

**DIVERSITY AND DISTRIBUTION OF SOIL
ARTHROPODS OF HARYANA IN RELATION TO
EDAPHIC FACTORS**

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Zoology

By

Kavita

Registration Number: 41900299

Supervised By

Dr. Joydeep Dutta (14336)

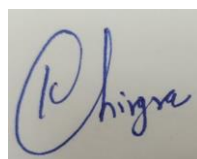
**Prof. and Head - Department of Zoology
School of Bioengineering and Biosciences**



**LOVELY PROFESSIONAL UNIVERSITY, PUNJAB
2024**

DECLARATION

I, hereby declared that the presented work in the thesis entitled “DIVERSITY AND DISTRIBUTION OF SOIL ARTHROPODS OF HARYANA IN RELATION TO EDAPHIC FACTORS” in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of Dr. Joydeep Dutta, working as Prof. and Head - Department of Zoology, in the School of Bioengineering and Biosciences, Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of another investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.



Kavita

41900299

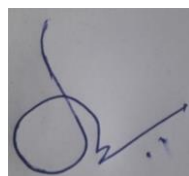
Zoology

Lovely Professional University,

Punjab, India.

CERTIFICATE

This is to certify that the work reported in the Ph. D. thesis entitled “DIVERSITY AND DISTRIBUTION OF SOIL ARTHROPODS OF HARYANA IN RELATION TO EDAPHIC FACTORS” submitted in fulfilment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Zoology, School of Bioengineering and Biosciences, is a research work carried out by Kavita, 41900299, is bonafide record of her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

A handwritten signature in blue ink, appearing to be 'Dr. Joydeep Dutta', written on a light-colored background.

(Signature of Supervisor)

Dr. Joydeep Dutta

Prof. and Head - Department of Zoology

School of Bioengineering and Biosciences,

Lovely Professional University,

Punjab, India.

ABSTRACT

Phylum Arthropoda comprises 84% of population of Kingdom Animalia. A single square yard of soil contains 500 to 2,00,000 arthropods. In soil food web, arthropods occupy higher trophic levels and acts as detritivores, decomposers, predators, soil structure engineers and biological population regulators. Because of their wide distribution and numerical abundance, the same are taking attention of soil zoologists from time to time and a long series of observations have been made throughout the different corners of the world. Although soil arthropods a boon for every ecosystem, agricultural land and many more systems, however, a very little is known about the soil arthropods fauna in Haryana.

The goal of the current study is to examine the diversity of soil arthropods occupying agricultural fields in different districts of this specific region as well as how it is affected by seasonal edaphic variations. The same is also watchful to be related with changing life cycles of the studied crops (from sowing till harvesting) as well as to the soil of a particular standing crop from farming fields and particular terrain type from the non-farming lands.

Haryana is autonomous in food production as well after the Uttar Pradesh, the largest confreere to the chief pool of food grains (wheat, rice, sugarcane, jowar, bajra, cotton) in India. Agricultural zone I (Karnal, Kaithal, Yamunanagar) along with agricultural zone II (Sirsa, Hisar, Rohtak) of Haryana are intentionally selected for farming fields as with healthier irrigation potential, heavy handed agricultural possibilities, more coverage of percentage area. Even about 80% citizenry in this state are either directly or indirectly relying on agriculture. Additionally, the present author has undertaken the adjoining non-farming land (industrial and forest) so as to compare diversity and distribution of soil arthropods with farming fields. Overall, the present investigation is based on 7 farming fields and 2 non - farming lands. Out of seven farming fields, first two belongs to sugarcane fields, Karnal and Yamunanagar; middle two to rice fields, Karnal and Kaithal; the next two to wheat fields, Sirsa and Hisar; and the remaining one to jowar field,

Rohtak. While out of two non - farming lands, one belongs to the forest land, Panipat, and the other to the outskirts of textile land, Panipat. Following objectives are undertaken to analyze the soil fauna of Haryana:

1. To study soil physical and chemical factors for the period of two years from inception.
2. To study the arthropod diversity of soil of different farm and non - farm land area.
3. To identify the arthropods through morphological and molecular techniques.
4. Seasonal distribution and correlation of the arthropods diversity with different edaphic factors.

For the first objective, soil samples were taken (from November 2020 to October 2022) from a depth of 15 cm. In each sample, soil from 5 independent points (250 gms) per study field was collected. They were then mixed to make up the sample 1.25 kg. This was then repeated on to three different sites of the same district's crop field. Collected soil samples were then immediately stored in labelled plastic bags with appropriate sample information (e.g. date, field, district) at 0 °C in the laboratory for arthropod extraction via Berlese - Tullgren Method (Berlese, 1913) and estimation of soil parameters such as soil temperature, moisture, pH, EC, OC content, OM content, available P, N, K, and metal analysis in the laboratory. For the second objective, soil arthropods extraction performed by the Berlese - Tullgren Method. The set up was made up of six funnels placed in two rows (three funnels in each row) and enlightened by 6 different 60 W bulbs (each one occupying position exactly over to respective funnels) along with 6 vials fitted below funnels where arrangements for total darkness were done. Because of this set up, soil creatures were forced to travel to the damp section. The whole apparatus is mounted on a plywood board set in a wooden framework resembling a rack where the collecting vials (tubes) are tightly fitted. The vials contain a mixture of 70% ethyl alcohol and glycerine in the proportion of 20:1 for collecting as well as preserving the specimen. The extraction continued for 72 - 96 hours, after which the soil fauna in vials was ready for identification. For the third objective, major level identification was done via optical

microscope and after that for minor level identification, the screened separated specific morphology bearing creatures in specific Eppendorf tubes were sent Zoological Survey of India to various scientists of specialization. For the last or fourth objective, correlation and regression performed to know the relationship between soil arthropod's diversity and distribution with seasonal variation of edaphic factors along with calculation of the species diversity indices.

Out of 79 observed taxa, 37 were identified while 42 remain unidentified. Reason behind so many unidentified specimens was either they were very few in number to analyze or once photographed then lost during screening or their damage during identification by specialists as mentioned in their identification reports. Among identified taxa, there were collembolans, acarina, diptera, thysanuran and araneae. Taxa with majority observed were collembolans and acarina. Collembolans were found with families of Hypogastruridae, Tullbergiidae, Neanuridae, Isotomidae, Paronullidae, Sminthuridae and genera of *Isotomurus*, *Cryptopygus*, *Proisotoma*. Acarina were found with families Histiostomatidae, Tetranychidae, Bdellidae, Pygmephoridae, Prasitidae, Laelapidae, Haplozetidae, Scheloribatidae, Protoribatidae, Epilohmanniidae, Acaridae and genera and/or species of *Histiostoma feroniarum*, *Eotetranychus Carapini*, *Bdella sp.*, *Mahunkania hallensis*, *Mahunkania secunda*, *Trachygamasus medianus*, *Cosmolaelaps indicus*, *Trachyoribates ovulum*, *Scheloribates curvialatus*, *Scheloribates thermophilus*, *Protoribates magnus*, *Epilohmannia minuta aegyptica*, *Acarus gracillis*, *Rhizoglyphus echinopus*.

Crop variety was found associated significantly with microarthropod groups as when compared taxa - wise - soil arthropods with respective crop variety then some were found associated with one specific crop variety while others with two specific crop varieties irrespective of their districts. Further, when arthropods abundance was compared with their respective crop life cycle i.e. from sowing to harvesting time period, jowar showed maximum abundance after one month of sowing, while sugarcane showed maximum abundance after three months of sowing, Wheat showed after four months, and rice

showed just after sowing. Thus, our hypothesis that crop life cycles affect arthropod abundance proves wrong.

In various soil samples, physical and chemical properties were analyzed. June was the month with the highest recorded soil temperature and it attained the base line in the month of January during study period. The soil in all the sampling fields was alluvial in nature. Soil moisture ranged 5.1% - 20.3%, pH 6.2 - 8.2, EC 0.81mS/m - 1.9mS/m, OC 0.1% - 0.69%, OM 0.16% - 1.11%, available N 103.45ppm - 577ppm, K 8.6 Kg/ac - 155Kg/ac, P 5.7 Kg/ac - 90.01 Kg/ac, S 6.5ppm - 133ppm, Zn 0.65ppm - 2.3ppm, Fe 0.75ppm - 6.9ppm, Cu 0.12ppm - 0.98ppm, Mn 2.002 ppm - 5.4 ppm.

Literature shows some interdependence studies of these physicochemical factors like SOC is positively correlated with soil microbial biomass carbon, which in turn reaches its optimal level when the soil pH is between 5.00 and 6.00 and declines when lower than 5.00. Additionally, pH influences the availability of nutrients in the soil, which has an indirect impact on the organization of microbial communities. However, in all the soils in Haryana belonging to various types of alluvial soils, soil pH and EC did not exhibit any association with the available Zn, Cu, Fe, and Mn. Instead, a lack of cationic micronutrients including Zn, Fe, Mn, and Cu has been observed over time in Indian soils as well as other soils throughout the world. However, it was discovered that there was a substantial positive correlation between OC, Fe and Cu availability. Because of this dependency, it has been difficult for us to determine how specific edaphic conditions can be related to the variety of soil arthropods. What the situation actually is, there are so many and so many infinite and undefined factors whose cumulative effect led soil arthropods to grow, develop, reproduce, increase or decrease, diverse or few, flourish or finish, migrate or remain native and so on. Then, to study impact of individual edaphic factor on diversity of soil arthropods is only seems hypothetical.

At last but not the least, this investigation will surely open new roads for entomologists, taxonomists, farmers seeking for soil fertility options, Ph.D. pursuing scholars and staff engaged under various projects of agriculture, alongwith incoming scholars wants to

disclose this region's fauna with more specifications as the present study gives only an elementary idea for the same.

ACKNOWLEDGEMENT

Agricultural intensification use inorganic fertilizers that not only altered the soil pH, structure as well as texture but also disrupted the niches for the microarthropods which are essential for nutrient recycling, a fundamental ecosystem service. No comprehensive work has been done from this region earlier. So, it is a first attempt to give a preliminary knowledge on the current state of soil from Haryana.

First and foremost my heart lifts up with praise to thank God, the creator and to whom I owe my whole hearted gratitude for His boundless grace that has been falling throughout the years like a gentle rain-a-shower of refreshment.

I would foremost like to express profound sagacity of gratitude whole heartedly to my teacher and esteemed guide **Dr. Joydeep Dutta**, M.Sc., Ph.D., Professor, Department of Zoology, Lovely Professional University, Phagwara, for having given me an opportunity as research scholar under his esteemed and meticulous guidance. I always admired his unique approach, constant encouragement, valuable suggestions, meticulous care, scientific advice, intellectual freedom that have led me in the right direction in all ways. I thank him for having shaped me to take up carrier in Zoology. Each fragment of the work reflects the elan touch of his concept interpretation.

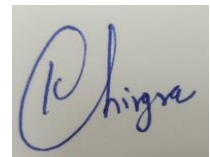
Together, we would like to thank the farmers of Yamunanagar, Karnal, Kaithal, Hisar, Sirsa, Rohtak, Panipat lands for their hospitality during the soil sampling phase and in addition to **Dr. Mandal**, **Dr. Shelley Acharya**, **Dr. Sovik** from Zoological Survey of India and **Dr. Meenakshi Bharti** from Punjab University for their valuable support in identifying soil arthropods.

My heart is feeling thankfulness for **Mrs. Sanju Abrol**, The Principal of D.B.G Government College, Panipat, for her immense support and no objection towards my own lab work of Ph.D. in their college. Also, RAC members whose recommendations during every ETP presentation as well result inspired me towards gaining more information

related with my own project. I express my hearty thanks to my seniors **Dr. Aijaz, Mrs. Ruby, Dr. Pooja Rani, Dr. Kavita Jain, Mr. Arvind, Mrs. Seema Rani** for their constant support and encouragement rendered for the successful completion of the thesis work.

