, higher population was noticed in 20t of FYM treated plot (5.67) and least soil macro-arthropods activity was recorded in T₉ (2.67).

Higher soil macro-arthropods activity was recorded in T₃ (9.33) at 30 DAG which was on par with remaining treatments except the plot treated with recommended dose of partially decomposed FYM (3.00) which harboured least number of macro-arthropods.

At 90 DAG, soil macro-arthropods population was significantly higher in T₇ (12.33). Least macro-arthropod abundance was noticed in T₄

Table 9: Impact of organic manure and fertilizers on the abundance of soil macro-arthropods during cropping season.

Treatments	Number of soil macro-arthropods at days after germination (#/trap).								
	BAT	10	20	30	45	60	90	105	Mean
T ₁	3.67 (2.03)	3.67 (2.00)	6.00 (2.52)	5.33 (2.28)	9.33 (3.09)	8.33 (2.86)	6.33 (2.42)	5.33 (2.28)	6.00 (2.41)
T ₂	2.00 (1.55)	3.33 (1.89)	4.67 (2.17)	6.00 (2.52)	3.00 (1.85)	9.33 (2.87)	9.67 (3.17)	6.67 (2.50)	5.58 (2.32)
T ₃	1.00 (1.22)	5.33 (2.32)	6.00 (2.46)	9.33 (3.11)	8.67 (2.98)	5.33 (2.33)	9.67 (3.08)	4.67 (2.20)	6.25 (2.46)
T ₄	2.67 (1.77)	5.33 (2.28)	6.33 (2.59)	8.67 (2.84)	3.00 (1.85)	6.33 (2.52)	3.00 (1.85)	6.67 (2.64)	5.25 (2.29)
T ₅	3.33 (1.93)	5.67 (2.46)	4.33 (2.18)	5.00 (2.33)	10.00 (3.23)	6.67 (2.51)	8.00 (2.91)	5.00 (2.26)	6.00 (2.41)
T ₆	1.33 (1.28)	3.33 (1.95)	5.33 (2.33)	8.33 (2.82)	5.67 (2.46)	7.00 (2.73)	6.00 (2.52)	5.00 (2.30)	5.25 (2.30)
T ₇	1.67 (1.44)	3.67 (2.00)	6.00 (2.49)	3.00 (1.85)	4.67 (2.17)	5.33 (2.35)	12.33 (3.50)	9.00 (3.01)	5.70 (2.35)
T ₈	3.33 (1.90)	5.33 (2.29)	2.33 (1.64)	5.67 (2.40)	9.00 (2.97)	8.00 (2.76)	8.00 (2.86)	9.33 (2.96)	6.37 (2.47)
T ₉	4.67 (2.20)	2.67 (1.66)	3.67 (2.00)	4.67 (2.22)	10.67 (3.24)	9.00 (2.96)	6.67 (2.66)	7.33 (2.58)	6.16 (2.43)
T ₁₀	2.67 (1.64)	4.33 (2.18)	6.00 (2.40)	7.67 (2.84)	3.00 (1.85)	7.67 (2.79)	6.67 (2.62)	4.00 (2.02)	5.25 (2.29)
Mean	2.63 (1.70)	4.26 (2.10)	5.06 (2.28)	6.36 (2.52)	6.70 (2.57)	7.30 (2.67)	7.63 (2.76)	6.30 (2.47)	
								S.Em±	CD @ 5%
Treatment								0.14	NS
Days								0.12	0.36
Interaction								0.41	1.16

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values, BAT = Before application of treatments

(3.00) which was on par with rest of the treatments except T₃ (9.67), T₂ (9.67) and T₇ (12.33).

There was no significant difference in soil macro-arthropods population among the treatments at 105 DAG. However, it ranged from 4.00 to 9.00 in T₁₀ and T₇, respectively.

4.1.8 Impact of different doses of organic manure and chemical fertilizers on the abundance of soil macro-arthropods during non-cropping season:

The data regarding the impact of different doses of organic manure on soil macro-arthropods during non-cropping season is given in the table 10.

4.1.8.1 Treatments effect:

There was no significant difference in soil macro-arthropods population among the treatments during non-cropping season. However, it ranged from 1.81 (T₇) to 2.48 (T₁) macro-arthropods per pitfall trap.

4.1.8.2 Duration effect:

Significantly higher macro-arthropods were collected at 240 DAG (3.20) followed by 270 DAG (2.76) which was on par with rest of the durations except 210 DAG (1.53) and 135 DAG (1.53) which harboured less number of soil macro-arthropods.

4.1.8.3 Interaction effect:

Significantly higher soil macro-arthropods activity was recorded in T₄ (4.33) than other treatments at 120 DAG and least number of soil macro-arthropods population was observed in T₅ and T₇ (1.00 each) which were on par with rest of the treatments except T₄ (4.33).

Table 10: Impact of organic manure and fertilizers on the abundance of soil macro-arthropods during non-cropping season.

Treatments	Number of soil macro-arthropods at days after germination (#/trap).											
	120	135	150	165	180	195	210	225	240	255	270	Mean
T ₁	2.33 (1.64)	1.00 (1.17)	2.00 (1.55)	2.00 (1.46)	3.00 (1.78)	2.00 (1.55)	1.33 (1.34)	3.00 (1.85)	4.67 (2.17)	2.33 (1.64)	3.67 (1.96)	2.48 (1.65)
T ₂	3.67 (2.00)	1.33 (1.34)	1.67 (1.46)	1.33 (1.26)	2.67 (1.76)	1.00 (1.17)	1.67 (1.35)	1.67 (1.38)	2.33 (1.64)	2.33 (1.64)	3.00 (1.85)	2.06 (1.53)
T ₃	2.00 (1.42)	1.00 (1.17)	5.00 (2.26)	1.00 (1.17)	2.00 (1.55)	1.67 (1.35)	2.00 (1.55)	3.00 (1.82)	2.33 (1.64)	1.33 (1.34)	3.67 (1.96)	2.27 (1.57)
T ₄	4.33 (2.15)	1.33 (1.18)	1.00 (1.17)	2.00 (1.55)	3.00 (1.72)	1.67 (1.38)	1.33 (1.26)	2.67 (1.77)	3.00 (1.61)	1.00 (1.22)	1.67 (1.38)	2.09 (1.49)
T ₅	1.00 (1.17)	1.00 (1.17)	1.00 (1.17)	2.00 (1.46)	2.33 (1.49)	3.00 (1.72)	1.33 (1.34)	2.33 (1.64)	3.33 (1.67)	1.00 (1.17)	2.33 (1.56)	1.87 (1.43)
T ₆	2.33 (1.64)	1.33 (1.34)	2.00 (1.55)	4.33 (1.89)	2.67 (1.71)	2.33 (1.64)	1.00 (1.22)	2.00 (1.58)	3.67 (2.00)	1.67 (1.38)	2.33 (1.64)	2.33 (1.60)
T ₇	1.00 (1.17)	1.00 (1.17)	2.00 (1.46)	2.33 (1.56)	3.00 (1.78)	2.00 (1.55)	1.67 (1.38)	0.67 (1.05)	2.67 (1.73)	2.00 (1.46)	1.67 (1.38)	1.81 (1.41)
T ₈	4.33 (1.99)	1.67 (1.38)	1.33 (1.26)	2.00 (1.55)	2.67 (1.76)	1.00 (1.17)	1.33 (1.26)	2.00 (1.55)	5.00 (2.11)	1.33 (1.34)	3.33 (1.79)	2.36 (1.56)
T ₉	1.33 (1.34)	1.67 (1.35)	1.00 (1.22)	1.33 (1.26)	1.67 (1.44)	2.00 (1.46)	2.33 (1.64)	2.67 (1.73)	2.33 (1.64)	2.00 (1.52)	4.00 (1.96)	2.03 (1.50)
T ₁₀	2.00 (1.55)	4.00 (2.00)	1.67 (1.46)	1.00 (1.17)	1.67 (1.38)	3.33 (1.93)	1.33 (1.26)	3.67 (2.00)	2.67 (1.61)	2.00 (1.55)	2.00 (1.55)	2.30 (1.59)
Mean	2.43 (1.61)	1.53 (1.32)	1.86 (1.46)	1.93 (1.48)	2.46 (1.64)	2.00 (1.49)	1.53 (1.36)	2.36 (1.64)	3.20 (1.78)	1.70 (1.43)	2.76 (1.70)	
											S.Em±	CD @ 5%
Treatment											0.09	NS
Days											0.09	0.29
Interaction											0.33	0.92

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values

Soil macro-arthropods activity was significantly higher in T₃ (5.00). Significantly least abundance was observed in T₅ (1.00) and showed on par in activity of soil macro-arthropods with rest of the treatments except T₃ (5.00) at 255 DAG.

Soil macro-arthropods population showed no significant difference at 210 DAG. However, the population ranged from 1.00 to 2.33 in T₆ and T₉, respectively.

At 240 DAG, the activity of soil macro-arthropods showed no significant difference. However, the abundance ranged from 2.67 to 4.67 in T₁₀ and T₁, respectively.

4.1.9 Effect of organic manures and chemical fertilizers on the abundance of soil nematodes:

The results of the impact of FYM, chemical fertilizers and their interaction on the abundance of soil nematodes in soybean ecosystem are presented in the table 11.

4.1.9.1 Treatment effect:

There was a significant difference in abundance of nematodes among the treatments. Significantly higher nematodes population was noticed in T₂ (235.11 nematodes / 100g soil) and was on par with rest of the treatment except T₁₀ (178.44), T₉ (174.11) and T₆ (171.11). Significantly lower nematodes population was observed in T₆ (171.11 nematodes / 100g soil).

4.1.9.2 Duration effect:

Nematodes abundance showed significant difference among the intervals. Significantly lower nematodes abundance was found at 120 DAG (135.36 nematodes / 100g soil) followed by 60 DAG (226.43

Table 11: Impact of organic manure and fertilizers on the abundance of soil nematodes during cropping season.

Treatments	Number of nematodes/100g of soil at days after germination			
	60	90	120	Mean
T ₁ . Rec. fertilizers (25:60:25: NPK Kg ha ⁻¹) + Rec. FYM (10 t ha ⁻¹) + Phorate 10G @ 1 kg <i>a.i.</i> ha ⁻¹ + herbicide (Lasso 50 EC @ 2.5 lit per ha) + fungicide seed treatment (Thiram + Bavistin- each 2g/kg of seeds).	286.33 (16.80)	265.33 (16.30)	116.00 (10.78)	222.55 (14.63) ^{cd}
T ₂ . 12.5 tonnes of FYM + 75 per cent of recommended fertilizer.	218.00 (14.74)	344.00 (18.54)	143.33 (11.96)	235.11 (15.08) ^d
T ₃ . 15.0 tonnes of FYM + 50 per cent of recommended fertilizer.	195.33 (13.99)	312.33 (17.67)	128.33 (11.32)	212.00 (14.33) ^{bcd}
T ₄ . 17.5 tonnes of FYM + 25 per cent of recommended fertilizer.	204.33 (14.27)	251.00 (15.84)	131.00 (11.43)	195.44 (13.85) ^{abcd}
T ₅ . 20.0 tonnes of FYM.	254.00 (15.90)	257.00 (16.03)	157.67 (12.55)	222.88 (14.82) ^d
T ₆ . 10.0 tonnes of FYM.	158.00 (12.49)	226.67 (15.04)	128.67 (11.35)	171.11 (12.96) ^a
T ₇ . Recommended FYM (partially decomposed).	298.67 (16.88)	229.00 (15.12)	129.33 (11.28)	219.00 (14.40) ^{bcd}
T ₈ . Recommended FYM + mulching (Glyricidia 2 t ha ⁻¹).	260.00 (16.09)	189.33 (13.76)	146.00 (12.09)	198.44 (13.98) ^{abcd}
T ₉ . Recommended fertilizer alone.	222.33 (14.83)	178.33 (13.35)	121.67 (11.04)	174.11 (13.07) ^{ab}
T ₁₀ . 50 per cent of recommended FYM.	167.33 (12.91)	216.33 (14.71)	151.67 (12.28)	178.44 (13.30) ^{abc}
Mean	226.43 (14.88)	246.93 (15.64)	135.36 (11.61)	
			S.Em±	CD @ 5%
Treatment			0.47	1.35
Days			0.26	0.74
Interaction			0.82	2.35

Note: Figures in the parentheses are $\sqrt{X+0.5}$ transformed values

nematodes / 100g soil). Significantly higher nematodes abundance was noticed at 90 DAG (246.93 nematodes / 100g soil).

4.1.9.3 Interaction effect:

There was a significant difference in abundance of nematodes among the treatments at 60 DAG. T₆ (158.00 nematodes / 100g soil) harboured significantly least number of nematodes compared to T₅, T₈, T₁ and T₄. Significantly higher nematodes population was observed in T₇ (298.67 nematodes / 100g soil).

Significantly least nematodes population was observed in T₉ (178.33 nematodes / 100g soil) at 90 DAG and higher nematodes population was found in T₂ (344.00 nematodes / 100g soil) which was on par with T₃ (312.33 nematodes / 100g soil) and T₁ (265.33 nematodes / 100g soil).

4.1.10 Impact of different doses of organic manures and chemical fertilizers on the relative abundance of soil invertebrates during cropping season:

The relative abundance of soil invertebrates recorded in different treatments during cropping season is presented in table 12.

The cryptostigmatid mites were relatively more abundant in the plots treated with 20t of FYM (34.94%) and least relative abundance was noticed in T₃ (24.91%).