I cherish my lovable dad **Mr. Dharam Pal Dhingra** and extraordinary supporting husband **Mr. Kamal Taneja** for their indefatigable energy in caring for me and a great interest in my education right, leading up to the level of obtaining a Ph. D degree, which I feel is an act that could not be thanked by mere words. My mother **Mrs. Sushma Kumari Dhingra** and mother-in-law **Mrs. Bhagwan Devi**, whom provided me with their special care, everlasting love and endless support in all dimensions of my studies. I fumble for words to express my heavy debts of my gratitude to my beloved son **Mr. Bhevin Taneja** for care and support in all pursuits.

Last but not the least I acknowledge the help extended by everyone directly or indirectly for the successful completion of my Doctor of Philosophy degree.



Kavita

(7/5/2024)

TABLE OF CONTENTS

<u>S. NO.</u>	<u>TITLE</u>	<u>PAGE NO</u>
1.	LIST OF TABLES	xii - xvii
2.	LIST OF FIGURES	xviii - xx
3.	ABBREVIATIONS	xxi - xxiii
4.	CHAPTER - 1 INTRODUCTION	1 - 19
5.	CHAPTER - 2 REVIEW OF LITERATURE	20 - 59
6.	CHAPTER - 3 METHODOLOGY	60-81
7.	CHAPTER - 4 RESULTS AND DISCUSSION	82 - 275
8.	CHAPTER - 5 CONCLUSION	276 - 279
9.	APPENDIX	280 - 312
10.	REFERENCES	313 - 376
11.	LIST OF PUBLICATIONS	377
12.	LIST OF CONFERENCES	378
13.	LIST OF WORKSHOPS	379

LIST OF TABLES

Table 1.1: Function of Macro - and Micro - nutrients in plants

Table 1.2: Standard value of edaphic factors according to Agricultural Department of Haryana

Table 1.3: Contribution of arthropods in annual plant litter turnover

Table 1.4: Influence of arthropods in distribution of microbial populations

Table 1.5: Contribution of soil arthropods feces to increase minerals in soil

Table 1.6: Activity of termites to ensure mineralization of organic compounds

Table 1.7: Contribution of soil arthropods towards soil structure

Table 2.1: Three zones of Haryana on the basis of ecology and cropping pattern

Table 2.2: Basic statistics from Statistical Abstract of Haryana 2018 - 2019

Table 2.3: District - wise nutrient deficiency in Haryana state

Table 3.1: Description of study fields

Table 4.1: Arthropod fauna at Sugarcane field, Yamunanagar during 2020 - 21

Table 4.2: Arthropod fauna at Sugarcane field, Yamunanagar during 2021 - 22

Table 4.3: Arthropod community and their month wise population at Sugarcane field, Yamunanagar during 2020 - 21

Table 4.4: Arthropod community and their month wise population at Sugarcane field, Yamunanagar during 2021 - 22

Table 4.5: Species diversity indices at Sugarcane field, Yamunanagar during 2020 - 21

Table 4.6: Species diversity indices at Sugarcane field, Yamunanagar during 2021 - 22

Table 4.7: Arthropod fauna at Sugarcane field, Karnal during 2020 - 21

Table 4.8: Arthropod fauna at Sugarcane field, Karnal during 2021 - 22

Table 4.9: Arthropod community and their month wise population at Sugarcane field, Karnal during 2020 - 21

Table 4.10: Arthropod community and their month wise population at Sugarcane field, Karnal during 2021 - 22

Table 4.11: Species diversity indices at Sugarcane field, Karnal during 2020 - 21

Table 4.12: Species diversity indices at Sugarcane field, Karnal during 2021 - 22

Table 4.13: Arthropod fauna at Rice field, Karnal during 2020 - 21

Table 4.14: Arthropod fauna at Rice field, Karnal during 2021 - 22

Table 4.15: Arthropod community and their month wise population at Rice field, Karnal during 2020 - 21

Table 4.16: Arthropod community and their month wise population at Rice field, Karnal during 2021 - 22

Table 4.17: Species diversity indices at Rice field, Karnal during 2020 - 21

Table 4.18: Species diversity indices at Rice field, Karnal during 2021 - 22

Table 4.19: Arthropod fauna at Rice field, Kaithal during 2020 - 21

Table 4.20: Arthropod fauna at Rice field, Kaithal during 2021 - 22

Table 4.21: Arthropod community and their month wise population at Rice field, Kaithal during 2020 - 21

Table 4.22: Arthropod community and their month wise population at Rice field, Kaithal during 2021 - 22

Table 4.23: Species diversity indices at Rice field, Kaithal during 2020 - 21

Table 4.24: Species diversity indices at Rice field, Kaithal during 2021 - 22

Table 4.25: Arthropod fauna at Wheat field, Sirsa during 2020 - 21

Table 4.26: Arthropod fauna at Wheat field, Sirsa during 2021 - 22

Table 4.27: Arthropod community and their month wise population at Wheat field, Sirsa during 2020 - 21

Table 4.28: Arthropod community and their month wise population at Wheat field, Sirsa during 2021 - 22

Table 4.29: Species diversity indices at Wheat field, Sirsa during 2020 - 21

Table 4.30: Species diversity indices at Wheat field, Sirsa during 2021 - 22

Table 4.31: Arthropod fauna at Wheat field, Hisar during 2020 - 21

Table 4.32: Arthropod fauna at Wheat field, Hisar during 2021 - 22

Table 4.33: Arthropod community and their month wise population at Wheat field, Hisar during 2020 - 21

Table 4.34: Arthropod community and their month wise population at Wheat field, Hisar during 2021 - 22

Table 4.35: Species diversity indices at Wheat field, Hisar during 2020 - 21

Table 4.36: Species diversity indices at Wheat field, Hisar during 2021 - 22

Table 4.37: Arthropod fauna at Jowar field, Rohtak during 2020 - 21

Table 4.38: Arthropod fauna at Jowar field, Rohtak during 2021 - 22

Table 4.39: Arthropod community and their month wise population at Jowar field, Rohtak during 2020 - 21

Table 4.40: Arthropod community and their month wise population at Jowar field, Rohtak during 2021 - 22

Table 4.41: Species diversity indices at Jowar field, Rohtak during 2020 - 21

Table 4.42: Species diversity indices at Jowar field, Rohtak during 2021 - 22

Table 4.43: Arthropod fauna at Forest land, Panipat during 2020 - 21

Table 4.44: Arthropod fauna at Forest land, Panipat during 2021 - 22

Table 4.45: Arthropod community and their month wise population at Forest land, Panipat during 2020 - 21

Table 4.46: Arthropod community and their month wise population at Forest land, Panipat during 2021 - 22

Table 4.47: Species diversity indices at Forest land, Panipat during 2020 - 21

Table 4.48: Species diversity indices at Forest land, Panipat during 2021 - 22

Table 4.49: Overall collembolans reported from different study fields

Table 4.50: Overall mites reported from different study sites

Table 4.51: Other arthropods reported from different study sites

Table 4.52: Unidentified specimens reported from different study fields

Table 4.53: Correlation between edaphic factors and soil arthropods observed at Sugarcane field, Yamunanagar

Table 4.54: Correlation between edaphic factors and soil arthropods observed at Sugarcane field, Karnal

Table 4.55: Correlation between edaphic factors and soil arthropods observed at Rice field, Karnal

Table 4.56: Correlation between edaphic factors and soil arthropods observed at Rice field, Kaithal

Table 4.57: Correlation between edaphic factors and soil arthropods observed at Wheat field, Sirsa

Table 4.58: Correlation between edaphic factors and soil arthropods observed at Wheat field, Hisar

Table 4.59: Correlation between edaphic factors and soil arthropods observed at Jowar field, Rohtak

Table 4.60: Correlation between edaphic factors and soil arthropods observed at Forest land, Panipat

Table A.1: Physicochemical analysis of edaphic factors during 2020 - 21 at Sugarcane field, Yamunanagar

Table A.2: Physicochemical analysis of edaphic factors during 2021 - 22 at Sugarcane field, Yamunanagar

Table A.3: Physicochemical analysis of edaphic factors during 2020 - 21 at Sugarcane field, Karnal

Table A.4: Physicochemical analysis of edaphic factors during 2021 - 22 at Sugarcane field, Karnal

Table A.5: Physicochemical analysis of edaphic factors during 2020 - 21 at Rice field, Karnal

Table A.6: Physicochemical analysis of edaphic factors during 2021 - 22 at Rice field, Karnal

Table A.7: Physicochemical analysis of edaphic factors during 2020 - 21 at Rice field, Kaithal

Table A.8: Physicochemical analysis of edaphic factors during 2021 - 22 at Rice field, Kaithal

Table A.9: Physicochemical analysis of edaphic factors during 2020 - 21 at Wheat field, Sirsa

Table A.10: Physicochemical analysis of edaphic factors during 2021 - 22 at Wheat field, Sirsa

Table A.11: Physicochemical analysis of edaphic factors during 2020 - 21 at Wheat field, Hisar

Table A.12: Physicochemical analysis of edaphic factors during 2021 - 22 at Wheat field, Hisar

Table A.13: Physicochemical analysis of edaphic factors during 2020 - 21 at Jowar field, Rohtak

Table A.14: Physicochemical analysis of edaphic factors during 2021 - 22 at Jowar field, Rohtak

Table A.15: Physicochemical analysis of edaphic factors during 2020 - 21 at Forest land, Panipat

Table: A.16 Physicochemical analysis of edaphic factors during 2021 - 22 at Forest land, Panipat

Table A.17: Physicochemical analysis of edaphic factors during 2020 - 21 at Outskirts of Textile land, Panipat

Table: A.18 Physicochemical analysis of edaphic factors during 2021 - 22 at Outskirts of Textile land, Panipat

LIST OF FIGURES

Figure 1.1: Examples of soil physical, chemical, and biological characteristics

Figure 3.1: Map showing study fields and lands

Figure 3.2: Study fields (1) Sugarcane field, Yamunanagar; (2) Sugarcane field, Karnal; (3) Rice field, Karnal; (4) Jowar field, Rohtak; (5) Wheat field, Sirsa; (6) Outskirts of textile land, Panipat; (7) Forest land, Panipat.

Figure 3.3: Methodology section (a) Soil samples drying; (b) Soil sample packing with labels; (c) Temperature measurement at fields; (d) Berlese - Tullgren set up; (e) Collection of arthropods sample wise; (f) Apparatus for soil physicochemical analysis; (g) Apparatus for metal analysis; (h) Screened vials ready for identification; (i) Couriers ready to dispatch.

Figure 4.1: Seasonal variation of edaphic factors in Sugarcane field, Karnal

Figure 4.2: Seasonal variation of edaphic factors in Sugarcane field, Yamunanagar

Figure 4.3: Seasonal variation of edaphic factors in Rice field, Karnal

Figure 4.4: Seasonal variation of edaphic factors in Rice field, Kaithal

Figure 4.5: Seasonal variation of edaphic factors in Wheat field, Sirsa

Figure 4.6: Seasonal variation of edaphic factors in Wheat field, Hisar

Figure 4.7: Seasonal variation of edaphic factors in Jowar field, Rohtak

Figure 4.8: Seasonal variation of edaphic factors in Forest land, Panipat

Figure 4.9: Seasonal variation of edaphic factors in Outskirts of Textile land, Panipat

Figure 4.10: Generalized labelled diagram of *Proisotoma minuta*

Figure 4.10: (a) Collembolans

Figure 4.11: Generalized labelled diagram of *Cosmolaelaps indicus*

Figure 4.11: (a) Acarina

Figure 4.12: Diptera, Thysanura, and Aranea

Figure 4.13: Unidentified specimens serial-wise

Figure 4.14: Collembolan (report) identified by Dr. Mandal from ZSI, Kolkata dated 28-3-2022

Figure 4.15: Collembolan (report) identified by Dr. Mandal from ZSI, Kolkata dated 15-11-2022

Figure 4.16: Mites (report) identified by Dr. Shelley Acharya from ZSI, Kolkata

Figure 4.17: Mites (report) identified byt Dr. Shelley Acharya from ZSI, Kolkata dated 16-1-2023

Figure 4.18: Impact of edaphic factors on soil arthropods during study period (2020 - 2022) at Sugarcane field, Yamunanagar

Figure 4.19: Impact of edaphic factors on soil arthropods during study period (2020 - 2022) at Sugarcane field, Karnal

Figure 4.20: Impact of edaphic factors on soil arthropods during study period (2020 - 2022) at Rice field, Karnal

Figure 4.21: Impact of edaphic factors on soil arthropods during study period (2020 - 2022) at Rice field, Kaithal

Figure 4.22: Impact of edaphic factors on soil arthropods during study period (2020 - 2022) at Wheat field, Sirsa

Figure 4.23: Impact of edaphic factors on soil arthropods during study period (2020 - 2022) at Wheat field, Hisar

Figure 4.24: Impact of edaphic factors on soil arthropods during study period (2020 - 2022) at Jowar field, Rohtak

Figure 4.25: Impact of edaphic factors on soil arthropods during study period (2020 - 2022) at Forest land, Panipat

ABBREVIATIONS

EC - electrical conductivity

N - nitrogen

P - phosphorus

K - potassium

cm - centimeter

⁰C - degree celsius

gms - grams

no. - numbers

Zn - zinc

Pb - lead

Cr - chromium

Fe - iron

Al - aluminium

Cu - copper

Ni - nickel

Mn - manganese

Be - beryllium

Mo - molybdenum

YN - Yamunanagar

KR - Karnal

KT - Kaithal

RO - Rohtak

HI - Hisar

SI - Sirsa

S - Sugarcane

J - Jowar

R - Rice

W - Wheat

FA - Forest land

IA - Industrial Area/Outskirts of textile land

r.f. - Relative Frequency

J - January

F - February

M - March

A - April

M - May

J - June

J - July

A - August

S - September

O - October

N - November

D - December

% - percentage

Mm - milli mos

ppm - parts per million

Kg/ac - kilograms per acre

(p) - preceding year (2020-21)

(s) - succeeding year (2021-22)

OC - organic carbon

OM - organic matter

SOC - soil organic carbon

SOM - soil organic matter

CEC - cation exchange capacity

ZSI - Zoological Survey of India

INTRODUCTION

CHAPTER 1: INTRODUCTION

A saying by Dr. A.P.J. Abdul Kalam emphasised the role of organic farming in agriculture, including soil health improvement, local inputs use, and use of local labour at relatively high intensity. In addition, father of organic farming (Albert Howard) stated oneness of soil with plants, animals, and man that cannot be divided (Howard et al., 1910; Sanderan, 2021). The latin meaning of agriculture is agri (field) and cultura (cultivation), denoting so many ways in which domestic fauna and flora sustain the global population of residents by supplying food and others (Harris & Fuller, 2014).

1.1 Agricultural statistics in Haryana

Production of sufficient food grains in Haryana makes it a leading supporter to the country's food grain production, so called the Food Mine or Bread Basket of the India. It will certainly assist India in meeting Sustainable Development Goal 2 (SDG 2) by 2030, including the elimination of hunger, the achievement of food security, and the promotion of environmentally sustainable agriculture. Despite occupying less than 1.4 percent of the geographical area, it ranks sixth as the largest producer of food grain, producing 16.38 million metric tonnes on a 4.47 - million - hectare area (Nagpal, 2022). In addition, it is the country's fourth-largest wheat producer, accounting for approx. 12% of total wheat production, while in terms of total rice production, it ranks tenth (Haryana, 2016). There is a surge of 94% in the overall production rate of paddy and wheat, and in contrast, an overall decline of 32% has been recorded between 1966 - 67 and 2015 - 16 in the production of maize, barley, bajra, and pulses (Kumar, 2017).

About 80% of the citizens in this state are either by a direct route or indirect based on agriculture. The cultivable area is 3.809 million hectares, the net sown area is 3.566 million hectares, and the area seeded more than once is 2.938 million hectares with 182.39% cropping intensity out of the total geographical land of 86.2%. A total of 2.936 million hectares of land is irrigated (45.3% using canals, 54.2% with tube wells, and 0.5% with other methods). The net irrigated area is 82.3% of the 5.446 million hectares

of gross irrigated land. The overall number of landowners is 15.28 lakh, of which 7.34 lakh (46.1%) are marginal farmers; the average landholding is greater than 2 hectares (Parameswaran et al., 2018).

1.2 The importance of soil physicochemical and biological properties in terms of supporting plant growth

Soil, the lifeline of plants, is a medium for unconsolidated materials and nutrients and contributes the terrestrial life via production of biomass, purification of water, resilience and restoration of ecosystems, pollutants detoxification, as well as cycling of C, S, N, P, and water (Tripathy, 2021). It is a complex system of varying biological, chemical, and physical features that come to light from the interplay of five fundamental factors (Jenny, 1980) which are climate, biota, topography, parent material, and time, wherein plants are supplied with water, nutrients, and oxygen so as to help their development. Although a complex of so many factors and properties, minor differences are adequate to cause minor variations in the distribution of plants in the field. It is highly difficult to categorize the edaphic components into chemical, physical, and biological groups in a straightforward manner because the majority of physical processes have a big impact on the chemical and biological soil characteristics and processes, which in turn regulate plant growth. Although a physical system, but still can be explained in terms of size of grain, porosity, apparent density, temperature, moisture content, and friability.

Here, amount of moisture, air as well as temperature of the soil affect plant growth. Unlike animals, plants are bound to the soil and have to cope with the hostile environment, and in nature, if physical condition of soils are optimal for growth, then rarely any plant species will find there. Various demonstrations representing the reaction to the degree of severeness of unfavourable conditions (e.g. soil compaction, oxygen deficiency, low soil temperature, and high sodium chloride concentrations) with different types of plants showed a similar curve for all plants, whether adapted or not. In addition, it also showed that different plant species develop different strategies to survive. Soil has

distinct colours (from black to red to white) due to the present mineral and OM contents in it. Black or dark brown-coloured soil indicates a high content of OM, while red-coloured soil indicates the presence of oxidised Fe.

Soil temperature being an important factor affects germination of seeds, growth in plants, and activity of microbes, varies with crops and varieties e.g., barley, wheat, and oat (winter crops) need low temperatures for germination of seeds, while cotton and sorghum (summer crops) require high temperatures for the same (Sghaier et al., 2022). When air occupies one-third of the soil's pore space and water occupies the remaining two-thirds, plant development is said to be at its best. So, the growth and yield of a crop are influenced by the availability of soil water.

Physical	Chemical	Biological
<ul style="list-style-type: none"> •soil color •aggregate stability •runoff and erosion •rooting depth •bulk density •water infiltration •water holding capacity •penetration resistance 	<ul style="list-style-type: none"> •OC and N •pH •particulate OM •active C •base saturation and cation exchange capacity •electrical conductivity •heavy metals 	<ul style="list-style-type: none"> •soil respiration •potential mineralizable N •microbial biomass •soil enzymes •pathogen, weed, and soil insect pressure •crop condition and root growth •earthworms

Figure 1.1: Examples of soil physical, chemical, and biological characteristics

Despite making up a minor portion of mineral soil, OM is crucial to soil conditioning and productivity. Additionally, it provides food for the bacteria and fungi that live in the soil, the latter of which is in charge of breaking down complex organic compounds into simpler ones that plants can readily access. The correct balance of OM, clay, and Ca creates the ideal physical conditions in the soil for increased crop output. Additionally, it can be utilized as mulch to stop soil from evaporating. In conclusion, earth provides all the vital minerals required by plants that are categorized into the two groups below based on the needs of plants (Epstein, 1965): Macro - elements (N, P, K, Ca, Mg, and S) and

Micro - elements (Fe, Mn, Zn, Cu, Mo, B, Co, and Cl) (Joshi et al., 2024). The following are the main roles that these elements play in plants (Table 1.1):

Table 1.1: Functions of Macro - and Micro - nutrients in plants

S. No.	Macro - and micro - nutrients	Important activities in plants
1	N	Plants absorb N from the soil in the form of nitrate or ammonium and combine it with substances made during the metabolism of carbohydrates to create amino acids and proteins. It contributes to the growth of plants and the production of yields. The uptake of some other nutrients is likewise dependent on the plant receiving a plentiful supply of N.
2	P	It is necessary for the development of the tissues creating the developing points in the plants, as well as for the growth of roots, photosynthesis, and other chemical-physiological processes. Soil used for agriculture lacks it.
3	K	It functions as an activator of over 60 enzymes and is necessary for blooming, photosynthesis, and optimum fruit quality. It is essential for the production of proteins and carbohydrates. It raises plant resistance to salt, drought, and frost. K-rich plants are less susceptible to illness.
4	Mg	As a component of the green pigment chlorophyll, it serves as a solar energy acceptor and participates in the enzyme activities that transport energy throughout plants.
5	S	It makes up 0.2% - 0.3% of the dry matter in plants and is a crucial part of the proteins involved in the production of chlorophyll. Thus, along with P and Mg, plays a crucial role in plant growth; however, this role is frequently underappreciated.
6	Ca	An important constituent of cell wall materials. The primary goal of Ca application is liming i.e. to lessen the acidity of the soil.
7	Fe, Mn, Zn, Cu, Mo, Cl, B	These comprises a portion that is analogous to the vitamins contained in human nutrition. An abundance of vitamin B might be detrimental to the development of the crop.
8	Na	Favorable for sugar beets
9	Si	Making cereal stalks more durable by preventing lodging
10	Co	Contributes to legumes' N-fixation
11	Al, Mn	When present at quantities above usual, toxic for plants

Therefore, it is essential to comprehend that each plant nutrient plays a specific role in the development and production of food, regardless of whether it is required in great or little quantities, and that one nutrient cannot be substituted for the another. According to

the agriculture department of Haryana, the standard values of EC, pH, OC, P, K, N, Zn, Fe, Mn, and Pb are listed as follows in Table 1.2:

Table 1.2: Standard value of edaphic factors according to Agricultural Department of Haryana

pH	< 6.5 (acidic); 6.5 - 8.5 (neutral or normal); >8.6 (alkaline)
EC (milli mos.)	< 0.8 (safe); 0.81 - 2.5 (medium); > 2.5 (unsafe)
OC (%)	< 0.4 (less); 0.41 - 0.75 (medium); > 0.75 (more)
P (kg/ac)	< 10 (less); 10 - 20 (medium); > 20 (more)
K (kg/ac)	< 55 (less); 55 - 135 (medium); > 135 (more)
Zn (ppm)	< 0.6 (less); > 0.6 (sufficient)
Fe (ppm)	< 4.5 (less); > 4.5 (sufficient)
Mn (ppm)	< 2.0 (less); > 2.0 (sufficient)
Pb (ppm)	< 0.20 (less); > 0.20 (sufficient)

1.3 Importance of soil arthropods in maintaining soil health

Soil arthropods control nearly every element of the turnover of OM, primarily by controlling the activity and functional makeup of soil microbes and their physical-chemical interaction with SOM (Filser et al., 2016; Lou et al., 2022). Thus, maintaining soil fertility, reducing climate change, halting land degradation, preserving above- and below-ground biodiversity, ecosystem services and supporting associated soil processes all depend on SOM. The two categories that are typically taken into account in the method for evaluating soil quality are acari and collembola. While other taxa, mainly symphyla, pauropoda, pseudoscorpionida, and others, are typically seldom discussed in soil quality research aiming at evaluating soil quality, deterioration, and pollution. Finally, some groups, like palpigrada, still lack the use of bioindicators in soil monitoring programs (Menta & Remelli, 2020). In addition, when trophic levels in soil with soil

arthropods (Lakshmi et al., 2020) were studied, it was found that collembola, diplura, protura, thysanura, symphyla, pauropoda, diplopoda, termites, beetles, etc. belong to the second trophic level, and collembola, mites, beetles, and chilopoda belong to the third trophic level, while on the fourth trophic level are pseudoscorpions, mites, chilopods, beetles, and collembolans.