The relative abundance of other Acari was more in the plots treated with 12.5 t of FYM + 75% of recommended fertilizer (43.06%). However, least abundance of other Acari was noticed in plots treated with recommended FYM + mulching with glyricidia (26.32%).

Table 12: Impact of organic manure and fertilizers on the relative abundance of soil invertebrates during cropping season.

Relative abundance (%)										
Treatments	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
Cryptostigmatids	29.94	32.98	24.91	26.81	34.94	33.13	26.76	33.87	27.45	28.38
Other Acari	34.59	43.06	38.77	41.15	33.17	36.16	38.79	26.32	35.29	30.61
Total Acari	64.60	75.44	64.05	67.78	68.01	69.29	65.28	60.19	63.05	58.46
Other invertebrates	35.39	23.70	35.53	32.03	32.09	30.96	34.43	39.80	36.86	41.87

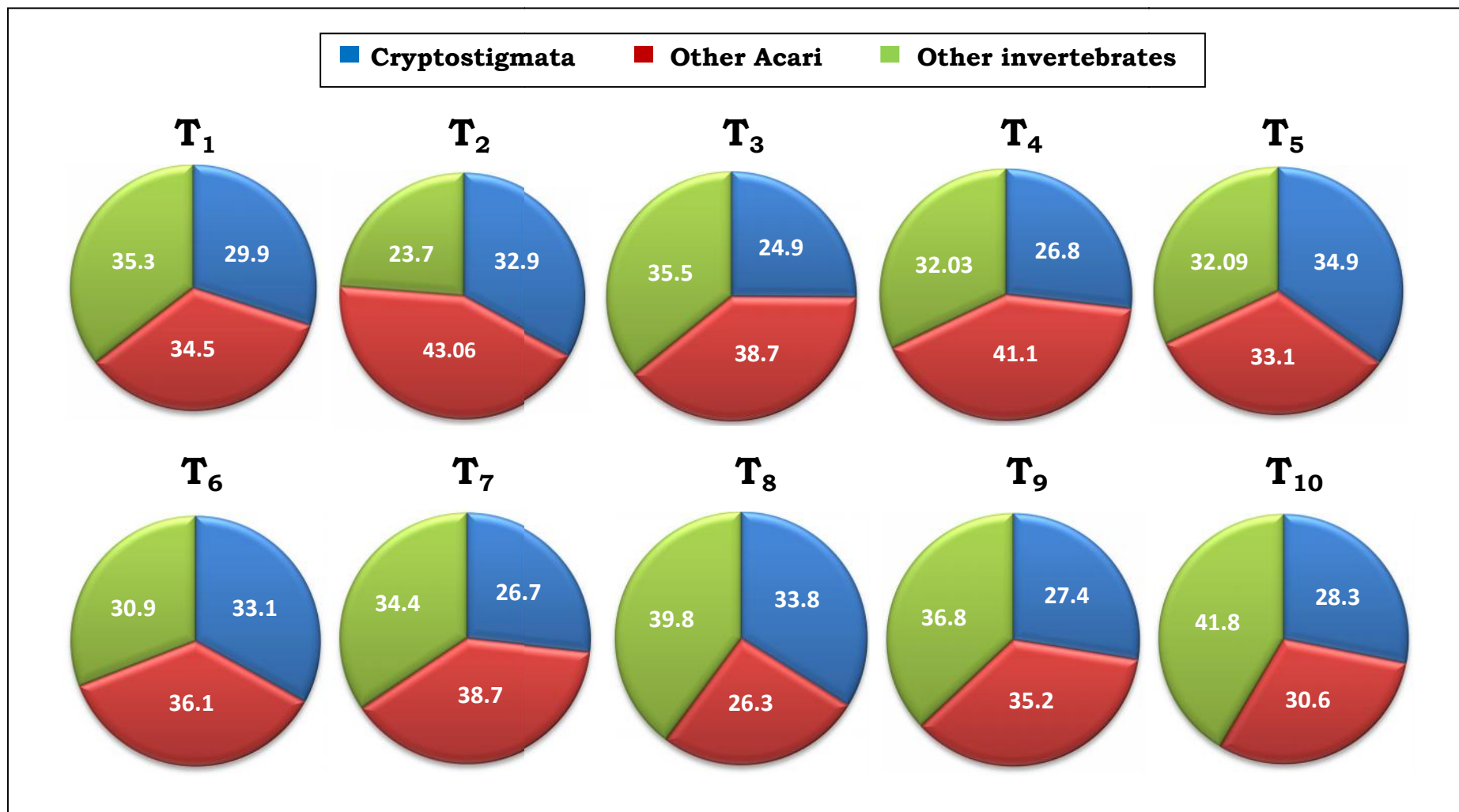


Fig. 2: Impact of organic manure and fertilizers on the relative abundance (%) of soil invertebrates during cropping season.

The relative abundance of total Acari was more in plots treated with 12.5 t of FYM + 75% of recommended fertilizer (75.44%). However, least relative abundance was recorded in plots treated with 50% of recommended FYM (58.46%).

More relative abundance of soil other invertebrates was observed in plots treated with 50% of recommended FYM (41.87%) and least was recorded in 12.5 t of FYM + 75% of recommended fertilizer treated plot (23.70%).

4.2 Effect of organic manures and chemical fertilizers on the agronomic parameters of soybean

4.2.1 Chemical properties of soil as influenced by different doses of FYM along with chemical fertilizers

Impact of different doses of FYM along with chemical fertilizers on soil organic carbon content, available nitrogen, available phosphorus, available potassium, exchangeable calcium, exchangeable magnesium, and soil pH are presented in table 13 and 14.

4.2.1.1 Organic carbon (%):

Significantly higher organic carbon content of soil was found in the 20 tonnes of FYM treated plot (0.68%) compared to other treatments. Significantly least organic carbon content of the soil was found in recommended dose of fertilizer alone treatment (0.43%) at before application of treatments. Modified treatments (3 to 8) recorded higher soil organic carbon content compared to T₁ and T₉ (Table 13).

Soil organic carbon content of the soil was significantly higher in 20 tonnes FYM treated plots (0.91%) compared to other treatments at 45 days after germination. Least organic carbon content of the soil was

found in the plots treated with recommended dose of fertilizer alone (0.60%) which was on par with T₁₀ (0.63%).

Significantly higher soil organic carbon content was recorded in T₅ (0.75%) at harvest also. Least organic carbon content of the soil was observed in recommended dose of fertilizer alone treatment (0.41%). The increase of soil organic carbon was 82.92% in T₅ over recommended dose of fertilizer at harvest. In rest of the treatments it varied from 21.95 (T₁₀) to 51.21% (T₄).

4.2.1.2 Available Phosphorus (P₂O₅):

At before application of treatments, available phosphorus content of the soil was significantly higher in T₅ (57.99 kg/ha) which was on par with T₄ (56.1 kg/ha) and T₂ (55.52 kg/ha) compared to other treatments. Further T₁ (50.20 kg/ha), T₆ (49.84 kg/ha) and T₇ (47.69 kg/ha) were on par with each other and least available phosphorus content was noticed in T₉ (39.28 kg/ha).

Significantly higher available phosphorus content of soil was found in 20 tonnes of FYM treated plot (77.74 kg/ha) at 45 days after germination. Further it was on par with T₁ (76.05 kg/ha) compared to other treatments. Significantly least available phosphorus content of soil was noticed in T₁₀ (59.45 kg/ha) which was on par with recommended dose of fertilizer alone treatment (59.81 kg/ha).

At harvest, available phosphorus content of the soil was significantly higher in T₅ (65.21 kg/ha) which was on par with T₁ (64.92 kg/ha) and T₃ (63.56 kg/ha). Significantly least available phosphorus content of soil was found in T₉ (51.86 kg/ha) which was on par with T₁₀ (51.98 kg/ha). The increase of available phosphorus was 25.74% in T₅ over recommended dose of fertilizer at harvest. In rest of the treatments it varied from 0.23 (T₁₀) to 25.18% (T₁).

Table 13: Impact of organic manures and fertilizers on soil organic carbon, available phosphorus and available potassium

Treatments	Organic carbon (%)				Av. Phosphorous (kg/ha)				Av. Potassium (kg/ha)			
	BAT	45DAG	At harvest	% increase over RDF	BAT	45DAG	At harvest	% increase over RDF	BAT	45DAG	At harvest	% increase over RDF
T1	0.50 ^{cd}	0.69 ^{cde}	0.52 ^{bc}	26.82	50.20 ^b	76.05 ^{ab}	64.92 ^a	25.18	237.44 ^{bc}	355.41 ^{cd}	274.77 ^{bc}	18.71
T2	0.50 ^{cd}	0.76 ^{bc}	0.55 ^{bc}	34.14	55.52 ^a	71.69 ^{cd}	58.82 ^d	13.42	249.39 ^{bc}	361.39 ^c	291.20 ^a	25.81
T3	0.55 ^{bc}	0.75 ^{bcd}	0.54 ^{bc}	31.71	44.85 ^c	69.62 ^{de}	63.56 ^{ab}	22.56	243.41 ^{bc}	349.44 ^{de}	282.24 ^{ab}	21.94
T4	0.58 ^{bc}	0.82 ^{ab}	0.62 ^{ab}	51.21	56.10 ^a	71.43 ^{cd}	61.91 ^{bc}	19.37	252.37 ^b	379.31 ^b	276.27 ^b	19.36
T5	0.68 ^a	0.91 ^a	0.75 ^a	82.92	57.99 ^a	77.74 ^a	65.21 ^a	25.74	270.29 ^a	418.13 ^a	291.20 ^a	25.81
T6	0.61 ^{ab}	0.80 ^{abc}	0.51 ^{bc}	24.39	49.84 ^b	68.01 ^e	62.40 ^b	20.32	249.39 ^{bc}	312.11 ^g	267.31 ^c	15.49
T7	0.58 ^{bc}	0.75 ^{bcd}	0.62 ^{ab}	51.21	47.69 ^{bc}	67.06 ^e	59.81 ^{cd}	15.33	231.47 ^d	340.48 ^{ef}	262.83 ^c	13.55
T8	0.52 ^{bcd}	0.81 ^{ab}	0.55 ^{bc}	34.14	43.07 ^d	74.03 ^{bc}	62.08 ^b	19.70	237.43 ^{bc}	336.00 ^f	271.79 ^{bc}	17.43
T9	0.43 ^d	0.60 ^e	0.41 ^c	--	39.28 ^e	59.45 ^f	51.86 ^e	--	221.01 ^d	310.41 ^g	231.45 ^d	--
T10	0.48 ^{cd}	0.63 ^{de}	0.50 ^{bc}	21.95	42.99 ^d	59.81 ^f	51.98 ^e	0.23	234.45 ^{cd}	313.40 ^g	237.44 ^d	2.58
SEM±	0.01	0.01	0.02		1.05	1.08	0.73		5.18	3.19	4.2	
CD at 5%	0.03	0.04	0.06		3.13	3.21	2.17		15.45	9.49	12.58	

BAT = Before application of treatment

DAG = Days after germination

RDF = Recommended dose of fertilizer

4.2.1.3 Available Potassium (K₂O):

Significantly higher available potassium content of soil was noticed in 20 tonnes of FYM treated plots (270.29 kg/ha) compared to rest of the treatments at before application of treatments. Available potassium content of the soil was least in T₉ (221.01 kg/ha). However, it was on par with T₇ (231.47 kg/ha) and T₁₀ (234.45 kg/ha).

At 45 days after germination, significantly higher available potassium content of soil was observed in 20 tonnes of FYM applied plots (418.13 kg/ha) compared to rest of the treatments. Available potassium content of soil was significantly minimum in T₉ (310.41 kg/ha) which was on par with T₆ (312.11 kg/ha and T₁₀ (313.4 kg/ha).

At harvest, available potassium content of soil was significantly higher in 20 tonnes of FYM treated plots (291.20 kg/ha) and T₂ (291.20 kg/ha) which were on par with T₃ (282.24 kg/ha) compared to rest of the treatments. Significantly least available potassium content of soil was noticed in recommended dose of fertilizer alone treatment (231.45 kg/ha) which was on par with T₁₀ (237.44 kg/ha). The increase of available potassium was 25.81% in T₅ and T₂ over recommended dose of fertilizer at harvest. In rest of the treatments it varied from 2.58 (T₁₀) to 21.94% (T₃).

4.2.1.4 Exchangeable Calcium:

Significantly higher exchangeable calcium content of soil was found in 20 tonnes of FYM applied plots (3.92 meq/100g) compared to rest of the treatments at before application of treatments. Significantly least exchangeable calcium content of the soil was observed in T₉ (3.15 meq/100g) which was on par with T₁₀ (3.23 meq/100g). Further, rest of the treatments were on par with each other except T₁ (3.28 meq/100g).

At 45 days after germination, 20 tonnes of FYM applied treatment recorded significantly higher exchangeable calcium content (7.39 meq/100g) of the soil which was on par with T₄ (6.88 meq/100g). Significantly least exchangeable calcium content of the soil was noticed in recommended dose of fertilizer alone treatment (5.01 meq/100g) which was on par with T₁₀ (5.28 meq/100g) and T₆ (5.39 meq/100g).

Significantly higher exchangeable calcium content of the soil was found in T₅ (6.37 meq/100g) at harvest. Recommended dose of fertilizer alone applied treatment recorded significantly least exchangeable calcium content of the soil (4.64 meq/100g).

4.2.1.5 Exchangeable Magnesium:

Significantly higher exchangeable magnesium content of the soil was recorded in 20 tonnes of FYM applied plot (2.08 meq/100g) at before application of the treatments. However, it was on par with T₄ (2.03 meq/100g), T₁ (2.03 meq/100g), T₇ (2.00 meq/100g), T₈ (1.97 meq/100g) and T₆ (1.89 meq/100g). Significantly least exchangeable magnesium content of the soil was noticed in T₂ (1.68 meq/100g) which was on par with T₉ (1.70 meq/100g), T₁₀ (1.81 meq/100g), T₃ (1.84 meq/100g) and T₆ (1.89 meq/100g).

At 45 days after germination, exchangeable magnesium content of the soil was significantly higher in T₅ (4.93 meq/100g) compared to rest of the treatments. Recommended dose of fertilizer alone applied plot recorded significantly least exchangeable magnesium content of the soil (2.88 meq/100g). However, it was on par with T₁₀ (3.04 meq/100g), T₁ (3.09 meq/100g) and T₂ (3.52 meq/100g).

Significantly higher exchangeable magnesium content of the soil was noticed in T₅ (3.39 meq/100g) which was on par with T₃ (3.17 meq/100g) and T₇ (3.17 meq/100g) compared to other treatments at

harvest. Recommended dose of fertilizer alone treated plot recorded significantly least exchangeable magnesium content of the soil (2.40 meq/100g) which was on par with T₁₀ (2.59 meq/100g), T₁ (2.61 meq/100g) and T₂ (2.64 meq/100g).

4.2.1.6 Soil microbial biomass C:

There was a significant difference in soil microbial biomass carbon among the treatments at before application of treatments. Significantly higher soil microbial biomass carbon was noticed in T₄ (2188.07 $\mu\text{g g}^{-1}$ soil) which was on par with T₂ (2178.91 $\mu\text{g g}^{-1}$ soil). Significantly least soil microbial biomass carbon was noticed in recommended fertilizer alone applied plots (1736.51 $\mu\text{g g}^{-1}$ soil) which was on par with 50 per cent of recommended FYM treated plot (1808.03 $\mu\text{g g}^{-1}$ soil).

Soil microbial biomass carbon showed significant difference among the treatments at 45 DAG. Significantly higher soil microbial biomass C was recorded in the plot treated with 20 t of FYM (5239.95 $\mu\text{g g}^{-1}$ soil) followed by plot treated with 17.5 t of FYM + 25 percent of recommended fertilizer (4231.80 $\mu\text{g g}^{-1}$ soil). Significantly least soil microbial biomass C was recorded in plot treated with the recommended fertilizer alone (1905.09 $\mu\text{g g}^{-1}$ soil) which was on par with 50 per cent of recommended FYM applied plots (1981.08 $\mu\text{g g}^{-1}$ soil).

At the time of harvest, significantly higher soil microbial biomass C was recorded in the plot treated with 20 t of FYM (4249.21 $\mu\text{g g}^{-1}$ soil). Significantly least soil microbial biomass C was recorded in plot treated with recommended fertilizer alone treatment (1729.62 $\mu\text{g g}^{-1}$ soil) which was on par with 50 per cent of recommended FYM applied plot (1740.26 $\mu\text{g g}^{-1}$ soil) and rest of the treatments showed significant difference among them.

Table 14: Impact of organic manures and fertilizers on soil exchangeable calcium, exchangeable magnesium, soil pH and microbial biomass carbon.

Treatments	Ex. Calcium (meq/100g)			Ex. Magnesium (meq/100g)			Soil pH			Microbial biomass carbon (μg /g soil)		
	BAT	45DAG	At harvest	BAT	45DAG	At harvest	BAT	45DAG	At harvest	BAT	45DAG	At harvest
T1	3.28 ^c	5.87 ^{cd}	5.17 ^d	2.03 ^{ab}	3.09 ^{cde}	2.61 ^{cd}	6.23 ^{bc}	6.24 ^e	6.41 ^{cd}	2098.42 ^{bc}	3173.47 ^{de}	2798.94 ^e
T2	3.47 ^b	6.03 ^{cd}	5.04 ^{de}	1.68 ^d	3.52 ^{bcde}	2.64 ^{cd}	6.51 ^{ab}	6.45 ^{bcd}	6.78 ^a	2178.91 ^{ab}	3834.84 ^c	3153.31 ^c
T3	3.52 ^b	6.56 ^{bc}	5.12 ^d	1.84 ^{bcd}	4.11 ^b	3.17 ^{ab}	6.32 ^{bc}	6.61 ^{ab}	6.57 ^{bc}	2004.79 ^{de}	3232.63 ^d	2893.26 ^d
T4	3.44 ^b	6.88 ^{ab}	5.84 ^b	2.03 ^{ab}	3.89 ^b	3.01 ^b	6.34 ^{bc}	6.31 ^{de}	6.11 ^f	2188.07 ^a	4231.80 ^b	3426.70 ^b
T5	3.92 ^a	7.39 ^a	6.37 ^a	2.08 ^a	4.93 ^a	3.39 ^a	6.52 ^{ab}	6.39 ^{cde}	6.41 ^{cd}	2061.53 ^{cd}	5239.95 ^a	4249.21 ^a
T6	3.44 ^b	5.39 ^{de}	5.15 ^d	1.89 ^{abcd}	3.95 ^b	3.04 ^b	6.32 ^{bc}	6.24 ^e	6.65 ^{ab}	2005.16 ^{de}	3099.22 ^e	2442.41 ^f
T7	3.52 ^b	6.24 ^{bc}	5.79 ^b	2.00 ^{abc}	3.68 ^{bcd}	3.17 ^{ab}	6.77 ^a	6.72 ^a	6.23 ^{ef}	1948.94 ^e	2299.62 ^f	1958.22 ^g
T8	3.41 ^b	6.13 ^{bc}	5.47 ^c	1.97 ^{abc}	3.73 ^{bc}	2.85 ^{bc}	6.14 ^c	6.57 ^{ab}	6.30 ^{de}	1981.66 ^{de}	2130.77 ^g	1918.49 ^g
T9	3.15 ^d	5.01 ^e	4.64 ^f	1.70 ^d	2.88 ^e	2.40 ^d	6.55 ^{ab}	6.76 ^a	6.45 ^{cd}	1736.51 ^f	1905.09 ^h	1729.62 ^h
T10	3.23 ^{cd}	5.28 ^{de}	4.88 ^e	1.81 ^{cd}	3.04 ^{de}	2.59 ^{cd}	6.27 ^{bc}	6.43 ^{bcde}	6.35 ^{de}	1808.03 ^f	1981.08 ^h	1740.26 ^h
SEM $\pm$	0.04	0.26	0.07	0.07	0.23	0.11	0.11	0.06	0.05	28.56	26.49	32.39
CD at 5%	0.12	0.77	0.21	0.21	0.68	0.32	0.32	0.19	0.16	84.83	78.68	96.21

BAT = Before application of treatments

DAG = Days after germination

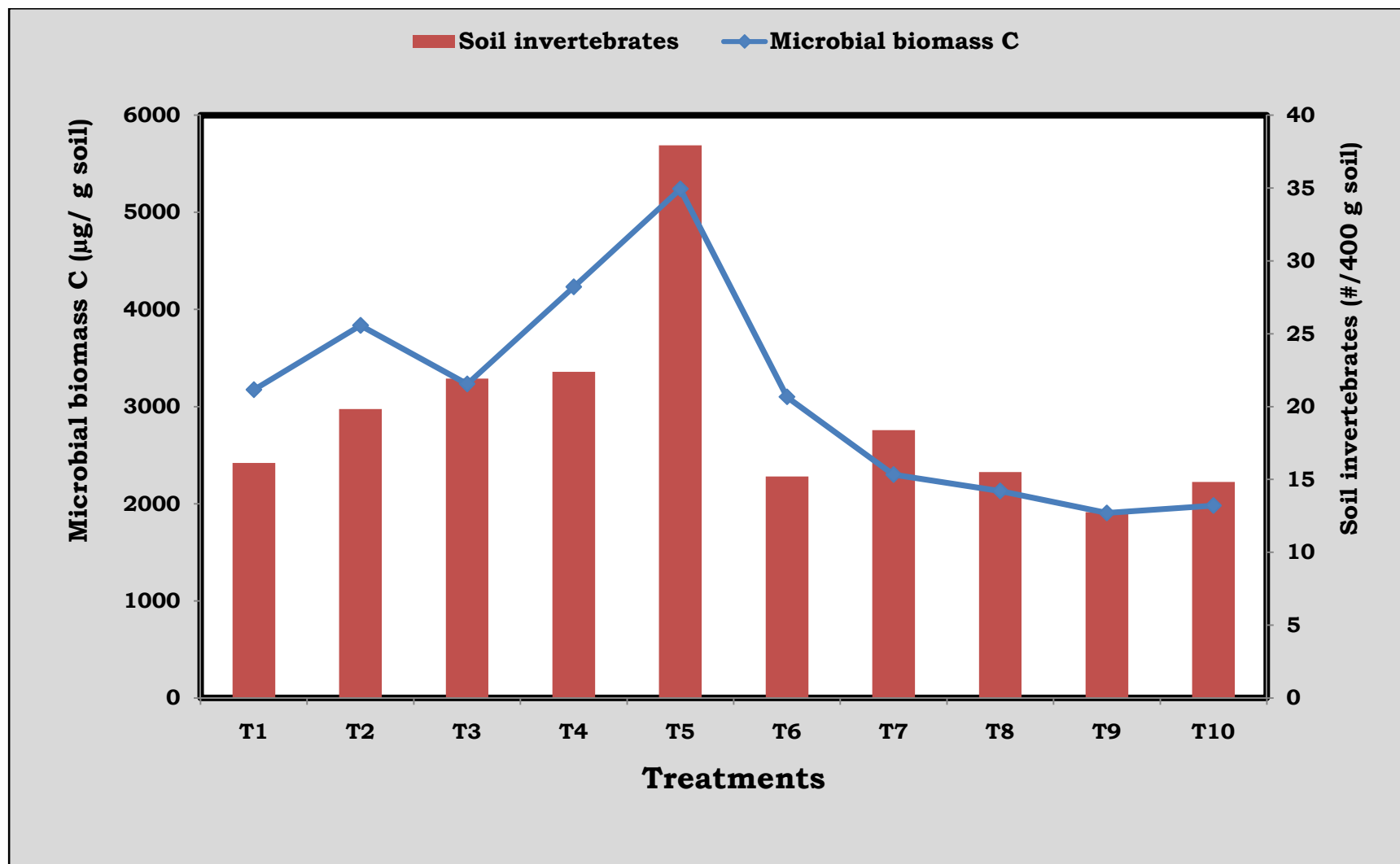


Fig. 3: Impact of microbial biomass carbon on the abundance of soil invertebrates

4.2.1.7 Soil pH:

At before application of treatments, significantly higher soil pH was found in T₇ (6.77) which was on par with T₉ (6.55), T₅ (6.52) and T₂ (6.51). Significantly lower soil pH was observed in T₈ (6.14) and was on par with T₁ (6.23), T₁₀ (6.27), T₆ (6.32), T₃ (6.32) and T₄ (6.34.)

Significantly higher soil pH was found in T₉ (6.76) at 45 days after treatment. However, it was on par with T₇ (6.72), T₃ (6.61) and T₈ (6.57). Significantly lower soil pH was recorded in T₆ (6.24) which was on par with T₁ (6.24), T₄ (6.31), T₅ (6.39) and T₁₀ (6.43).

At harvest, higher soil pH was found in T₂ (6.78) which was on par with T₆ (6.65) compared to other treatments. Significantly lower soil pH was recorded in T₄ (6.11) which was on par with T₇ (6.23).

4.2.2 Impact of different doses of organic manure and chemical fertilizers on the production of leaves biomass during crop growth:

Impact of different doses of organic manure and chemical fertilizers on the production of leaves biomass during crop growth are presented in the table 15.

4.2.2.1 Cotyledon production:

There was no significant difference in the dry weight of cotyledon among the treatments. However, higher cotyledon weight was noticed in T₉ (10.66 kg/ha) compared to other treatments. Least cotyledon production was noticed in T₄ and T₂ (10.10 kg/ha each).

4.2.2.2 Unifoliate leaves:

Production of unifoliate leaves showed no significant difference among the treatments. However, higher and lower weight was observed

in 50% of recommended FYM (50.22 kg/ha) and 12.5t of FYM + 75% of recommended fertilizer (45.33 kg/ha) applied plots, respectively.

4.2.2.3 First trifoliolate leaves:

No significant difference was observed among the treatments for the production of first trifoliolate leaves. However, T₈ (80.33 kg/ha) showed higher biomass of leaves compared to other treatments. Least biomass was found in T₃ (65.22 kg/ha).

4.2.2.4 Second trifoliolate leaves:

There was a significant difference in biomass of second trifoliolate leaves among the treatments. Significantly higher biomass was noticed in 20t of FYM applied plot (113.44 kg/ha) followed by plot treated with 12.5t of FYM + 75% of recommended fertilizer (106.77 kg/ha). Latter treatment was on par with remaining treatments except T₈ (81.88 kg/ha) which showed least biomass of second trifoliolate leaves.