Soil arthropods play two key roles in the soil food web (Potapov et al., 2022; Lavelle et al., 1995): 1. As litter transformers (compose a sizable portion of, fragment, or comminute and humidify ingested plant debris, improving its quality as a substrate for microbial decomposition and fostering the growth and dispersal of microbial populations), and 2. As ecosystem engineers (organisms that physically modify the habitat, regulating the availability of resources to other species) (Jones et al., 1994).

1.3.1 To cycle and recycle nutrients in soil: Most of the net terrestrial primary production is decomposed as well as recycled through detritus food webs (Polis, 1996). The breakdown of plant litter, a mixture of labile substrates like sugars, starches, etc. in conjunction with other elements like cellulose, lignins, tannins, etc. is caused by the interaction of physical and biological processes (Crossley, 1977). Saprophagous arthropods indirectly influence decomposition through the conversion of plant litter into feces, the re-ingestion of fecal material, the comminution of the same litter, the mixing of this litter with soil, and the regulation of the microflora through feeding and the spread of microbial inoculum (Swift et al., 1979 and Lavelle, 1997). Saprophagous arthropods have an immediate impact on decomposition because they consume plant litter and cling to microorganisms. With the exception of a few termite species, soil arthropods only consume a small portion of net primary production, such as 4% to 20% for millipedes and isopods, and 10% or less for oribatids (Berthet, 1967 and Van der Drift, 1965). Plant litter decomposes rapidly in humid tropics due to the influence of microarthropods on decomposition processes, whereas biological turnover rates are slowed in cold temperate zones by low winter temperatures and the slow breakdown of toxic plant secondary compounds (Witkamp, 1971). Due to the massive amounts of waste that they filter

through coprophagy, it is essential for maintaining sufficient nutrition. When it comes to contributing to the breakdown of litter in damp, undisturbed settings, millipedes are frequently among the most significant soil invertebrates (Curry, 1993). Table 1.3 lists some further contributions made by arthropods.

Table 1.3: Contribution of arthropods in annual plant litter turnover

Soil arthropods	Annual plant litter turnover
Collembola (Petersen, 1994)	20%
Oribatid mites (Berthet, 1967)	20%
Isopoda and Diplopoda (Hassall, 1977; Gere, 1963 and Van der Drift, 1975)	3% - 10%
Termites (Collins, 1981)	Upto 60%
Symphyla (Dickinson & Pugh, 1974)	2%

In habitats where earthworms are absent or limited, such as the acidic sandy soils of coniferous forests, collembola may play a much greater role in the physical degradation of organic materials (Stebaeva, 1989). Before being released in feces and upon the death of consumers, particularly microarthropods, a sizeable amount of the nutrients in the litter/soil system are concentrated and briefly trapped in microbial biomass (Stebaeva et al., 1976 and McBrayer et al., 1974). Collembola grazing significantly stimulates the growth and respiration of fungus (Filser, 2002). Additionally, it might result in a greater mobilization of the N and Ca that is already present, which might affect the availability of nutrients in particular environments like acidic forest soils, where sizable nutrient pools are more likely to be immobilized in stores of accumulated OM (Ineson et al., 1982). When isopods fed on oak and alder litter inhabited by the microflora (Kautz & Topp, 2000), the microbial respiration increased 10 - 20 fold over that in plots where isopods were absent. The availability of the macronutrients C, N, P₂O₅, P, K⁺, Mg²⁺, and Ca²⁺ in the topsoil increased as a result of this, there is an increase in microbial respiration. As a

result, nutrients are metabolized, liberated from detritus, and continuously made accessible for plant uptake, with minimal loss from the system (Ausmus & Witkamp, 1974). Arthropods that graze on the microflora also control how quickly things break down, limiting unexpected microbial blooms (Wijaya et al., 2023; Reichle, 1977). Arthropods also have an impact on how microbial populations are distributed in the soil by carrying bacteria or their progeny on or inside of them, as demonstrated in Table 1.4:

Table 1.4: Influence of arthropods in distribution of microbial populations

Soil Arthropods	Dispersion of microbial community by transportation of microbes or their propagules	Reference
Millipedes	<i>Streptomyces spp.</i> conidia proliferated in large numbers on their cuticle, and Actinomycetales, Bacillales, and Enterobacteriales populations of gut bacteria were abundant and dispersed in feces.	Szabó et al., 1983
Collembolan, <i>Pogonognathellus longicornis</i>	<i>Pogonognathellus longicornis</i> (Müller) feces contains live fungi (Dematiaceae) spores.	Poole, 1959
Isopods	Spread bacterial (especially microbial) propagules in feces	Hassall et al., 1987
Soil Arthropods (collembola, oribatida, isopoda, and diplopoda) biomass	Significant quantities of Na ⁺ , K ⁺ , N, PO ₄ ³⁻ and Ca ²⁺ are present in the biomass of soil arthropods (collembola, isopoda, oribatida, and diplopoda), which serves to temporarily trap ions and prevent leaching. Arthropod remains might contribute significantly to the total amount of elements (such as calcium), present in soil, comparable to that of a crop that is still standing and living.	Hassall, 1977; Cornaby, 1975; Teuben & Verhoef, 1992; Seastedt & Tate, 1981

According to Table 1.5, nutrients that the soil fauna was unable to absorb from food could concentrate in the following forms in feces:

Table 1.5: Contribution of soil arthropods feces to increase minerals in soil

Soil Arthropods	Contribution of feces to increase minerals in soil	Reference
Collembola	According to research, feces contain more than 40 times as much NO ₃ ⁻ nitrogen as their meal (fungi and algae), and their contribution increased the availability of nitrate in the forest	Teuben & Verhoef, 1992

	floor by a ratio of 2.4.	
<i>Glomeris marginate</i> (Millipede)	About 9% of the total N present in <i>Corylus</i> (Betulaceae) litter was returned to the soil as NH ₃ in the feces of <i>Glomeris marginata</i> . It has also been demonstrated that other species of <i>Glomeris</i> have higher N levels in feces than in diet.	Bocock, 1963; Marcuzzi, 1970
<i>Oniscus asellus</i>	S contents in <i>Oniscus asellus</i> feces were higher than in the leaf litter that the isopod consumed.	Mitchell et al., 1983
Termite	With an estimated 2 and 59 kg ha ⁻¹ of N and C, respectively, feces represent significant reservoirs.	Zaady et al., 2003
Millipedes	Feces have an eight-fold higher moisture content and a pH that ranges from 5.5 to 7.7 higher than the ingested litter. As a result, the substrate is more favorable for increased microbial activity, particularly bacterial activity, which speeds up further degradation.	McBrayer, 1973

Specifically in the drier, warmer regions of the earth, termite feeding and other activities promote conditions that favor microbial populations and the mineralization of organic materials (Chen et al., 2023) (Table 1.6) as:

Table 1.6: Activity of termites to ensure mineralization of organic compounds

Activity of Termites	References
In tropical scrubland, reduce litterfall by 91% annually.	Buxton, 1981
As a significant amount of their food, polysaccharides (cellulose and hemicelluloses), are digested by bacteria, gut symbiotes, flagellated protozoa.	Lee & Wood, 1971
Fungi and other microorganisms found in the nest externally consume materials that are tough to break down (like lignin) and transform them into a form that is easy to ingest. For instance, the usual C:N ratios of wood and leaf litter, which are 25 - 100:1 and 200 - 1200 : 1, respectively, are both decreased by the white-rot process. The ratios of the termitomyces fungi produced in macrotermite gardens (5:1-10:1) are a lot closer to those of the termites' own tissues. As a result, the termite colony receives organic material that is relatively high in N.	Varma et al., 1994; Cornwell et al., 2009; Boddy & Jones, 2008; Schuurman, 2012; Traniello, & Leuthold, 2000
Certain termite species are capable of ingesting non-dietary N by the fixation of atmospheric N by intestinal bacteria, and this source may contribute a significant portion of the N required by a colony.	Bentley, 1984; Collins, 1983; Prestwich et al.,

	1980
Termites feed on fungi that contain up to 38% protein, which is presumably enough to provide the colony's protein requirements. By consuming these fungi, termites are able to efficiently assimilate nutrients from plant litter into their biomass (e.g., > 50% absorption of ingested N). The eventual outcome of these dietary modifications is an almost total breakdown of the plant components that the termites originally obtained, leaving very little behind.	Rohrmann & Rossman, 1980; Gowda & Rajagopal, 1990; Lee, 1983; Lee & Wood, 1971
Predation-related N turnover typically ranges between 1 and 25 kg ha ⁻¹ , with the potential to approach 100 kg ha ⁻¹ per year.	Lee, 1983

1.3.2 Help in forming a fertile soil structure: In addition to facilitating root encroachment and preventing surface crusting and topsoil erosion, optimal water-holding capacity, aeration, and nutrient retention are supported by a healthy soil structure. Arthropods have a variety of effects on the structural characteristics of soils. Even though it has been reported that some collembola and oribatid mites actively construct micro-tunnels in the soil matrix (Rusek, 1985). Due of their modest size, mesofauna are typically not considered important in this process. The following are some of the channels and niches that the larger animals instead make to help them move across the soil (Oades, 1993):

Table 1.7: Contribution of soil arthropods towards soil structure

Soil Arthropods	Contribution towards soil structure	Reference
Termite and Ant	Increase soil aeration, topsoil retention, water infiltration through the soil profile, and soil storage.	Lepage, 1974
	The organic stuff (from excretions, salivary and other secretions, dietary leftovers) that builds up there, creates an environment that is conducive to plant roots penetrating it. This improves the soil's porosity and water-holding capacity, which in turn improves aeration and water infiltration.	Gillman, 1972; Rogers, 1972; Robinson, 1958; Robinson, 1978
	A 36% increase in crop yields and a three-fold increase in infiltration rates were observed in insect-free plots when compared to experimental crop yields in plots containing ant and termite populations.	Evans, 2011

Termites	When compared to plots where termites were present, those that had been rid of them had much less water infiltration and storage, more runoff, and sediment movement (bedload).	Elkins et al., 1986 and Whitford 1991
	Two termite species, <i>Macrotermes subhyalinus</i> and <i>Odontotermes sp.</i> , were active in the soil, and their infiltration rates were 2 to 6 to over 9 cm ³ s ⁻¹ which were 2-3 times greater than those of uninfested soil.	Léonard & Rajot, 2001
Ant	Four common ant species had infiltration rates around their nests that were, on average, 120 mL per minute, which is more than three times as quick as through the nearby farmed soil.	Majer et al., 1987
	After large rainfall events, the infiltration paths and sinks supplied by ant nests reduced overland water flow rates, limiting post-fire hill-slope erosion.	Richards, 2009
Millipedes	Thanks to their numerous twin leg pairs, calcified head capsule, and leverage from their labrum, collum, or flat back in some species, millipedes can push through densely packed soil particles and form tunnels. These organisms may potentially unintentionally increase water infiltration by devouring decaying root systems and making channels in the soil.	Hopkin & Read, 1992; Blower, 1985; Blower, 1955
	One of the key players in blending OM with mineral soil.	Jacot, 1940
Helleria brevicornis (Isopod)	Reported to dig vertical burrows up to 10 cm deep in dirt.	Kühnelt, 1976
Oribatids	They move to the lowest points in the soil profile and leave behind feces, which help to thoroughly mix OM.	Wallwork et al., 1967
Symphylans	They moved swiftly up and down the profile, dispersing their feces widely across the earth.	Edwards, 1990