4.2.2.5 Third trifoliolate leaves:

Significantly higher biomass of third trifoliolate leaves was observed in plot applied with double dose of FYM (125.99 kg/ha) compared to other treatments. However, it was on par with rest of the treatments except recommended dose of fertilizer applied plot (91.55 kg/ha).

4.2.2.6 Rest of the leaves:

There was a significant difference observed in the biomass of rest of the leaves. Significantly higher biomass was noticed in 20t of FYM applied plots (1331.99 kg/ha). Plots treated with recommended fertilizer alone showed least biomass of rest of the leaves (1009.22 kg/ha) which was on par with 50% of recommended FYM applied plot (1070.55 kg/ha).

Table 15: Production of leaf biomass in different treatments during crop growth

Treatments	Leaf biomass at different intervals (kg/ha)							
	Cotyledon (30 DAG)	Unifoliolate leaves (37 DAG)	1st Trifoliolate leaves (45 DAG)	2nd Trifoliolate leaves (52 DAG)	3rd Trifoliolate leaves (60 DAG)	Rest of the leaves (90 DAG)	Total leaf biomass	Root biomass (60 DAG)
T ₁	10.44	45.44	78.66	106.77 ^{ab}	123.99 ^a	1119.44 ^c	1484.74 ^{cd}	407.40 ^{ab}
T ₂	10.10	45.33	69.55	106.99 ^{ab}	113.55 ^{ab}	1153.99 ^{cd}	1499.52 ^c	378.14 ^{ab}
T ₃	10.44	47.88	65.22	101.77 ^{abc}	112.33 ^{ab}	1257.66 ^b	1595.29 ^b	418.51 ^{ab}
T ₄	10.10	46.66	71.11	105.55 ^{ab}	121.66 ^a	1250.44 ^b	1605.52 ^b	381.85 ^{ab}
T ₅	10.44	47.44	68.33	113.44 ^a	125.99 ^a	1331.99 ^a	1697.62 ^a	449.99 ^a
T ₆	10.44	45.88	71.44	97.66 ^{abc}	123.77 ^a	1143.44 ^d	1492.62 ^c	369.62 ^b
T ₇	10.33	47.55	73.44	89.66 ^{bc}	106.88 ^{ab}	1155.88 ^{cd}	1483.73 ^{cd}	366.29 ^b
T ₈	10.33	48.44	80.33	81.88 ^c	122.99 ^a	1219.33 ^b	1563.29 ^{bc}	400.73 ^{ab}
T ₉	10.66	49.33	69.55	89.33 ^{bc}	91.55 ^b	1009.22 ^e	1319.63 ^e	358.14 ^b
T ₁₀	10.44	50.22	67.11	99.77 ^{abc}	102.54 ^{ab}	1070.55 ^e	1400.63 ^{de}	361.85 ^b
S.Em±	0.34	2.37	7.54	7.59	8.63	22.53	30.61	26.81
CD @ 5%	NS	NS	NS	22.54	25.63	66.92	90.91	79.63

NS: Non significant

DAG: Days after germination

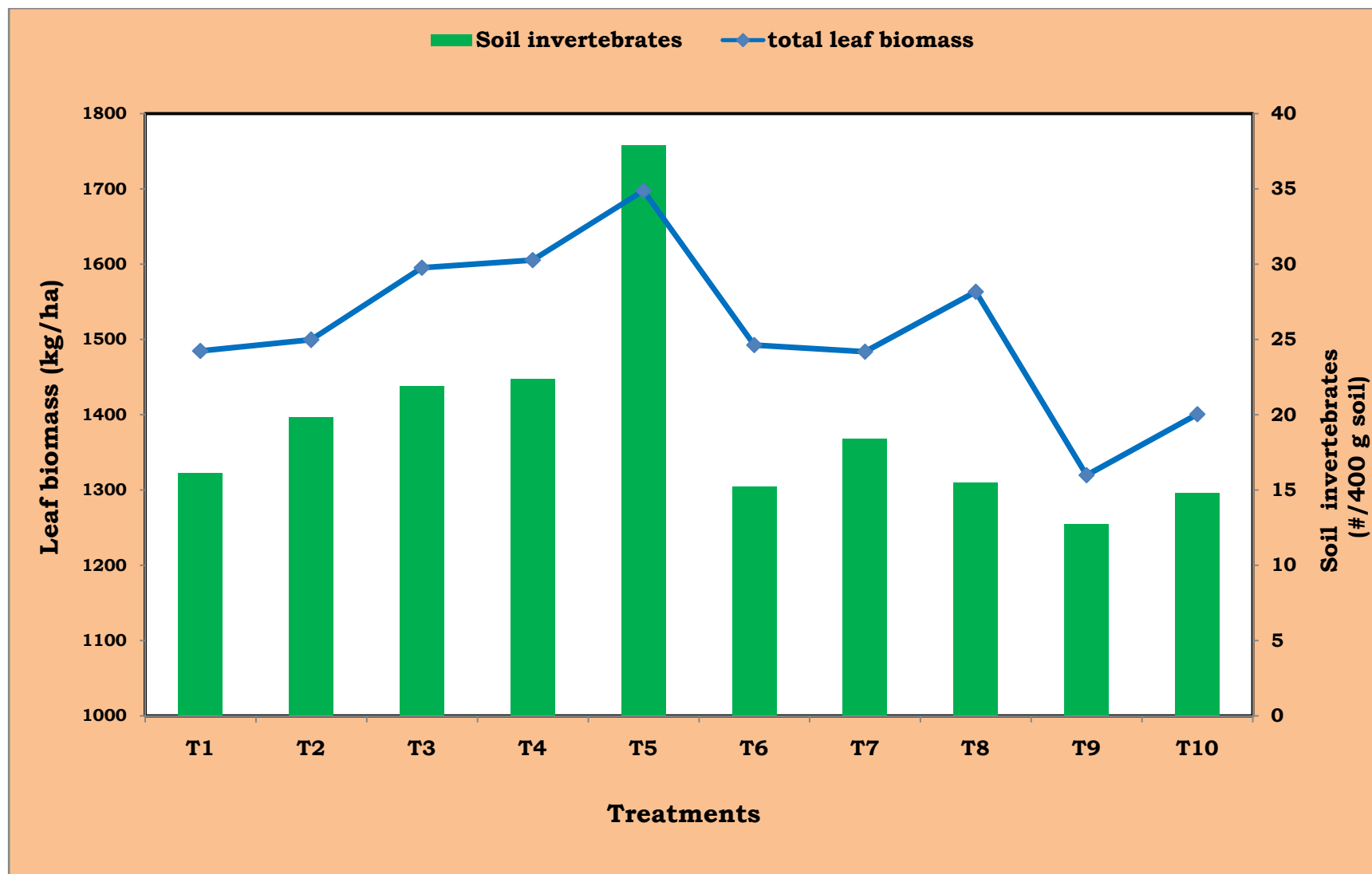


Fig. 4: Impact of total leaf biomass on the abundance of soil invertebrates

4.2.2.7 Total leaf biomass:

Significant difference was noticed for the production of total leaf biomass. The plots treated with 20t of FYM (1697.62 kg/ha) showed significantly higher total leaf biomass production compared to other treatments. Significantly least total leaf biomass was observed in plot treated with recommended fertilizer alone (1319.63 kg/ha) which was on par with 50% of recommended FYM applied plot (1400.63 kg/ha).

4.2.2.8 Root biomass:

Significantly higher root biomass production was noticed in T₅ (449.99 kg/ha) followed by T₃ (418.51 kg/ha). Least root biomass was found in T₉ (358.14 kg/ha) which was on par with rest of the treatments except T₅.

4.2.3 Impact of different doses of organic manure and chemical fertilizers on growth parameters of soybean crop:

Impact of different doses of organic manure and fertilizers on plant biomass, *Rhizobium* nodules per plant, *Rhizobium* nodules weight, Grain yield of soybean crop are presented in table 16.

4.2.3.1 Plant biomass:

Significantly higher plant biomass was noticed in T₅ (29.33 g/plant). Least plant biomass was observed in T₁₀ (19.00 g/plant) followed by T₉ (20.17 g/plant) which was on par with rest of the treatments except T₅.

4.2.3.2 *Rhizobium* nodules:

The number of *Rhizobium* nodules per plant was significantly more in the plot treated with recommended dose of partially decomposed FYM (29.56). Least number of nodules per plant was noticed in plot

treated with recommended fertilizers alone (16.33) followed by plot treated with recommended FYM (17.00).

Significantly higher *Rhizobium* nodules weight per plant was found in T₁ (0.33 g) which was on par with rest of the treatments except T₂ (0.17 g) which harboured lowest *Rhizobium* nodules weight per plant.

4.2.4 Impact of different doses of organic manure and chemical fertilizers on yield parameters of soybean crop:

The influence of different doses of FYM and fertilizers on the yield parameters are presented in table 16.

4.2.4.1 Number of pods:

Significantly higher number of pods per plant was observed in T₅ (31.20) followed by T₂ (25.87) which was on par with rest of the treatments except T₁₀ (19.57) and T₉ (18.40).

4.2.4.2 Test weight:

There was no significant difference in the test weight of the grains. However, higher test weight was observed in package of practice followed plots (13.83 g/100 seeds) and least was in T₄ (12.36 g/100 seeds).

4.2.4.3 Grain yield:

Significantly highest grain yield was recorded in the plots treated with 20 t of FYM (21.91 q/ha). Plot treated with recommended fertilizer alone obtained least grain yield (14.19) followed by plot applied with 50 per cent of recommended FYM (15.55).

The higher trend of yield was noticed in all the FYM applied treatments compared to RDF. It varied from 9.58 (T₁₀) to 54.40% (T₅). However, the yield increase over package of practices followed treatment

Table 16: Impact of organic manures and fertilizers on the growth and yield parameters of soybean.

Treatments	<i>Rhizobium</i> nodules (#/plant)	<i>Rhizobium</i> nodule weight (g/plant)	Plant biomass (g/plant)	Test weight (g/100 seeds)	No. of Pods/plant	Grain yield (q/ha)	% increase over RDF	% increase over POP
T1	24.67 ^{abc}	0.33 ^a	26.00 ^{ab}	13.83	24.17 ^b	18.02 ^d	26.99	--
T2	18.22 ^c	0.17 ^b	22.33 ^{ab}	13.48	25.87 ^b	19.54 ^{bc}	37.70	8.43
T3	21.00 ^{abc}	0.22 ^{ab}	21.17 ^{ab}	12.91	25.60 ^b	20.08 ^b	41.51	11.43
T4	29.11 ^{ab}	0.24 ^{ab}	22.67 ^{ab}	12.36	23.57 ^{bc}	19.86 ^{bc}	39.95	10.21
T5	24.11 ^{abc}	0.26 ^{ab}	29.33 ^a	13.13	31.20 ^a	21.91 ^a	54.40	21.58
T6	17.00 ^c	0.21 ^{ab}	26.00 ^{ab}	12.49	21.70 ^{bcd}	17.85 ^d	25.79	-0.94
T7	29.56 ^a	0.28 ^{ab}	20.33 ^b	13.08	24.10 ^b	17.07 ^e	20.29	-5.27
T8	24.33 ^{abc}	0.22 ^{ab}	22.33 ^{ab}	13.07	21.63 ^{bcd}	19.25 ^c	35.65	6.82
T9	16.33 ^c	0.22 ^{ab}	20.17 ^b	12.51	18.40 ^d	14.19 ^g	--	-21.25
T10	18.67 ^{bc}	0.23 ^{ab}	19.00 ^b	13.78	19.57 ^{cd}	15.55 ^f	9.58	-13.71
SEM±	3.57	0.05	2.96	0.68	1.53	0.22		
CD at 5%	10.61	0.14	8.79	NS	4.56	0.66		

RDF = Recommended dose of fertilizer,

POP = Package of practices for soybean cultivation (treatment no.1)