The main invertebrate component forming the soil aggregates is feces, which contains fine mineral particles and undigested organic materials (Pawluk, 1985 and Rusek, 1985). In addition to enhancing the soil's capacity to store nutrients (such as cations) and reducing their quick drainage (Kühnelt, 1976), they act as substrates on which inorganic nutrients may be adsorbed and rendered accessible to plants (Pawluk, 1987; Ciarkowska & Niemyska-Lukaszuk, 2002; Kubiena, 1955; Loranger et al., 2003; Dunger, 1958; Nardi, 2019 and Schaller, 1950). More than one tonne of macronutrients per acre can be

stored in humus, including Ca, P, N, K, and Mg (Weetman & Webber, 1972). These nutrients are also utilized in chelation processes, which aid in the uptake of micronutrients by plants, guard against abrupt pH changes in the soil, and sustain a wide range of microbes that promote mineralization activity (Burns & Martin, 1986). The feces pellets of collembola are essential for the creation and maintenance of the microstructure in various arctic, alpine, and other weakly formed soils (Van Vliet & Hendrix, 2003). Organic mineral micro - aggregate forms seen in termite feces are also thought to improve the structural stability and porosity of tropical soils (Eschenbrenner, 1986 and Garnier - Sillam & Harry, 1995). Arthropod faeces often contribute more to the development of the main and moderate forms of humus (Van der Drift, 1951; Kubina, 1955 and Rusek, 1975) as well as the construction of primitive soils. These mull-like forms may include a large millipede contribution as well (Romell, 1935; Eaton, 1943). There can be a substantial amount of feces produced. For instance, it was determined that collembolan populations at densities typical of forest soils produced roughly 175 cc of faecal pellets m² annually (Schaller, 1949), which equates to the formation of a soil layer that is about 0.2 mm deep (Cragg, 1961). Desert isopods (*Hemilepistus reaumuri*) produced faecal pellets ranging from 2 to 41 g m² year⁻¹ based on site characteristics (primarily moisture regime); these pellets were then disseminated and mixed with soil after rainstorm episodes (Yair & Rutin, 1981). Millipede eating of litter in forests would create a layer of faecal pellets 0.5-1 cm thick on the soil surface each year (Striganova, 1971). Millipedes (Glomeridae) on rocky sites may contribute in the succession process by generating a substrate that is favorable for the colonization of higher plants by consuming the debris that builds up in cracks and depositing their waste there (Kühnelt, 1976).

1.4 Soil arthropods

Soil, a natural habitat for living components, is known to support too many varieties in the form of flora and fauna. This life is believed to exert a profound influence on the fertility and productivity of soil. The arthropods among the faunal components of soil,

undoubtedly occupy a significant level with regard to their numerical abundance, behavioural activities, and distribution. According to a recent estimate, the soil fauna may contain up to 360,000 species, or 23% of all documented organisms (Decans et al., 2006). Arthropods make up 85% of this population. They have reportedly been found in practically all ecosystems and in a variety of soil types. Because of their wide distribution and numerical abundance, the same are taking the attention of soil zoologists from time to time, and a long series of observations have been made in different corners of the world. Although soil arthropods are a boon for every ecosystem, agricultural land, and many more systems, however, about the diversity of soil arthropods, relatively little is known in Haryana cropping regions. Being the largest phylum of Kingdom Animalia, soil arthropods are primarily recognised for their active role in improving biological and physicochemical conditions, biological population regulators, OM decomposition, agricultural productivity, nutrient cycling, bio-indicators, and plant growth. Also, it can be understood by the examples of ants, dung beetles, and termites. Ants nest enhance water infiltration, dung beetles decompose the dung, and termites decompose plant debris.

Phylum Arthropoda comprises 84% of the population of Kingdom Animalia. A single square yard of soil contains 500 to 200,000 arthropods; however, this depends on the management systems, soil type, and plant community (Eisenbeis & Wichard, 1987). As majestically numerous, so numerous species groups still need to be documented taxonomically, and their biology and natural history have not yet been explained. Only 10% of micro-arthropod species and probably 10% of the population as a whole have been defined (Andre et al., 2002). Arthropods, on the other hand, occupy higher trophic levels in the soil food web and function as predators, detritivores, decomposers, soil engineers, and biological population regulators (Swift et al., 2004). The absence of large arthropod species has an effect on litter decomposition, whereas the presence of micro-arthropod fauna increases mass loss and detritus mineralization by around 23% (Seastedt, 1984). Previous studies investigating effect of collembola on plant growth showed no effect on (e.g., Endlweber & Scheu, 2006; Forey et al., 2015) or decreased shoot biomass

(e.g., Endlweber & Scheu, 2007; Schütz et al., 2008). Several other studies also reported that collembola did not affect (Endlweber & Scheu, 2006) or decreased root biomass (e.g. Haase et al., 2008; Winck et al., 2020). Furthermore, in contrast to microorganisms, which constitute the majority of the soil's living component (60 - 80%), described as (Lavelle et al., 1995) having limited ability to move in soil to search for food, being vigorous only for a brief period of time (the time required to ingest the OM everywhere), and only occurring in a small number of micro-sites (where temperature and moisture conditions are suitable for their acculturation). Indeed, increases in soil arthropod abundance generally increase plant growth metrics (Jernigan et al., 2022).

Arthropods in the soil are represented by insects and non - insect forms. The insect forms include different orders, namely collembola, protura, diplura, thysanura, orthoptera, hymenoptera, coleoptera, psocoptera, diptera, and the larvae of numerous more orders. These individuals often exhibit differences with regard to their distribution and abundance and are known to exhibit both beneficial and harmful roles. The non-insect forms are represented largely by acarine and, to a lesser extent, by pseudoscorpions, centipedes, millipedes, isopods, etc. Soil biologists reported that acarines undoubtedly occupy the topmost level in numerical abundance and are represented by four different groups: 1. cryptostigmatids, 2. mesostigmatids, 3. prostigmatids, and 4. astigmatids. In the order of dominance, next come the collembolans. Both the last groups are more or less omnipresent in their distribution, which indicates their wide tolerance range, and they also initiated most of the workers on soil arthropods to focus their efforts on investigating different aspects of these groups, leading to the availability of a large amount of literature contributed by them. Protura, diplura, and pauropoda species are less significant to the soil community and have less impact on soil processes (Petersen & Luxton, 1982).

There are so many ways to classify soil arthropods:

A. On the basis of faunal size:

i) Soil microarthropods: The acarine taxa and collembola, make up the majority of soil microarthropods. These species may be the dominating arthropods in a wide range of habitats, from the equatorial to the polar regions, from temperate and tropical forests and grasslands to scorching and frigid deserts (Gressitt, 1961; Wallwork, 1982; Curry, 1993; Bandeira & Torres, 1988). They are common in most soils (Wallwork et al., 1967; Hale, 1967), even those under cultivation (Behan - Pelletier, 2003). With body lengths ranging from 0.2 mm to 10 mm, microarthropods operate as both predators and prey, transporting energy from the soil's microflora and microfauna to the macrofauna at higher trophic levels (Coleman et al., 2004).

ii) Soil macro arthropods: More than 10 mm size of soil arthropods (centipedes, termites, millipedes and mole crickets etc.) come under this category.

B. On the basis of their functional role:

i) Shredders that chew up dead plant materials e. g. millipedes, snow bugs, termites and certain mites.

ii) Predators that feed on many other types of organism e. g. centipedes, spiders, ground beetle, scorpion, tiger beetle etc.

iii) Herbivorous who feed on numerous roots of plants. e. g. symphylans, mole cricket etc.

iv) Mycophilic (Fungal feeder) that feed upon fungi. e. g. collembola, mites etc.

C. On the basis of inhabitation in Soil (Eisenbeis & Wichard, 1987):

i) Euedophon: Arthropods inhabiting lowest soil layer e. g. collembola

ii) Hemiedophon: Arthropods found in upper soil layer on plant debris, leaves, litters etc.

iii) Atmobiosis: Arthropods on the soil's surface, as well as those in the top strata (the herbaceous, shrubbery, and tree layers), make up the atmobiosis.

D. According to conventional taxonomy: soil arthropods are classified as: Insecta , Myriapoda , Crustacea and Arachnida .

F. Based upon the percentage of presence or microhabitat utilization:

- (a) Permanent Soil Residents live whole life span in soil e. g. collembolan.
- (b) Transient Soil Residents connect the food chains in the brown world of the soil and the green world of plants, such as cicada.

1.5 Soil arthropods as bioindicators

Class Insecta, which includes the main arthropods, is an excellent indicator group due to its diversity and susceptibility to changes in soil properties. Inputs of dead matter into the soil, changes in soil moisture content, seasonal variation, litter depth, temperature, and agricultural systems, including the use of manure, tillage, fertilizers, and pesticides, all have a significant impact on the abundance and distribution regarding populations of diptera (Frouz, 1999). Soil termites are used as indicators of soil quality because of their effects on soil texture and profiles, the distribution of OM and plant nutrients, and the development of underground galleries (Stork & Eggleton, 1992). Termite foraging and activity encourage microbial populations and the mineralization of organic molecules (Culliney, 2013). Termite - modified soils were much more concentrated in sulphate and chloride anions, bicarbonates, as well as Ca, NH₃, Mg, inorganic P (Ndiaye et al., 2004). The ant species mounds are abundant in higher exchangeable cations such Ca, K, and Na⁺ as well as trace metals like Mn, Fe, and Zn (Wali & Kannowsk, 1975). Additionally, ant mounds have higher levels of microbiological activity than uninhabited reference soils and have higher quantities of ammonium and nitrate salts (Amador & Görres, 2007), accessible P, K. In ant mounds, the pH of the soil increases as SOM and soil nutrients rise (Frouz & Jilkova, 2008).

In environments with high anthropogenic activity, coleoptera insects like carabid beetles are effective indicators of changes in soil properties like pH, salt chloride levels, and calcium content (Avgan & Luff, 2010). Carabid beetles serve as predators for sustainable agricultural systems and control outbreaks of various pest species (Luff, 1996). Scarabaeidae beetles are essential for the digestion of dung, carrion, and leaf litter in

addition to returning nutrients to the soil (Greenslade, 1985). Communities of staphylinids can be used as bioindicators of human impact on soil ecosystems through the use of species diversity indices and individual relative abundance in the sample (Ruzicka & Bohac, 1994). Collembolans assist in the degradation of plant wastes by combining organic material and mineral soil particles, stimulate mineralization by choosing to feed only on fungus, and help to produce humus (van Amelsvoort et al., 1988). As a result of their sensitivity to pesticide and herbicide use, isopoda can rapidly decline in plantations that are intensively managed for agriculture and forestry (Fischer et al., 1997). Isopoda biomass helps soil hold K, Na, PO₄, N, and Ca ions (Teuben & Verhoef, 1992). Because isopoda can survive high amounts of metals, particularly Cu (Hopkin et al., 1993), Zn, Pb, and Cd (Prosi & Dallinger, 1988), they are an excellent indicators of soil pollution by heavy metals. The rates at which OM decomposes and bacterial and fungal invaders proliferate are positively impacted by mites. Faecal pellets are created by assisting the spread of bacterial and fungal propagules across the soil and leaf litter, which encourages further decomposition and contributes to better soil structures (Maraun et al., 1998). The activities that have a deleterious impact on the mite community on agricultural fields include pesticide use, monocultures, rotations, and cultivation procedures (Tomlin & Miller, 1987). Once the reason for the change in soil parameters is recognized in advance, mites produce good results for soil quality (Linden et al., 1994). As a result of their involvement in the decomposition of plant matter, diplopods and symphyla affect the distribution of microbial communities in soil (Szabó et al., 1983) and the amount of nutrients available to bacteria and fungi on the soil's surface (Paoletti et al., 2007). Additionally, they feed and defecate, which decreases the C : N ratios in the soil and releases mineral nutrients. They also aid in the breakdown of leaf litter by breaking it up and introducing microbes through faecal pellets. Furthermore, their feces have a pH that is rather high, which promotes the growth and concentration of bacteria that fix N (Bagyaraj et al., 2016).