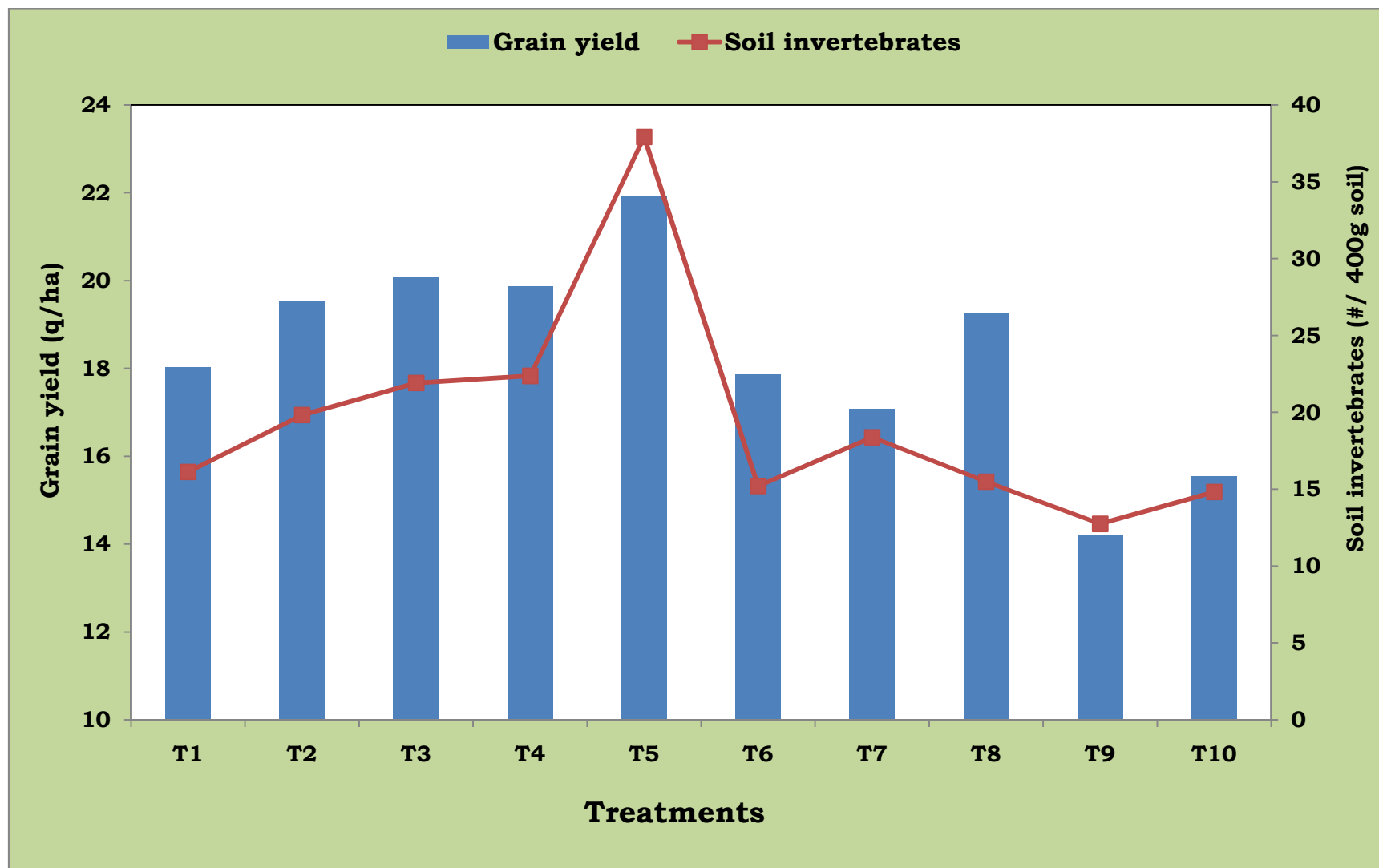


Fig. 5: Impact of soil invertebrates on grain yield of soybean

(T₁) varied from 6.82 (T₈) to 21.58% (T₅). Further, reduced yield level was noticed in T₆ (-0.94%), T₇ (-5.27%), T₁₀ (-13.71%) and T₉ (-21.25%) over package of practices followed treatment.

4.3 Impact of different doses of organic manure along with chemical fertilizers on termite infestation to soybean at harvesting stage:

Damage caused by termites varied from 35.37 to 47.89%. Least damage was noticed in plots treated with 12.5 t of FYM + 75 % of recommended fertilizer (35.37%) compared to recommended dose of partially decomposed FYM (47.89%), but was on par with rest of the treatments (Table 17.)

4.4 Impact of different doses of organic manure along with chemical fertilizers on stem fly (*Melanagromyza sojae*) infestation to soybean at harvesting stage:

The effect of different doses of organic manure and chemical fertilizers on basal tunnelling and secondary tunnelling by stem fly are presented in the table 17.

4.4.1 Basal tunnelling length:

There was a significant difference in basal tunnelling length among the treatments. Significantly least basal tunnelling was recorded in T₂ (28.04 %) and was on par with 20 t of FYM (30.00%), T₄ (32.08%) and T₃ (33.33%). Higher basal tunnelling length was recorded in package of practice followed plot (39.66%).

4.4.2 Secondary tunnelling length:

No significant difference was observed among the treatments for secondary tunnelling length. However, the secondary tunnelling varied from 2.54 (T₉) to 3.59% (T₁).

Table 17: Impact of organic manure and fertilizers on the termite and stem fly infestation to soybean at harvesting stage.

Treatments	Termite damage	Stem fly damage		
	Plant damage (%)	Basal tunnelling (%)	Secondary tunnelling (%)	Total tunnelling (%)
T ₁ . Rec. fertilizers (25:60:25: NPK Kg ha ⁻¹) + Rec. FYM (10 t ha ⁻¹) + Phorate 10 G @ 1 kg <i>a.i.</i> ha ⁻¹ + herbicide (Lasso 50 EC @ 2.5 lit ha ⁻¹) + fungicide seed treatment (Thiram + Bavistin- each 2g/kg of seeds).	36.94 (37.35) ^a	39.66 (39.01) ^d	3.59 (10.82)	43.25 (41.09) ^c
T ₂ . 12.5 tonnes of FYM + 75 per cent of recommended fertilizer.	35.37 (36.46) ^a	28.04 (31.87) ^a	3.31 (10.29)	31.35 (33.96) ^a
T ₃ . 15.0 tonnes of FYM + 50 per cent of recommended fertilizer.	38.25 (38.17) ^{ab}	33.33 (35.19) ^{abcd}	3.03 (9.86)	36.35 (37.02) ^{abc}
T ₄ . 17.5 tonnes of FYM + 25 per cent of recommended fertilizer.	37.06 (37.42) ^a	32.08 (34.44) ^{abc}	3.10 (9.96)	35.18 (36.35) ^{ab}
T ₅ . 20.0 tonnes of FYM.	41.82 (40.26) ^{ab}	30.00 (33.17) ^{ab}	2.13 (8.06)	32.13 (34.49) ^{ab}
T ₆ . 10.0 tonnes of FYM.	39.00 (38.57) ^{ab}	37.17 (37.54) ^{cd}	3.54 (10.57)	40.71 (39.62) ^{bc}
T ₇ . Recommended FYM (partially decomposed).	47.89 (43.73) ^b	35.65 (36.57) ^{bcd}	2.83 (9.62)	38.48 (38.28) ^{abc}
T ₈ . Recommended FYM + mulching (Glyricidia 2 t ha ⁻¹ .).	41.40 (40.00) ^{ab}	38.03 (38.01) ^{cd}	3.54 (10.69)	41.58 (40.10) ^{bc}
T ₉ . Recommended fertilizer alone.	37.13 (37.50) ^a	37.86 (37.93) ^{cd}	2.54 (7.17)	40.40 (39.43) ^{bc}
T ₁₀ . 50 per cent of recommended FYM.	37.85 (37.82) ^{ab}	36.33 (36.99) ^{bcd}	3.64 (10.81)	39.96 (39.14) ^{bc}
S.Em±	2.01	1.43	1.69	1.55
CD @ 5%	5.99	4.25	NS	4.61

4.4.3 Total tunnelling length:

Significantly least total stem tunnelling was noticed in T₂ (31.35%) and was on par with T₅, T₄, T₃ and T₇. The latter two treatments were on par in total tunnelling length with the highest total tunnelling length recorded treatment T₁ (43.25%).

4.5 To assess the relationship, if any between soil fertility status and abundance of soil invertebrates of soybean:

4.5.1 Relationship among soil invertebrates, microbial biomass C and soil chemical parameters:

The soil invertebrates exhibited a significant positive relation with available phosphorus, available potassium, exchangeable calcium, exchangeable magnesium and microbial biomass C. Soil organic carbon showed positive non-significant correlation with abundance of soil invertebrates. However, soil pH showed negative non-significant correlation (Table 18).

The results of the multiple linear regression analysis showed that the influence of available potassium, exchangeable calcium, organic carbon and microbial biomass C on the abundance of soil invertebrates was up to 60 percent. Further, the results indicated that with a unit increase of available potassium and organic carbon would lead to 0.201, 43.366 units decrease in the abundance of soil invertebrates. However, a unit increase of exchangeable calcium and microbial biomass carbon would lead to 10.912, 0.014 units increase in the abundance of soil invertebrates, respectively (Table 19).

4.5.2 Relationship among available phosphorus, soil invertebrates and microbial biomass C:

The available phosphorus exhibited a significant positive relation with soil invertebrates, available potassium, exchangeable calcium,

Table 18: Correlation among soil invertebrates, microbial biomass C and soil fertility.

Parameters	X₁	X₂	X₃	X₄	X₅	X₆	X₇	X₈
X ₁ = Soil invertebrates	1.00	0.367**	0.217*	0.535**	0.435**	-0.053	0.147	0.571**
X ₂ = Available phosphorous		1.00	0.759**	0.777**	0.730**	0.034	0.592**	0.623**
X ₃ = Available potassium			1.00	0.787**	0.797**	0.041	0.757**	0.707**
X ₄ = Exchangeable calcium				1.00	0.863**	0.008	0.673**	0.711**
X ₅ = Exchangeable					1.00	0.003	0.692**	0.697**
magnesium						1.00	-0.068	-0.106
X ₆ = Soil pH							1.00	0.639**
X ₇ = Organic carbon								1.00
X ₈ = Microbial biomass carbon								

* Significant at p=0.05%

** Significant at p=0.01%

Table 19: Stepwise regression analysis showing the significant variables against soil invertebrates.

Variables	Multiple regression co-efficient	Standard error	't' value	'F' value	R² value
X ₃ = Available potassium	-0.201	0.044	-4.553**	32.875	0.607
X ₄ = Exchangeable calcium	10.912	1.719	6.347**		
X ₇ = Organic carbon	-43.366	13.80	-3.143**		
X ₈ = Microbial biomass carbon	0.014	0.002	6.441**		

** Significant at p=0.01%

Regression equation: $Y = 15.918 - 0.201X_3 + 10.912X_4 - 43.366X_7 + 0.014X_8$

Table 20: Stepwise regression analysis showing the significant variables against available phosphorous.

Variables	Multiple regression co-efficient	Standard error	't' value	'F' value	R² value
X ₃ = Available potassium	0.083	0.386	3.810**	84.68	0.661
X ₄ = Exchangeable calcium	4.359	0.473	4.674**		

** Significant at p=0.01%

Regression equation: $Y = 14.142 + 0.083X_3 + 4.359X_4$

exchangeable magnesium, organic carbon and microbial biomass C. However, positive non-significant relation existed with soil pH (Table 18).

Multiple linear regression analysis showed that the influence of available potassium and exchangeable calcium on the quantity of available phosphorous was up to 66 per cent. Further, the results revealed that with a unit increase of available potassium and exchangeable calcium would lead to 0.083 and 4.359 units increase in the amount of available phosphorous, respectively (Table 20).

4.5.3 Relationship among available potassium, soil invertebrates and microbial biomass C:

Available potassium had significant relationship with soil invertebrates, available phosphorous, exchangeable calcium, exchangeable magnesium, soil organic carbon and microbial biomass carbon. Soil pH had positive non-significant correlation with available potassium (Table 18).

The multiple linear regression analysis revealed that the influence of soil invertebrates, available phosphorous, exchangeable calcium, exchangeable magnesium, soil organic carbon and microbial biomass carbon on the quantity of available potassium was up to 81 per cent. Further, the results showed that with a unit increase in soil invertebrates would lead to 0.89 units decrease in the amount of available potassium. However, a unit increase of available phosphorous, exchangeable calcium, exchangeable magnesium, soil organic carbon and microbial biomass carbon would lead to 1.037, 12.044, 13.509, 52.665 and 0.018 units increase in the amount of available potassium, respectively (Table 21).

4.5.4 Relationship among exchangeable calcium, soil invertebrates and microbial biomass C:

The exchangeable calcium exhibited a significant positive relationship with soil invertebrates, available phosphorous, available potassium, exchangeable magnesium, soil organic carbon and microbial biomass carbon. However, it had positive non-significant correlation with soil pH (Table 18).

Multiple linear regression analysis showed that the influence of soil invertebrates, available phosphorous, available potassium and exchangeable magnesium on the amount of exchangeable calcium was up to 83 per cent. Further, the results indicated that with an unit increase in soil invertebrates, available phosphorous, available potassium and exchangeable magnesium would lead to 0.016, 0.021, 0.006 and 0.606 units increase in the amount of exchangeable calcium, respectively (Table 22).

4.5.5 Relationship among exchangeable magnesium, soil invertebrates and microbial biomass C:

The exchangeable magnesium exhibited a significant positive relationship with soil invertebrates, available phosphorous, available potassium, exchangeable calcium, soil organic carbon and microbial biomass carbon. However, it had positive non-significant correlation with soil pH (Table 18).

The results of the multiple linear regression analysis showed that the influence of available potassium and exchangeable calcium on the amount of exchangeable magnesium was up to 78 per cent. Further, the results showed that with a unit increase in available potassium and exchangeable calcium would lead to 0.005 and 0.425 units increase in the amount of exchangeable magnesium, respectively (table 23).

4.5.6 Relationship among soil pH, soil invertebrates and microbial biomass C:

The soil pH had no significant relationship with soil invertebrates, other soil parameters and microbial biomass carbon. However, it had positive non-significant correlation with available phosphorous, available potassium, exchangeable calcium and exchangeable magnesium. Soil invertebrates, soil organic carbon and microbial biomass carbon showed negative non-significant correlation with the soil pH (Table 18).

4.5.7 Relationship among soil organic carbon, soil invertebrates and microbial biomass C:

Soil organic carbon had significant positive relationship with available phosphorous, available potassium, exchangeable calcium, exchangeable magnesium and microbial biomass carbon. Abundance of soil invertebrates and soil pH showed positive and negative non-significant correlation with soil organic carbon, respectively (Table 18).

The outcome of the multiple linear regression analysis indicated that the influence of available potassium and exchangeable magnesium on the amount of soil organic carbon buildup was up to 59 per cent. Further, the results indicated that with a unit increase in the available potassium and exchangeable magnesium would lead to 0.001 and 0.04 units increase in the amount of soil organic carbon, respectively (Table 24).

4.5.8 Relationship among microbial biomass C, soil invertebrates and soil parameters:

Microbial biomass carbon exhibited a significant positive relationship with soil invertebrates and all soil parameters except soil pH which showed negative non-significant correlation with microbial biomass carbon (Table 18).

Table 21: Stepwise regression analysis showing the significant variables against available potassium.

Variables	Multiple regression co-efficient	Standard error	't' value	'F' value	R² value
X ₁ = Soil invertebrates	-0.890	0.201	-4.431**	61.101	0.815
X ₂ = Available phosphorous	1.037	0.361	2.877**		
X ₄ = Exchangeable calcium	12.044	4.887	2.464*		
X ₅ = Exchangeable magnesium	13.509	6.238	2.166*		
X ₇ = Organic carbon	52.665	29.669	1.775		
X ₈ = Microbial biomass carbon	0.018	0.005	3.665**		

Regression equation: $Y = 65.854 - 0.89X_1 + 1.037X_2 + 12.044X_4 + 13.509X_5 + 52.665X_7 + 0.018X_8$

* Significant at p=0.05%

** Significant at p=0.01%

Table 22: Stepwise regression analysis showing the significant variables against exchangeable calcium.

Variables	Multiple regression co-efficient	Standard error	't' value	'F' value	R² value
X ₁ = Soil invertebrates	0.016	0.004	4.413**	107.568	0.835
X ₂ = Available phosphorous	0.021	0.008	2.636*		
X ₃ = Available potassium	0.006	0.002	3.082**		
X ₅ = Exchangeable magnesium	0.606	0.121	4.998**		

* Significant at p=0.05%

** Significant at p=0.01%

Regression equation: $Y = -0.072 + 0.016X_1 + 0.021X_2 + 0.006X_3 + 0.606X_5$

Table 23: Stepwise regression analysis showing the significant variables against exchangeable magnesium.

Variables	Multiple regression co-efficient	Standard error	't' value	'F' value	R² value
X ₃ = Available potassium	0.005	0.001	3.796**	154.858	0.781
X ₄ = Exchangeable calcium	0.425	0.056	7.608**		

** Significant at p=0.01%

Regression equation: $Y = -0.697 + 0.005X_3 + 0.425X_4$

The results of the multiple linear regression analysis showed that the influence of soil invertebrates, available potassium and soil organic carbon on the amount of microbial biomass carbon was up to 71 per cent. Further, the results showed that with a unit increase in soil invertebrates, available potassium and soil organic carbon would lead to 21.678, 6.864 and 1635.818 units increase in the amount of microbial biomass carbon, respectively (Table 25).

4.6 To assess the relationship, if any between abiotic factors and abundance of soil invertebrates of soybean:

4.6.1 Correlation between abiotic factors and abundance of total soil invertebrates:

There was a significant relationship between the abundance of total soil invertebrates and abiotic factors. Maximum temperature of the atmosphere and soil temperature showed significant negative correlation with total soil invertebrates. Minimum relative humidity and soil moisture had significant positive correlation. Other parameters were non-significant. Similarly, positive correlation was observed with minimum temperature, maximum relative humidity and total rainfall. However, sunshine hour had negative correlation with the total soil invertebrates (Table 26). The contribution of abiotic factors on the abundance of total soil invertebrates was 63 per cent (Table 27).

When the data was subjected to multiple linear regression analysis, the results showed that the influence of the atmospheric maximum temperature on the abundance of total soil invertebrates was up to 40 percent. Further, the results indicated that with a unit change of maximum temperature would lead to decrease of 3.044 units in total soil invertebrate's abundance (Table 28).

Table 24: Stepwise regression analysis showing the significant variables against organic carbon.

Variables	Multiple regression co-efficient	Standard error	't' value	'F' value	R² value
X ₃ = Available potassium	0.001	0.00	5.001**	63.959	0.595
X ₄ = Exchangeable magnesium	0.040	0.019	2.146*		

* Significant at p=0.05%

** Significant at p=0.01%

Regression equation: $Y = 0.082 + 0.001X_3 + 0.040X_4$

Table 25: Stepwise regression analysis showing the significant variables against soil microbial biomass carbon.

Variables	Multiple regression co-efficient	Standard error	't' value	'F' value	R² value
X ₁ = Soil invertebrates	21.678	2.910	7.450**	70.627	0.711
X ₃ = Available potassium	6.864	1492	4.600**		
X ₇ = Organic carbon	1635.818	557.99	2.932**		

** Significant at p=0.01%

Regression equation: $Y = -850.271 + 21.678X_1 + 6.864X_3 + 1635.81X_7$

4.6.2 Correlation between abiotic factors and abundance of total acari:

There was a significant negative relationship existed among the abundance of total acari and maximum temperature of the atmosphere and soil temperature. Minimum relative humidity had significant positive correlation. Total acari had positive non-significant correlation with minimum temperature, maximum relative humidity, total rainfall and soil moisture, where as negative non-significant correlation with sunshine hours (Table 26). The contribution of abiotic factors on the abundance of total acari was 57 per cent (Table 27).

The results of the multiple linear regression analysis showed that the influence of maximum temperature on the abundance of total acari was up to 34 percent. Further, the results indicated that with change of a unit of maximum temperature would lead to decrease of 2.212 units of total acari (Table 28).

4.6.3 Correlation between abiotic factors and abundance of other acari:

Other acari had significant negative relationship with maximum temperature (Table 26). Remaining abiotic factors were non-significant. Minimum temperature, maximum relative humidity, minimum relative humidity, total rainfall and soil moisture had positive non-significant correlation with other acari abundance. The sunshine hours showed negative non-significant correlation. The contribution of these abiotic factors on other acari abundance was 43 per cent (Table 27).

The results of the multiple linear regression analysis revealed that the influence of maximum temperature on the abundance of other acari was up to 22 percent. Further, the results indicated that with a change

Table 26: Correlation between soil invertebrates and abiotic factors in soybean ecosystem

Particulars	Maximum temperature	Minimum temperature	Maximum RH	Minimum RH	Sunshine hours	Total rainfall	Soil moisture	Soil temperature
Soil invertebrates	-0.636**	0.029	0.410	0.545*	-0.398	0.253	0.479*	-0.566*
Total acari	-0.584*	0.046	0.382	0.513*	-0.371	0.241	0.458	-0.520*
Other acari	-0.469*	0.002	0.362	0.380	-0.264	0.146	0.360	-0.430
Cryptostigmata	-0.706**	0.152	0.325	0.708**	-0.538*	0.432	0.585*	-0.611**
Other invertebrates	-0.741**	-0.060	0.427	0.565*	-0.418	0.222	0.457	-0.613**

** Correlation is significant at 0.01% level.

* Correlation is significant at 0.05% level.

Note: Figures indicates the coefficient of correlation (r).

RH: Atmospheric relative humidity

Table 27: Regression equation between soil invertebrates and abiotic factors in soybean ecosystem

Particulars	Regression equation	R ² value
Soil invertebrates	$Y=338.154 - 11.345X_1 + 7.106X_2 - 0.761X_3 - 1.499X_4 + 6.315X_5 - 0.127X_6 + 2.527X_7 - 1.030X_8$	0.635
Total acari	$Y=223.859 - 8.396X_1 + 5.439X_2 - 0.539X_3 - 0.969X_4 + 5.419X_5 - 0.102X_6 + 2.126X_7 - 0.520X_8$	0.571
Other acari	$Y=146.244 - 6.142X_1 + 4.079X_2 - 0.120X_3 - 0.871X_4 + 4.024X_5 - 0.089X_6 + 1.641X_7 - 0.482X_8$	0.436
Cryptostigmata	$Y=76.474 - 2.258X_1 + 1.341X_2 - 0.414X_3 - 0.102X_4 + 1.402X_5 - 0.012X_6 + 0.526X_7 - 0.365X_8$	0.807
Other invertebrates	$Y=122.381 - 3.244X_1 + 1.781X_2 - 0.248X_3 - 0.595X_4 + 0.915X_5 - 0.027X_6 + 0.479X_7 - 0.397X_8$	0.774

a= constant

X₁= Maximum temperature

X₂= Minimum temperature

X₃= Maximum relative humidity

X₄= Minimum relative humidity

X₅= Sunshine hours

X₆= Total rainfall

X₇= Soil moisture

X₈= Soil temperature

Table 28: Stepwise regression analysis showing the significant abiotic variables against soil invertebrates

Particulars	Variables	Multiple regression coefficient	Standard error	't' value	'F' value	R ² value	Regression equation
Soil invertebrates	X ₁ = Maximum temperature	-3.044	0.923	-3.299**	10.886**	0.405	Y=100.688-3.044X ₁
Total acari	X ₁ = Maximum temperature	-2.212	0.769	-2.875*	8.267*	0.341	Y=71.688-2.212X ₁
Other acari	X ₁ = Maximum temperature	-1.397	0.658	-2.124*	4.513*	0.220	Y=44.706-1.397X ₁
Cryptostigmata	X ₄ = Minimum RH	0.208	0.052	4.012**	16.095**	0.501	Y=-6.069+0.208X ₄
Other invertebrates	X ₁ = Maximum temperature	-0.838	0.190	-4.415**	19.489**	0.549	Y=29.078-0.838X ₁

* Significant at p=0.05%

** Significant at p=0.01%

RH: Atmospheric relative humidity

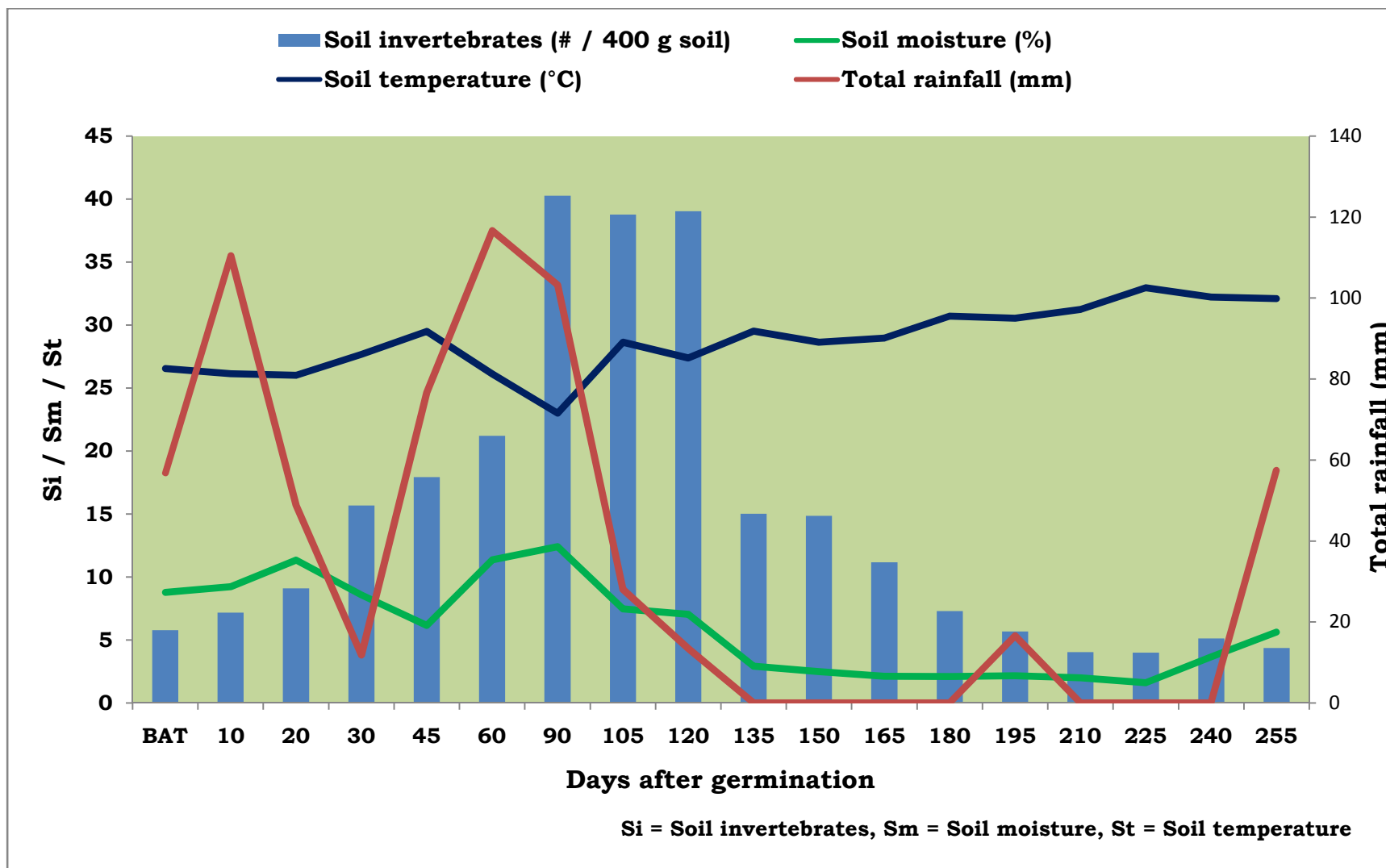


Fig. 6: Impact of abiotic factors on abundance of soil invertebrates

in unit of maximum temperature would lead to decrease in 1.397 units in the abundance of other acari (Table 28).