Agriculture is the backbone of our economy and has enabled humans to manipulate ecosystems and maximise population growth (Naiyer & Sarfraz, 2015). It is entirely

dependent on having healthy soils, or on the soil's continuous ability to serve as a vital living ecosystem that is sustainable for humans, animals, and plants. Based on farming practices, agricultural farms can be distinguished into two types, such as organic and conventional farms. In organic farms, to maintain soil fertility, green manures and animal manures are used as fertilizers. While using organic fertilisers, it must be confirmed that the farm soil may remain fertile for hundreds of years. However, due to the massive usage of chemical fertilizers today, the ground is rapidly losing its fertility due to the inadequate minerals these fertilizers contain. Further, the use of chemical pesticides also paves the way for the accumulation of metals in agricultural soils. Numerous organisms, ranging in size from minuscule bacteria to substantial soil creatures including ants, termites, springtails, mites, earthworms, and ground beetles, are found in agricultural soil. The use of these kinds of metallic fertilisers can lead to the accumulation of heavy metals in agricultural soils, which affects the diversity of soil - dwelling arthropods. Therefore, the proper deficit and excess of heavy metals must be examined in order to evaluate their impact on soil arthropod diversity. In this research, the study areas of Haryana major crops (sugarcane, rice, wheat, and jowar) farming fields in Yamunanagar (YN), Karnal (KR), Kaithal (KT), Sirsa (SI), Hisar (HI), and Rohtak (RO) according to their maximum productivity along with adjoining non - farming land of outskirts of textile industries and forests have been selected. In previously surveyed literature, no record was found for the diversity and distribution of soil fauna, especially in the Haryana cropping zone. Therefore, this work was aimed at examining how different farming and nonfarming lands affect the soil, nature, and arthropod diversity.

REVIEW OF LITERATURE

CHAPTER 2: REVIEW OF LITERATURE

The chapter literature review comprised relevant literature on the history of Haryana, the history of agriculture in Haryana, geography vs. agriculture, physical vs. chemical analysis, seasonal variation of arthropods, arthropod's relative abundance, diversity indices of arthropods, identification of arthropods, and correlation of arthropods with edaphic factors.

2.1 History of Haryana

Haryana is a blessed land where the pious river Saraswati flowed; saints and sibyls wrote Puranas on its embankment (Wilson, 1868); Lord Krishna delivered the celestial message of Bhagavad - Gita to wobbling Arjuna (Buck, 2019). After 1857, when haryanvi took an extensive part in the First War of Independence, Haryana lost its identity. The period 1858 - 1965 is a chronicle of sheer neglect, coupled with the gradual destitution of Haryana both by British rule and Punjabi administration (Mittal, 1986). When Haryana came into existence in 1966, it was so backward that critics even doubted its likelihood. However, subsequent developments in every sphere made Haryana the rivalry of other states (Haryana State Gazetteer, Volume I).

2.2 History of Agriculture in Haryana

Haryana became a state on the Indian political map in November, 1996. Archaeological evidence reveals that agriculture was practiced in this state before the Harappan civilization, yet primaeva literary references were discovered even in the Vaman-Purana. The kings and rulers were always concerned about increasing agricultural output. The Harshavardhan era, which lasted from 606 to 647 AD, was a pivotal time in Haryana's agricultural history (Smith, 1999). Firojshah Tughlaq ruled the realm from 1351 to 1388 A.D., and heroic efforts were made to improve agriculture during his reign (Banerjee, 1967), since recurring famines and droughts hindered the state's ability to advance in agricultural production. Agricultural science and technology made no or negligible

progress during the medieval period. The government has prioritized the welfare of farmers since the formation of Haryana in 1966. In an effort to promote growth and sustainability in agricultural productivity, an excessive number of short- and long-term policy-based procedures were started after that. The state is divided into three zones, each with its unique set of advantages and disadvantages, based on its ecology and cropping pattern (Table 2.1). This has led to the development of farming and cropping techniques (Haryana Kisan Ayog, Government of Haryana, Working Group Report on Productivity Enhancement of Crops in Haryana, 2013):

Table 2.1: Three zones of Haryana on the basis of ecology and cropping pattern

Agricultural Zone	Districts	Area %	Agricultural options
I	Sonipat, Yamunanagar, Ambala, , Panipat, Kurukshetra, Kaithal, Karnal	32	Wheat, Sugarcane, Rice, Maize,
II	Faridabad, Sirsa, Hisar, Jind, Fatehabad, Rohtak, Palwal	39	Wheat, Rice, Sugarcane, Cotton, Bajra
III	Mewat, Bhiwani, Rewari, Jhajjar, Mahendergarh, Gurugram,	29	Millet, Mustard, Rapeseed,

Zones I and II have greater facilities for irrigation and general infrastructure.

2.3 Geography and Agriculture

The Northern Indian State of Haryana is situated between latitudes of 27° 37' and 30° 35' and longitudes of 74° 28' and 77° 36'. Its borders are UP on the east, Punjab on the west, The Shivalik Hills, HP, and Uttaranchal on the north, and Delhi, Rajasthan, and The Aravali Mountains on the south. Haryana's elevation is between 700 and 900 feet above sea level. The Trans - Gangetic Plains Region includes Haryana, which is well - known for its Ghaggar semi-desert sandy plain, Yamuna Plain, Shiwalik Hills, and Aravali Hills (Surya & Saha, 2015). The Ghaggar Yamuna Plain makes up the majority of the state and is made up of silt, clay, sand, and hard calcareous balls that resemble gravel (locally known as kankar), is the source of rivers such the Saraswati, Tangri, Ghaggar, and

Markanda. The other two are hilly areas that border Rajasthan. However, the majority of Haryana's territory is flat and covered in loamy soil, thereby, making it ideal for agriculture.

2.4 Climate of Haryana

The climate of Haryana is driven by the sub - tropical wet climate of Himachal Pradesh and Uttar Pradesh, along with the semi - arid climate of Rajasthan. Altogether, it has a sub - tropical continental type of climate, which is portrayed as very hot in summers and very cold in winters (Singh, 1976). South - Western Haryana has a semi - arid type of climate, while the North - Eastern region has a humid sub - tropical type of climate.

2.5 Seasons in Haryana

The State of Haryana has three distinct seasons: Winter lasts from the middle of September until the middle of March. Summer season runs from April to June, with temperatures averaging between 12 to 30 °C on average. However, the months of December and January are particularly chilly, with typical highs only reaching 3 to 4 degrees Celsius. This season's average temperature ranges between 35 °C (lowest) and 45 °C (maximum). Rainy Season: July to September, with sporadic precipitation in December and January. The average temperature ranges from 25 °C (lowest) to 32 °C (highest). The state receives little and unpredictable rainfall. The yearly rainfall ranges from 45 - 60 cm (Mechanization and Technology Division, Ministry of Agriculture, Department of Agriculture and Cooperation, Government of India; Mehta et al., 2014).

2.6 Major crops in Haryana

Crop production is broadly divided into Rabi (when seeds are sown at the start of autumn in November - December and harvesting of mature crop is done in June - July, e.g., wheat, sugarcane) and Kharif (when seeds are planted around the beginning of the rainy season in July and mature crops are harvested in September and October, e.g., paddy,

maize, jowar, and bajra), while major cereals produced are wheat, maize, rice, and bajra. South - Eastern Haryana is better suited for the cultivation of high - quality agricultural products, tropical fruits, exotic vegetables, and herbal and medicinal plants (Mechanization and Technology Division, Ministry of Agriculture, Department of Agriculture and Cooperation, Government of India; Mehta et al., 2014). North - Western Haryana is better suited for the cultivation of rice, wheat, vegetables, and temperate fruits. Although rice - wheat, bajra - wheat, cotton - wheat, and sugarcane - wheat are among the state's major agricultural systems, the following are Haryana's principal crops:

2.6.1 Wheat: It produces 13% of the crop on an all - India basis, ranking fourth after Punjab, Madhya Pradesh, and Uttar Pradesh. Sirsa district is the largest wheat producer, followed by Hisar district. It has the most agricultural land in Haryana.

2.6.2 Rice is mostly grown in the state's northern, eastern, and central regions, where more water is available. Karnal is Haryana's top rice producer. It is Haryana's largest processor and exporter of basmati rice. After wheat, this is Haryana's second most important crop.

2.6.3 Jowar: Rohtak is the largest producer of jowar. The area under its production has decreased over the years.

2.6.4 Sugarcane is a commercial crop in Haryana. It produces around 3% of the same product in India. The largest producer of sugarcane is Yamunanagar, followed by Karnal. It covers the maximum area in the state under commercial crops.

2.6.5 Bajra: The largest producer of bajra is Bhiwani, followed by Mahendragarh. It requires less water and grows within 2 - 3 months.

2.6.6 Cotton: Haryana is the major producer of cotton in India. The highest producer of cotton is Sirsa, followed by the districts of Hisar, Bhiwani, Jind, Rohtak, and Jhajjar.

A trend of five important crops, rice, jowar, bajra, wheat, and sugarcane, was carried out in a geographical analysis of agriculture (from 1966 - 67 to 2010 - 2011) in Haryana districts (Sihmar, 2014), based on secondary sources of data acquired from Statistical Abstract Haryana 2011 - 12. As a result, from 1966 - 67 to 2011 - 12, the area under rice and wheat increased while that under bajra, jowar, and sugarcane dropped. Yamunanagar also has the biggest sugarcane production, followed by Karnal and Kurukshetra. Sirsa has the highest wheat production, followed by Hisar. Karnal has the highest rice production, followed by Kaithal, Kurukshetra, and Fatehabad. Bhiwani has the most bajra production, whereas Rohtak has the highest jowar production. Some fundamental statistics from the Statistical Abstract of Haryana 2018 - 2019 on Haryana's farming and non - farming areas are as follows (Table 2.2):

Table 2.2: Basic statistics from Statistical Abstract of Haryana 2018-2019

S. No.	Statistics	Dimensions
1	Average Rainfall	38.2 cm
2	Total Area	44,212 km ²
3	Net Area Sown	3,508 ha
4	Area Sown More Than Once	3,041 ha
5	Total Cropped Area	6,549 ha
6	Production of Total Cereals	17,976 t
7	Total Area of Rice Crop	1,422 ha
8	Total Area of Wheat Crop	2,530.5 ha
9	Total Area of Bajra Crop	449.3 ha
10	Total Area of Sugarcane Crop	114.9 ha
11	Total Area under Maize Crop	6.4 ha
12	Total Area of Cotton Crop	668.5 ha
13	Net Area Irrigated	3,261 ha
14	Gross Area Irrigated	5,993 ha
15	Area under Forests	1,780 km ²
16	Registered Working Factories	12,931
17	Total Divisions, Districts	6, 22