4.6.4 Correlation between abiotic factors and abundance of cryptostigmatids:

Cryptostigmatids abundance had significant negative relationship with maximum temperature, sunshine hours and soil temperature and significant positive correlation with minimum relative humidity and soil moisture (Table 26). Remaining abiotic factors were non-significant. However, minimum temperature, maximum relative humidity and total rainfall showed positive non-significant correlation with abundance of cryptostigmatids. The impact of abiotic factors on cryptostigmatids was 80 per cent (Table 27).

Multiple linear regression analysis showed that the influence of minimum atmospheric relative humidity on the abundance of cryptostigmatids was up to 50 percent. Further, the results indicated that with a unit increase of minimum relative humidity would lead to 0.208 units increase in abundance of cryptostigmatids (Table 28).

4.6.5 Correlation between abiotic factors and abundance of other invertebrates:

Maximum temperature and soil temperature showed significant negative correlation with abundance of other invertebrates and minimum relative humidity showed significant positive relationship (Table 26). The other parameters were non-significant. However, other invertebrates population had negative non-significant correlation with minimum temperature and sunshine hours whereas positive non-significant correlation with maximum relative humidity, total rainfall and soil moisture. The contribution of abiotic factors on the abundance of other invertebrates was 77 per cent (Table 27).

When the data was subjected to multiple linear regression analysis, the results revealed that the influence of maximum temperature on the abundance of other invertebrates was up to 54 percent. Further, the results indicated that with a change in unit of maximum temperature would lead to decrease of 0.838 units in abundance of other invertebrates (Table 28).

Discussion

V. DISCUSSION

The results of the investigation related to the development of conservation practices for below ground biodiversity in soybean ecosystem have been discussed in this chapter.

5.1 Impact of organic manures and chemical fertilizers on the abundance of below ground arthropods in soybean ecosystem:

5.1.1 Impact of different doses of FYM and chemical fertilizers on the abundance of soil invertebrates in soybean ecosystem during cropping season:

Soil application of 20t of FYM per hectare along with native soil fauna recorded significantly higher abundance of total soil invertebrates, total acari, cryptostigmata, other acari and other invertebrates compared to other treatments. It may be due to abundant food supply (organic matter and microbial biomass), optimum moisture and temperature in the soil. Further, it may be due to periodic addition of senescent leaves with petiole to the soil. Similarly, several earlier investigators *viz.*, Morris (1922 and 1927), Russel (1961), Hryniuk (1962), Ayuke *et al.*, (2004), Prasanna (2006), Girish (2006) and Satish (2009) have recorded increase of nearly all invertebrate group following manuring. The results are similar to the investigation of Ben *et al.* (2007) who concluded that by adding organic amendments resulted in increased numbers of micro-arthropods, springtails as well as mites.

The present studies are also in close conformity with the result of Marshall (1977) who concluded that the response from a combination of manures and fertilizers to be additive, only slightly surpassing that produced by either amendments applied alone. Similarly, Srinivas Reddy (2002), Prasanna (2006), Girish (2006) and Satish (2009) also recorded a

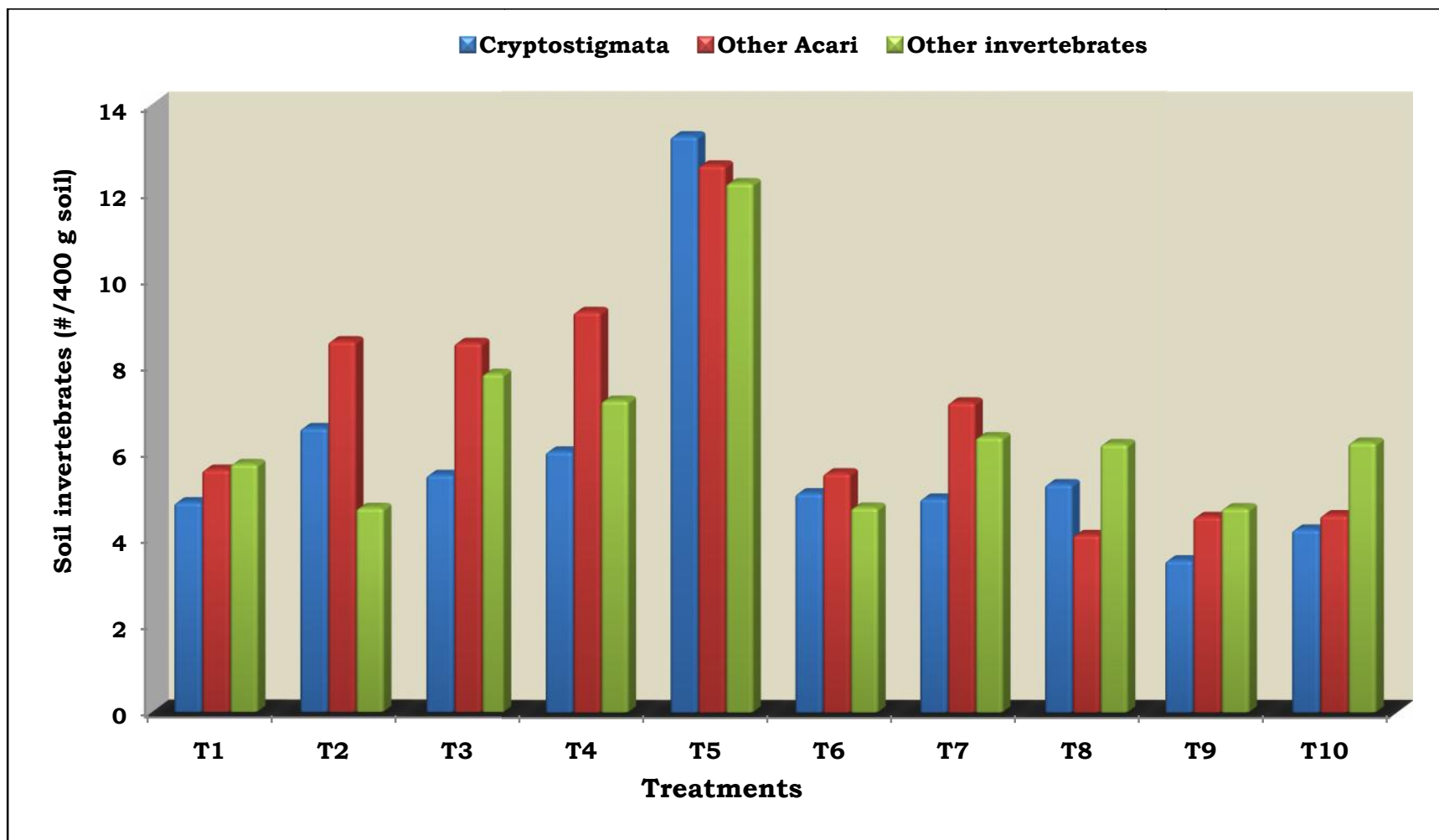


Fig. 1: Impact of organic manure and fertilizers on the abundance of soil invertebrates in soybean ecosystem during cropping season.

good amount of soil fauna from FYM alone and FYM + fertilizers treated plots in soybean ecosystem.

There was a fluctuation of soil invertebrates population in soybean ecosystem and the gradual increase in the abundance of the soil invertebrate from BAT was noticed. Highest population was noticed at 90 DAG. The peak population occurred when there was sufficient food availability with optimum moisture in food, soil moisture and lower soil temperature. The abundance of soil invertebrates was higher in cropping season and lower during non-cropping season. This may be due to higher soil temperature, lower moistural level both in the soil and food. The present findings are in close agreement with the observations of Srinivas Reddy (2002), Prasanna (2006), Girish (2006) and Satish (2009) who reported two peaks of the soil fauna during the post monsoon period (September-October) and pre-monsoon period (May-June) in soybean ecosystem.

5.1.2 Effect of different doses of FYM along with chemical fertilizers on the abundance of soil invertebrates during non-cropping season:

Lower abundance of soil invertebrate was observed in soybean during non-cropping season compared to the cropping season among the treatments. Other acari dominated among the soil invertebrates during non-cropping season. This may be due to wider food adoptability compared to other fauna. Further, lower abundance of soil invertebrates may be due to inadequate amount of moisture in soil and food, high soil temperature, exposure to sunlight with no cover crop and unavailability of suitable food. The plots treated with FYM or FYM + fertilizer recorded significantly higher abundance of soil invertebrates compared to fertilizer alone treated plot. This may be due to initial enhanced food, periodical

dried floral parts availability and water holding capacity of the soil due to application of FYM.

In the non-cropping season the highest abundance was recorded at 120 DAG, further, it reduced gradually up to 225 DAG. It may be due to low soil moisture content (<3%) and increase in the soil temperature by 2-3°C without rainfall which reduced the abundance of fragile invertebrates. The abundance of soil invertebrate increased at 270 DAG. It may be due to occurrence of rainfall in the previous fortnights, which increased the soil and food moisture. The present findings closely agree with the findings of Srinivasa reddy (2002), Prasanna (2006), Girish (2006) and Satish (2009) where they noticed less abundance of soil invertebrates from January to April during non-cropping season in soybean ecosystem.

5.1.3 Effect of different doses of FYM along with chemical fertilizers on the abundance of soil macro-arthropods:

There was no significant difference in soil macro-arthropods population among the treatments during cropping season. However, higher soil macro-arthropods abundance was recorded in plot treated with recommended doses FYM + mulching of glyricidia (2t per ha). It may be due to the availability of adequate conditions like soil moisture, low soil temperature and dense coverage of mulched leaves on the soil surface. The less activity of macro fauna in T₁₀ may be due to lower dose of FYM application and less ground cover by the standing crop.

The overall population of soil macro arthropods during non-cropping season was less compared to cropping season. It may be due to unsuitable conditions *viz.*, low soil moisture, higher soil temperature, seasonal variability between primary and secondary consumers and unavailability of food. However, higher soil macro-arthropods abundance

was observed in plot followed with package of practices. There is no literature to compare the present findings.

5.1.4 Effect of organic manures and chemical fertilizers on the abundance of nematodes:

Significantly lower nematodes population was observed in recommended FYM treated plot followed by recommended fertilizer alone. Significantly higher nematodes population was noticed in 12.5t of FYM + 75% recommended fertilizer followed by 20t of FYM treated plot. This may be due to availability of higher amount of manures in plot treated with extra quantity of FYM compared to other treatments. These results are in close conformity with the findings of Kundu and Mishra (1993) who reported lower nematode population in phorate applied plots. Nematodes abundance was significantly higher at 90 DAG compared to other durations.

5.1.5 Effect of different doses of FYM and chemical fertilizers on the relative abundance of soil invertebrates:

Relative abundance of other acari and total Acari was higher in the plot treated with 12.5 t of FYM + 75% of recommended fertilizer. Least abundance of other acari and total Acari was in plot treated with FYM + mulching with glyricidia and 50% of recommended FYM, respectively. Cryptostigmatids were relatively more abundant in plot treated with 20t of FYM and least relative abundance was noticed in plot treated with 15.0 t of FYM + 50% of recommended fertilizer. Maximum relative abundance of other invertebrates was recorded in plot treated with 50% of recommended FYM and least was recorded in 12.5 t of FYM + 75% recommended fertilizer treated plot. The variation in the relative abundance of soil invertebrates may be due to the availability of their food or host and moisture content of food and soil. Earlier studies by

Prasanna (2006), Girish (2006) and Satish (2009) also noticed higher faunal composition in modified treatments i.e. FYM applied plots.

5.2 Effect of organic manures and chemical fertilizers on the agronomic parameters of soybean:

5.2.1 Chemical properties of soil as influenced by different doses of FYM along with chemical fertilizers:

5.2.1.1 Soil organic carbon:

Application of 20t of FYM significantly increased soil organic carbon content compared to recommended fertilizer alone applied treatment at before imposition of treatments, 45 DAT and harvest. It revealed that by increased quantity of FYM application there was an increase in the soil organic carbon content may be due to enhanced faunal activity and microbial biomass, added cadavers, excreta and microbial organic carbon. This study coincides with the findings of Purakayastha *et al.* (2008) who found that significant enhanced soil organic carbon fractions was greater when farmyard manure was applied conjointly with 100% NPK. The present results are also supported by the finding of earlier reports (Gupta *et al.*, 1988, Yadav *et al.*, 2005, Devaraja, 2005, Prasanna, 2006, Girish, 2006 and Satish, 2009).

5.2.1.2 Available phosphorus:

Significantly higher available phosphorus was recorded in the plot treated with 20t of FYM compared to rest of the treatments. Least available phosphorus content of soil was recorded in plots treated with recommended fertilizer alone. These results indicated that incorporation of FYM increases the available phosphorus content of soil compared to recommended fertilizer alone. The increase in the available phosphorus content of soil may be attributed to organic acid produced during decomposition of FYM, preventing the conversion of soluble form of

phosphorus to insoluble form of phosphorus and enhanced the solubilization of native phosphorus in the soil. Addition of phosphate solubilizing bacteria might have active in the FYM applied treatments. Similar changes were observed by Gopal Krishnan and Panniappan (1992), Mathur *et al.* (1998), Devaraja (2005), Prasanna (2006), Girish (2006) and Satish (2009).

5.2.1.3 Available potassium:

Double dose of FYM recorded significantly maximum available potassium content of soil compared to rest of the treatments. Significantly lower available potassium was recorded in plot treated with recommended fertilizer alone. The available potassium increased due to the addition of FYM alone or in combination with fertilizer. This may be due to addition of potassium through FYM and also minimizes potassium loss due to leaching by retaining potassium at exchange site and thereby increasing the availability. This results coincides with the findings of Bhattacharyya *et al.* (2008) who showed that continuous application of NPK + 10 t FYM annually to soybean resulted in buildup of available K. Similar results were observed by Bansal (1992), Mathur *et al.* (1998), Devaraja (2005), Prasanna (2006), Girish (2006) and Satish (2009).

5.2.1.4 Exchangeable calcium:

Application of 20t of FYM significantly increased the exchangeable calcium content of soil compared to chemical fertilizer alone applied treatments. The increased content of exchangeable calcium of FYM plots is attributed to release of calcium during mineralization of added organic matter and also due to retention of calcium by added organic matter. Higher soil faunal activity also enhanced the base content of soil. The increase in the exchangeable calcium content of soil due to FYM application has been reported by Sureshlal and Mathur (1988), Devaraja (2005), Prasanna (2006), Girish (2006) and Satish (2009).

5.2.1.5 Exchangeable magnesium:

The plots treated with 20 t of FYM recorded significantly higher magnesium content of soil than the recommended fertilizer alone. This may be due to continuous application of manures and fertilizer. The release of magnesium during the mineralization of added organic manures might have contributed to higher magnesium. Increase in the exchangeable magnesium content of soil due to addition of FYM has been reported by Arun Prasad *et al.* (1991), Devaraja, (2005), Prasanna (2006), Girish (2006) and Satish (2009).

5.2.1.6 Soil microbial biomass C:

Significantly higher soil microbial biomass C recorded in the plot treated with the double doses of FYM. It may be due to the more availability of the organic matter as food source with good moisture retention capacity compared to the other treatments. The present findings coincides with the findings of Shashi *et al.* (2007) who reported that addition of FYM @ 20.0 t ha¹ increased the microbial population and improved soil properties compared to that of untreated plots. Significantly higher soil microbial biomass C recorded at 45 DAG as compared to before application of treatments and at the harvest. Similarly, Asha (2003) reported that significantly higher soil microbial biomass C in wetland compared to dry land. Satish (2009) and Rajkumar (2010) also found the similar results.

5.2.1.7 Soil pH:

FYM treated plot recorded less soil pH than the plot treated with the recommended fertilizer alone. The variation may be due to addition of organic manures with fertilizers since the past seven years. Addition of manures that altered the ionic constituents in each treated plots through

mineralization. The present findings are in close agreement with findings of Singh *et al.* (1980) and Satish (2009).

5.2.2 Impact of different doses of organic manure along with chemical fertilizers on the production of leaf biomass during crop growth:

There was no significant difference noticed among the treatments for the biomass of cotyledon, unifoliate and first trifoliate leaves. This may be due to the utilization of stored food from the seed and utilization of nutrients in the initial stages of crop growth. However, numerically higher biomass of cotyledon, unifoliate leaves and first trifoliate leaves was observed in T9, T10 and T8, respectively.

Higher biomass of leaf (from second trifoliate leaves onwards) was observed in plots treated with double the dose of FYM followed by FYM + fertilizer compared to fertilizer alone applied plot. Least leaf biomass was obtained in plot treated with recommended fertilizer alone.

Production of root biomass was higher in 20t of FYM applied plot compared to other treatments. Least biomass of roots was observed in recommended fertilizer alone treated plots. This may be due to congenial micro climate (aggregate formation, soil moisture etc.) for root and root hairs development in these treatments compared to recommended dose fertilizer alone.

5.2.3 Effect of various levels of FYM and chemical fertilizers on the growth and yield of soybean crop:

The plot treated with 20 t of FYM produced significantly higher plant biomass and number of pods per plant compared to T₉ and T₁₀. The plot receiving the additional FYM attributed higher plant biomass and pods per plant than recommended FYM or recommended fertilizer alone.

The maximum grain yield was obtained in the plot receiving 20 t of FYM ha⁻¹. The least grain yield was obtained in the treatment receiving recommended fertilizer alone. The increase in grain yield may be due to the higher availability of available phosphorus, potassium, calcium and magnesium to the crop and it was supported by producing higher plant biomass. The present findings are on par with the findings of Devaraja (2005), Girish (2006) and Satish (2009) where they got higher grain yield in plots treated with 17.5t of FYM/ha + 25 per cent of recommended fertilizers.

5.3 Impact of different doses of organic manure along with chemical fertilizers on termite infestation at harvesting stage:

Least damage caused by termites was noticed in plot treated with 12.5 t of FYM + 75 % of recommended fertilizer followed by package of practice applied plot. This may be due to application of phorate and other agrochemicals which acts as a toxic/repellency in action. Termite infestation was more in plot treated with recommended dose of partially decomposed FYM. This may be due to availability of partially decomposed organic manure at early part of the crop growth and for termites and the activity might have attracted to the soybean root zone in the later part of the crop growth.

5.4 Impact of different doses of organic manure along with chemical fertilizers on stem fly (*Melanagromyza sojæ*) infestation at harvesting stage:

There was a significant difference in basal and total tunnelling length among the treatments. Significantly least basal and total tunnelling length was recorded in plot treated with 12.5 t of FYM + 75% of recommended fertilizer. Higher basal and total tunnelling length was recorded in package of practice followed plot. No significant difference was observed among the treatments for secondary tunnelling length.

However, lower and higher basal tunnelling length was recorded in plot treated with recommended fertilizer alone and package of practice applied plot respectively. The variation of stem tunnelling may be depended on the pith thickness, stem girth and petiole length of the leaves through which the maggots travelled during feeding activity. Various modified treatments might have influenced by the plant nutrients present in the soil during different growth stage.

The present findings are in contrary with the findings of Prasanna (2006) and Satish (2009) where, they reported significantly lower damage of stem fly in the plot treated with recommended package of practices. Similarly Girish (2006) and Satish (2009) reported significantly higher total stem tunneling length in the plot treated with 12.5t of FYM+ 75% of recommended fertilizer applied compared to T₁ harvesting stage.

5.5 To assess the relationship, if any between soil fertility status and abundance of soil invertebrates of soybean:

The soil invertebrates exhibited a significant positive relation with available phosphorus, available potassium, exchangeable calcium, exchangeable magnesium and microbial biomass C. However, soil pH showed negative non-significant correlation. The influence of these soil chemical parameters on the abundance of soil invertebrates was up to 60 percent. The available phosphorus exhibited a significant positive relation with soil invertebrates, available potassium, exchangeable calcium, exchangeable magnesium, organic carbon and microbial biomass C. Among them, the influence of available potassium and exchangeable calcium on the quantity of available phosphorous was up to 66 per cent. Available potassium had significant relationship with soil invertebrates and all the soil chemical parameters except the soil pH. Influence of these soil chemical parameters on the quantity of available potassium was up to 81 per cent. The exchangeable calcium exhibited a

significant relationship with soil invertebrates, available phosphorous, available potassium, exchangeable magnesium with the influence of 83%. The exchangeable magnesium exhibited a significant relationship with available potassium, exchangeable calcium. The soil pH had no significant relationship with soil invertebrates, other soil parameters and microbial biomass carbon. Soil organic carbon had significant relationship with available potassium and exchangeable magnesium with the influence of 59%. Microbial biomass carbon exhibited a significant positive relationship with soil invertebrates and all soil parameters except soil pH. The present findings are closely related with the findings of Satish (2009) where he reported significant relation between soil chemical parameters and soil invertebrates. Further, he also noticed >50% of influence of soil chemical parameters (specially microbial biomass carbon) on soil invertebrates.

5.6 To assess the relationship, if any between abiotic factors and abundance of soil invertebrates of soybean:

A significant negative relationship existed between the abundance of soil invertebrates and maximum temperature of atmosphere and soil temperature. However, sunshine hours showed negative non-significant correlation with soil invertebrates. Similar negative correlation with soil temperature was recorded for Acari in deciduous forest (Sinha *et al.*, 1991) and soil insects in *Dalbergia sissoo* (Shukla *et. al.*, 1996). Maximum relative humidity, minimum relative humidity, total rainfall and soil moisture showed positive relationship with soil arthropods abundance. Similarly, positive correlation with soil moisture was recorded for micro-arthropods, Collembola and Cryptostigmata in waste land (Bhattacharya and Raychaudhuri, 1979); Collembola in grave yard (Choudhuri *et. al.*, 1978); Acari in forest (Banerjee and Roy, 1988); total soil fauna in forest (Dhar and Raina, 1988); Collembola in forest (Vats and Narula, 1990b); Collembola in deciduous forest (Sinha *et al.*, 1991);

cryptostigmatid mites in forest (Sheela and Haq, 1991); Acari in forest (Banerjee, 1996); Collembola in rubber (Chakraborti and Bhattacharya, 1996); mites and soil insects in *Dalbergia sissoo* (Marnta Singh *et. al.*, 1996 and Shukla *et. al.*, 1996); Collembola in agro-forestry (Badejo *et. al.*, 1998); Precipitation was significantly correlated with Collembola (Palacios *et al.*, 2007).

Among all the abiotic factors, maximum temperature of the atmosphere had negative influence of 40% on the abundance of total soil invertebrates, 34% on total acari, 22% on other acari and 54% on other invertebrates. Minimum relative humidity showed 50% of impact on abundance of cryptostigmata. Similarly, Satish (2009) also observed 73, 65, 64, 63 and 55% impact of abiotic factors on the abundance of cryptostigmatids, total acari, total soil invertebrates, other acari and other invertebrates, respectively in soybean ecosystem.

Summary

VI. SUMMARY

The investigation on the impact of organic manure and chemical fertilizers on the abundance of soil invertebrates, soil fertility and impact of abiotic factors on soil invertebrates in soybean ecosystem was carried out at the Zonal Agriculture Research Station, University of Agricultural Sciences, GKVK, Bangalore, during *kharif* season of 2010.

Soil application of 20 tonnes of FYM/ha recorded significantly higher soil invertebrates, soil total Acari, other Acari, cryptostigmatids and other invertebrates as compared to other treatments during the cropping season. Least abundance of soil invertebrates was observed in the plot treated with recommended fertilizer alone. The highest population of total soil invertebrates was noticed during 90 DAG. Least population of soil invertebrates was noticed at before application of treatments and non-cropping season.

The plots treated with FYM or FYM + fertilizer recorded significantly higher abundance of soil invertebrates compared to fertilizer alone treated plot during non-cropping season.

There was no significant difference in soil macro-arthropods activity among the treatments during both cropping season and non-cropping season. However, higher soil macro-arthropods abundance was recorded in plot treated with recommended dose of FYM + mulching of glyricidia (2t per ha) and least soil macro-arthropods abundance was recorded in plot treated with recommended fertilizer alone during cropping season. Similarly, higher and lower soil macro-arthropods abundance was recorded in plot treated with package of practices and recommended dose of partially decomposed FYM, respectively during non-cropping season.

Lower nematode population was observed in recommended FYM treated plot followed by recommended fertilizer alone. The plot treated with 12.5t of FYM + 75% recommended fertilizer and 20t of FYM supported higher nematodes population.

Relative abundance of other acari and total Acari was higher in plot treated with 12.5 t of FYM + 75% of recommended fertilizer. Least abundance of other acari and total Acari was found in plot treated with FYM + mulching with glyricidia and 50% of recommended FYM, respectively. Cryptostigmatids were relatively more abundant in plot treated with 20t of FYM and least relative abundance was noticed in plot treated with 15.0 t of FYM + 50% of recommended fertilizer. Maximum relative abundance of other invertebrates recorded in plot treated with 50% of recommended FYM and least in 12.5 t of FYM + 75% recommended fertilizer treated plot.

Application of 20t of FYM significantly increased the soil organic carbon content, available phosphorous, available potassium, exchangeable calcium, exchangeable magnesium and microbial biomass carbon in the soil compared to recommended fertilizer alone applied treatment. FYM treated plots recorded less soil pH than the plot treated with the recommended fertilizer alone.

There was no significant difference in the biomass production of cotyledon, unifoliate and first trifoliate leaves noticed among the treatments.

Higher production of leaf biomass (from second trifoliate leaves onwards) and root biomass was observed in plots treated with double the dose of FYM followed by FYM + fertilizer compared to fertilizer alone applied plot.

Significantly higher plant biomass and number of pods per plant were produced in the plot treated with 20 t of FYM compared to recommended fertilizer and 50% of recommended FYM treated plot.

Soil application of 20 t of FYM recorded higher grain yield compared to chemical fertilizers alone and package of practices followed treatments.

Least damage caused by termites was noticed in plot treated with 12.5 t of FYM + 75 % of recommended fertilizer followed by package of practice applied plot. Termite infestation was more in plot treated with recommended dose of partially decomposed FYM.

Plot treated with 12.5 t of FYM + 75% of recommended fertilizer recorded least stem tunnelling by the stem fly. Higher tunnelling length was recorded in package of practice applied plot.

The soil invertebrates exhibited a significant positive relation with available phosphorus, available potassium, exchangeable calcium, exchangeable magnesium and microbial biomass C. However, soil pH showed negative non-significant correlation. The significant relationship was also found among the soil chemical parameters.

There was a significant negative relationship existed between the abundance of soil invertebrates and maximum temperature of the atmosphere and soil temperature. Negative correlation was observed with sunshine hours. However, maximum relative humidity, minimum relative humidity, total rain fall and soil moisture had positive correlation. Maximum temperature of the atmosphere had significant negative impact on abundance of soil invertebrates compared to other abiotic factors.

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* Originals not seen