2.7 Physical and chemical analysis of soil

According to J.W. Doran, the main interface between agriculture and the environment is a thin layer of soil that covers the earth's surface. This layer of soil determines whether

most land - based species will survive or go extinct. The soil supports the roots of plants, stores nutrients needed for plant growth, is a haven for numerous insects and other species, filters precipitation, and controls the runoff of extra rainwater and flooding. By holding onto N, P, and other nutrients, SOC, the foundation of soil fertility and the driving force behind all soil types, contributes significantly to the maintenance of fertility. Additionally, if a bit more OC is sequestered in the soil (a procedure known as soil carbon sequestration), less carbon will be released into the atmosphere, which would help to lessen the issue of global warming and climate change. The physical, biological, and chemical characteristics of the soil determine its fertility. Significant amounts of nutrients are taken from harvested goods over time in all agricultural systems, which can also occur as a result of soil erosion, runoff, leaching, crop residue burning, and other factors (Envi Stats India, 2019: Vol. II, Environment Accounts 12). As a result, it is vital to monitor soil changes and investigate soil dynamics in order to improve the effectiveness of applied nutrients and raise agricultural production. In the framework of sustainable agriculture, an assessment of the soil fertility level of a region is essential. Understanding the effects of present farming techniques and identifying the suitability of these soils will be made easier with the help of an intertemporal and interspatial analysis of trends in soil nutritional quality. Physical and chemical properties of various soil samples from Haryana were determined, and they ranged from loamy to sandy loam in texture, 0.08 - 0.93% in OC, 6.8 - 9.8 in pH, 0.09 - 4.80 dS/m in EC, and were within the permissible EC limit (Malik et al., 2017). Soil examination of different states (Rajasthan, Uttar Pradesh, Punjab, and Haryana) shows that the soils of Punjab and Haryana are good, stable, and rich in farming (Kumar and Singh, 2019). Soil EC, pH, and OC levels ranged from 0.09 - 1.10 dS/m, 7.2 - 8.9, and 0.25 - 0.97% respectively, in distinct sugarcane - growing edaphic and agro - climatic zones of Haryana, according to a soil survey. Furthermore, the available N, P, and K levels ranged from 203.7 - 319.8, 19.7 - 96.5, and 121.3 - 582.3 kg ha⁻¹ (Verma et al., 2014). The soils of Haryana for cultivating sugarcane were thus classified low in accessible N, medium in P, and high in K. Cu, Zn, Fe, and Mn DTPA - extractable critical limits were surpassed. DTPA - extractable Cu,

Zn, Fe, and Mn were found to have significant and positive relationships with OC and accessible N ($r = 0.957^*$), P_2O_5 ($r = 0.598^*$), K_2O ($r = 0.316^*$), and DTPA - extractable Zn, Cu, Fe, and Mn ($r = 0.430^*$). According to the Haryana soil nutrient index, soils' DTPA - Zn content is insufficient, although their DTPA - Mn, Fe, and Cu contents are adequate. This emphasizes the necessity for Zn treatment to increase agricultural productivity. The amount of DTPA - extractable Cu, Zn, and Fe was discovered to be positively and strongly correlated with the amount of OC in the soil. In all of the investigated soil series, soil pH did not link to the amounts of available Cu, Zn, Fe, and Mn (Malik et al., 2017). Additionally, shortages in cationic micronutrients including Mn, Zn, Fe, and Cu have been found over time in Indian soils (Singh and Behera, 2011) as well as many other soils throughout the world (Alloway, 2008). The amount of Cu in the soil is positively connected to soil pH via a logarithmic relationship. Soil microbial biomass C, biomass N, and Fe levels are positively associated to soil pH and negatively related to soil EC (Mohd et al., 2014). Soils with an EC of less than 1 dS/m are classified as non-saline. Most crops and microbiological processes in these soils are unaffected by salt, and vice versa (Hardie & Doyle, 2012; Smith & Doran, 1997). Although soil EC does not directly detect ions or salt compounds, it has been linked to specific quantities of nitrates, chloride, K, sodium, sulphate, and ammonia (Adviento - Borbe et al., 2006). A larger concentration of hydrogen ions in the soil results in a higher rate of EC (Bruckner, 2012). The use of sewage water for crop irrigation in agricultural soil alters the physicochemical parameters as well as the heavy metal content of the soil when compared to agricultural soil where crops are irrigated either by tube well water or by canal, and it was discovered that the use of sewage water definitely improves the fertility status of the soil when compared to soil irrigated by natural sources. Investigated percentage gains were those for C from OM (+49.18%), the overall N content (+109.08%), readily available K (+49.02%), accessible P (+72.06%), the EC (+58.61%), and ability to hold water (+22.31). In contrast to tube-well irrigation, sewage irrigation results in a rather stable level of Fe and Cd concentrations in the soil while on the other hand, sewage irrigation raises Zn, Cu, and Pb concentrations.

These are in line with Indian standards and demonstrate good soil quality in sewage-irrigated soil samples, but if untreated sewage water is consistently used for irrigation by farmers, long-term use of sewage effluents in the fields will undoubtedly increase the heavy metal content and, in the future, affect humans and animals (Tobriya, 2015). A study about spatial geographical distribution of heavy metal content and physical-chemical characteristics of different soil series of north - western India found that the soils of Hisar district were moderately to strongly alkaline in nature (pH 8.0 - 8.6) and vary in availability of heavy metals (Pb, Cr, Cd, Co, and Ni). This study investigated the attributes of the aeolian and the top fluvial plain soil series in the Hisar district of Haryana. It was determined that the soil's OC content ranged from low to medium (0.38 - 0.50%), and its texture ranged from sandy to sandy clay loam with a low to moderate CEC (8.63 - 12.84 c mol kg⁻¹). The soil had a 5% calcium carbonate concentration. The mean readings for Pb, Cr, Cd, Co, and Ni were found to be below the allowable limit and ranged 0.57 - 1.31, 0.01 - 0.03, 0.00 - 0.025, and 0.03 - 0.15 mg kg⁻¹, correspondingly (Ganpat et al., 2020). By visiting the Ministry of Agriculture, Cooperation, and Farmers Welfare's soil health portal (www.soilhealth.dac.gov) for the most recent years for which such data is available, i.e., 2017 - 18 to 2018 - 19, it was possible to determine the level of soil samples deficient in P, K, S, Zn, B, and OC (Table 2.3).

Table 2.3: District-wise nutrient deficiency in Haryana state

S. No.	District Code	Per cent sample deficient in terms of nutrients (2017 - 18 to 2018 - 19)					
		P* (%)	K* (%)	S* (%)	Zn* (%)	B* (%)	SOC* (%)
1	Ambala	57.1	56.5	25.2	27.9	35.2	86.8
2	Bhiwani	63.4	23.8	12.5	62.1	50.7	87.7
3	Faridabad	99.9	0.09	0.06	1.74	45.1	99.6
4	Fatehabad	91.3	72.7	8.84	27.0	29.4	79.4
5	Gurugram	81.1	21.4	4.85	19.4	62.3	96.4
6	Hisar	91.4	7.64	4.36	40.3	25.0	88.7
7	Jhajjar	73.1	48.7	10.1	39.8	59.6	97.6

8	Jind	97.5	0.50	0.42	10.9	3.23	99.6
9	Kaithal	94.6	46.7	8.31	31.8	45.2	61.5
10	Karnal	63.1	12.8	3.19	9.35	46.5	90.4
11	Kurukshetra	96.3	30.6	4.10	6.13	24.8	90.4
12	Mahendragarh	93.9	25.7	24.0	27.0	48.3	92.6
13	Panchkula	90.8	4.60	3.62	6.27	63.1	73.7
14	Panipat	40.9	57.1	3.99	24.7	67.2	93.3
15	Rewari	97.1	84.3	5.73	18.8	45.1	97.3
16	Rohtak	76.0	52.7	16.6	56.5	58.8	98.2
17	Sirsa	81.0	12.8	5.65	29.8	30.9	97.2
18	Sonipat	90.6	15.9	2.22	25.8	67.2	88.9
19	Yamunanagar	99.1	98.6	3.62	8.34	16.8	90.4
20	Haryana	80.4	29.6	7.86	30.2	40.2	90.2

*P - phosphorus; S - sulphur; K - potassium; Zn - zinc; SOC - soil organic carbon; B - boron;

Physical and chemical characteristics are physical and chemical markers of soil health, respectively. Physically inadequate soils are difficult to mechanize, have a low level of water penetration, more surface runoff, weak cohesiveness, low levels of aeration, and low root density. The equilibrium of water and gases is influenced by the soil's texture (Beutler et al., 2002). Increased levels of OM in the soil allow for greater soil particle agglomeration, increasing soil structure, and resulting in lower bulk densities of soils in environments with fewer human interruptions, such as native forests (Bini et al., 2013). Increased substrate microporosity enhances soil permeability for air, root systems, and water (Tejada et al., 2006). It has been found that the granular soil structure is the most suited for plant growth, allowing for a better balance between macro and micropores and, as a result, between the air and water proportions (Dexter, 2004). The structure corresponds to the arrangement of the primary soil components (sand, silt, and the clay), and is modified by cropping techniques and compactness. Particles less than 0.2 mm collide to form microaggregates (20 - 250 mm), which then collide to form

macroaggregates, which in turn collide to form soil aggregates. Microaggregates are more reliable and less disruptive to the usage and maintenance of soil. Additionally, they are responsible for the long - term stability of SOC (Six et al., 2004). Macroaggregates are particularly involved in the changing patterns of the OM of the soil and are more adaptable to soil use and management (Six et al., 2004). Soil aggregate dispersion is typically less severe when soils receive a less amount of OM, which results in higher microbial activity (Qin et al., 2010). The performance of decomposing bacteria and their approach to organic materials are hampered by the decrease in SOM, which is followed by aggregate dispersion, which lowers macro - porosity and soil oxygenation (Degens et al., 2000; Tejada et al., 2006; and Chodak & Niklinska, 2010). Aeration, permeability, and nutrient cycling in microsites are influenced by soil aggregates, which also serve as a haven for soil organisms like bacteria. The soil aggregates are in turn molded by the soil biota (microorganisms, creatures, and flora). In addition to promoting microbial life and affecting soil aggregation, many organic substances, including secretions, mucilages, mucigels, and the cell lysates, are produced by organisms like worms, soil creatures, mycorrhizal - arbuscular fungi, bacteria, and plants. These substances also act as cementing materials. The chemical and physical makeup of the soil and its biological components have an effect on the hydrological processes (erosion, irrigation, water runoff, and infiltrate rate). They are also necessary for the availability of nutrients and water in the soil. Due to the charges in their carboxylic and phenolic structures, which bind water molecules and reduce percolation throughout the soil profile, humic substances increase soil water retention. Due to the inverse relationship between water availability and microbial activity, which decides available water content as a determinant of soil microbial activity, soil physical attributes that affect water availability and aeration will also affect soil microbial activity (Geisseler et al., 2011). Chemical characteristics of soil have an impact on its capacity to supply plants with nutrients and/or hold back pollutants that are harmful to the environment and plant growth. In particular, when taking into account the soil's potential for growing high-yield crops, soil pH, OM, CEC, and nutrient levels are the primary chemical properties used in the assessment of

soil health (Kelly et al., 2009). By promoting nutrient cycling, plant biomass, and OM, soil chemical indicators can also be used to evaluate the soil's capacity to support forest production and sustainability (Schoenholtz et al., 2000). The soil pH, accessible P, K, Cu, Fe, Mn, and Zn were the key chemical parameters to be assessed. Soil pH was a crucial indication since it is directly related to nutrient availability and solubility, which affects microbial activity. As a result, measuring pH enables the prediction of the potential for nutrient availability in a particular production system (Sousa et al., 2007). SOC has a significant role in defining the health of the soil and typically has a positive correlation with crop productivity (Bennett et al., 2010). The amount of carbon from OM in the soil affects key processes that operate in the soil, including the capacity to hold water and maintain aggregate stability as well as the ability to store nutrients, particularly N (Silva & Mendonça, 1997). Additionally, microbial activity is influenced by the biological carbon in the soil. As a result, this plays a crucial role in soil fertility. High OM concentration lowers the effectiveness of pesticides and necessitates more pesticide applications. By assembling with soluble organic substances, pesticide sorb on organic components and transit via soil or groundwater can be made easier (Sojka & Upchurch, 1999). The most crucial nutrient for plants, N, can be found in soil in a number of distinct chemical compounds (Cantarella, 2007). However, organic N or potentially mineralizable N stored in soil organic material has predominantly been considered when evaluating soil N, notably nitrate (Cantarella, 2007). A key component for agricultural output, P, is essential for defining the condition of the soil. P seems to be the nutrient limiting agricultural yields in tropical soils together with N, especially in extensively oxidized, worn-out soils where the bulk of the total soil P is bound in clay minerals and oxides. However, microbial and organic P are the stocks that can become available fast (Pankhurst et al., 2003; Zhang et al., 2006). Orthophosphates are plentiful in the soil solution. Extensive tillage appears to decrease both beneficial microbial activity and soil aggregation, which causes crusting and compaction. It is now generally acknowledged that reduced tillage intensity and mechanical soil disturbance can enhance soil health,

maintain or even boost yields, and reduce production costs by saving on labour, equipment, and fuel.

Due to previous activities such as heavy traffic, commercial or industrial activity, administered lumber, petroleum accidents, auto as well as machine repair, scrap metal, furniture refinishing, wildfires, garbage dumps, or garbage dumps, as well as frequent in urban areas and other sites with prior use of contaminants like lead paint, chemical fertilizers, pesticides (for example, lead arsenate use on orchard land). Children and adults are more likely to be exposed to harmful substances when they ingest or breathe in soil particles and/or consume food that was produced in or on contaminated soil. Contaminated soil also limits soil biological activity, turns plants toxic, and lowers crop production and/or quality. Additionally, soil health is related to biological traits of the soil including biological diversity and environmental stability. Emergences of plant diseases are invariably undeniable indicators of ecosystem instability and, as a result, of the ecosystem's poor health. This means that a healthy soil's biological population has the potential to lower the quantity of plant pathogens present and, as a result, lower the frequency and severity of disease (Bruggen & Grunwald, 1996). Over the past few decades, significant efforts have been made to increase agricultural output through increased fertilisation and pesticide use, better soil management practices, improved watering and crops, and widespread conversion to farming (Tilman et al., 2002). Several studies (Tilman et al., 2001; Foley et al., 2005; Vitousek et al., 2009) have raised fears that intensifying farming is severely restricting the soil's capacity to maintain its other functions, leading to widespread ecosystem degradation, and gradually decreasing productivity. Microorganisms may also provide a thorough evaluation of soil health because they have a role in so many diverse soil processes; this is an assessment that cannot be done only by chemical or physical testing (Nielsen et al., 2002; Kibblewhite et al., 2008; Mueller et al., 2011; Sharma et al., 2011). Several studies have shown that organic farming practices have positive benefits on soil microbial populations, processes, and activities (Clark et al., 1998; Doran et al., 1996; Drinkwater et al., 1995). Applications of pesticides may promote modifications in the dynamics of populations and

biodiversity by preventing or eliminating components of the soil microbes community. Fungicide use can cause considerable changes in the composition of the bacterial ones and fungus populations in soil (Sall et al., 2006; Sigler & Turco, 2002). Despite knowing that the bulk of research has revealed enhanced microorganism diversity within soils from systems of organic farming as compared with standard farming systems, certain studies have shown contradictory results. In soils managed within organic and standard regimes, the size, design, and activities of the soil microbial community were assessed, and conflicting results that were related to the management methods (Shannon et al., 2002). Additionally, they found that the differences in microbe populations in soils with varied management practices were subtle rather than obvious. (Liu et al., 2007). Therefore, maintaining a healthy habitat for the numerous creatures that comprise up the soil web of food is necessary for controlling soil health (enhancing soil function). This can be achieved by keeping the soil protected at all times, limiting soil disturbance, growing as many diverse plant species as is helpful, maintaining plant life in the soil as regularly as is helpful, and so on.

2.8 Seasonal Arthropods Diversity with their relative abundance

In sugarcane, alfalfa fodder, cotton, wheat, and citrus orchards, a variety of edaphic and climatic parameters as well as the amount of soil arthropods were examined. Between sample months and crops, there were considerable variations in soil arthropod's number. The collembola order made up 38% of the total number of 13,673 soil arthropods which were tested, followed by hymenoptera, acarina, myriapods, 5% coleoptera, 5% orthoptera, and 5% araneae close behind. When compared to the winter, it was discovered that the mean abundance per sample was higher in the summer. Between all crops, there were significant differences in overall abundance per sample ($p < 0.05$). The levels of soil arthropod abundance identified by cluster analysis are as follows: extremely prevalent (collembola, myriapoda, acarina, hymenoptera), somewhat prevalent (orthoptera, araneae, coleoptera), not as prevalent (dermaptera, hemiptera, diptera), and scarce (blattaria, isoptera, dipluran, lepidoptera) (Shakir & Ahmed, 2015). The

classification of hymenoptera and family members formicidae (50.5% as well as 38.7%, respectively) constituted the most prevalent and plentiful group, whilst the order of crustacea and family members armadillidae (22.2% as well as 1.63%, correspondingly) were less dominant and abundant (Ogedegbe et al., 2014). Study on the arrangement and different perspectives of soil arthropods says collembola (13.54 and 19.70), hymenopterans (14.83%), and acari (mites, 13.22%) have the highest density and quantity of soil microarthropods (Abbas & Parweij, 2012). The number of individuals of soil arthropods peaked in a pine forest in January and July respectively (Reddy & Alfred, 1977). During the dry and rainy seasons, collembola and acari both experienced two peaks, one in the month of July and the other one in November. Studies have shown that the seasonal fluctuations in the collembola and acari species follow a predictable and comparable pattern (Bhagawati et al., 2018; Bhagawati et al., 2020; Esenowo et al., 2017; Fusaro et al., 2018). Soil arthropods in both cultivated and uncultivated fields fluctuated significantly, reaching their peak in the monsoon season (July and August) and then gradually declining in the summer season (April and May) (Paul et al., 2011). As long as species living in deep soil layers found favorable conditions, oribatid mite populations reached their peak, but when soil cultivation was present, it affected the seasonal changes of the oribatid mite population (Jeleva, 1970). However, the total number of soil oribatids was unaffected by the use of fertilizers. According to an analysis on soil fauna inhabiting various environments located at altitudes between 110 to 2000 meters, the biggest population was found in October and the beginning of spring, while the smallest population was found in mid-winter as well as mid - summer (Frenzel, 1936). There are population maxima during the fall and a population minima over the summertime for mites and collembola (Behan - Pelletier, 2003). According to a thorough investigation on soil arthropods at Cothii near Oxford, the majority of taxa did not exhibit more sample variation while samples were collected from nearby and distant portions of the area (Mac Fadyen, 1953). Instead, they displayed a comparatively similar distribution across each plant type. The majority of the animal population was confined to the very top 5 cm of the earth, while some species dove deeper during the winter. Additionally, it was noted

that the population size of the majority of species consistently fluctuated between a minimum in August and a maximum in February. The species makeup did, however, vary relatively little throughout the course of the year. Collembola populations peaked in the spring and late summer. It was also discovered that every species has a unique seasonal fluctuation, which may change based on the locality. Two elements that seemed to be contributing to this variance were temperature and precipitation (Bellinger, 1954). The approaching months of winter reportedly triggered structural changes in the mite community of the litter and compost layer on the numerical level, according to studies on the entire biology of soil in forests mites in Implode, Michigan. The majority of the fauna was discovered in the profile's lower 7 - 10 cm, which was divided into separate layers of litter and humus. In the summer, mite populations were reportedly four times higher than those of collembolans, and somewhat more than half of the soil population was found in litter at this time. Although there was less litter in the winter than there was in the summer, there was a bigger population of humus. In a litter, the adult population peaked in the summer, whereas the young population peaked in the winter. The number of adults in humus grew gradually over the summer and into the late winter. In a Missouri community of oak-hickory trees, a colony of microarthropods was discovered (Dowdy, 1965). The typical density of mites per square foot is 296 at a soil depth of 10 inches. When the temperature dropped below freezing in December and January, acarina (mites) populations peaked. When the temperature was 8°C in March, the population was at its peak. In November, the lowest peak was visible. When 84% of the total number of collembola was gathered, January and February saw the largest peak. March saw the collection of relatively few collembolas. Collembolan communities peaked in November as well as January along with are positively connected with soil moisture level, biological carbon content, and average particle size of calcium carbonate, according to a research study (Chaudhary & Roy, 1971 a) carried out in a barren or natural field of West Bengal. When examined the vertical spread and changing seasons of *Lepidocyrtus* species, they made the following attempt and found that the state of West Bengal noticed a monsoon peak in July with a winter high in December. Acarina (mites) which live in soil could

survive a minimum temperature that reached up to 18 °C, as well as during this time their population increased (Behan - Pelletier & Kanashiro, 2010). A comprehensive investigation (Choudhury & Roy, 1972) on both the qualitative and quantitative makeup of the collembolan creatures of West Bengal, India, provided an in-depth analysis of the seasonal shifts in the abundance and distributional patterns of collembola (both parallel and a vertical direction) in relation to multiple soil features, such as moisture in the soil, OC from the soil, phosphate, nitrate, carbonates of Ca, soil pH levels, particle size, or soil cover. In rare circumstances, the winter maxima was also attained. They proposed that soil elements like moisture, nitrate, OC, and phosphate were associated to the increase in population density. Additionally, it was discovered that, at least occasionally, the population and the particle size had a substantial correlation. The top layer of earth is where they discovered the majority of the people. There were 266 more microarthropods in uncultivated areas than in flower and vegetable gardens, where various agronomic practices and traditional gardening techniques, such as tilling, raking, and weeding, were used (Saha et al., 2020). Mites made up the majority of the population (37.06%), followed by ants (25.21%) and springtail populations (19.29%). The monsoon season (227 individuals) had the highest concentration of soil arthropods, followed by the pre - monsoon (188 individuals), and the post - monsoon (176 individuals). Ecological research upon the soil meso - and micro - organisms of unmanaged plots in Western Bengal was documented and revealed (Choudhury & Banerjee, 1975) that in terms of population scale, the mesostigmata, prostigmata, astigmata, and collembola are outnumbered by the cryptostigmatic mites in the monsoon months of July and August. The populations of both prostigmata or astigmata mites were significantly low to both the qualitative and quantitative composition; subsequently, both acari as well as collembola populations emerged to be molded by the microbial complex and OM present in soil. Abundance follows mesostigmata, which is then followed by collembola. In accordance with the population dynamics of soil creatures about the categories of collembola, coleoptera, homoptera, hymenoptera, or diptera (Baweja, 1939), the highest - ever population of these insects happened in the late fall and was sparked by an unexpected

rise in the total number of collembolans, but the population of soil insects lowered as the number of collembolans increased. In addition, mite and collembola populations displayed a peak in the autumn and a trough in the summer (Behan - Pelletier, 2003), demonstrating that distinct collembola life forms were rigidly restricted to particular bio layers, particularly to a particular range of moisture. This study found that the number of collembola barely changed over the course of a year. Similar to this, monthly soil samples from Moorland were taken from juncus grassland, alluvial grassland, lime stone grassland, and heather litter (Hale, 1966). Collembolans were found to be distributed non-randomly across the lowland regions region, and collection was found in every type of soil that was looked into. Inter - specific collection most likely occurred in areas with a disproportionate amount of food. Early summer and winter were found to have higher collembola in the lower part of the two layers, indicating that harsh weather conditions caused a vertical shift. Vertical migration caused a decline in population in the top layer of the soil, however differential morals may also have played a role. The majority of collembolan's peak population was concentrated on the limestone grassland due to summertime and initial winter population swings. Early July was the peak time for both heather litter and alluvial grassland. Another discovery was that, with increasing depth, the population densities of microarthropods such as acarina, psocoptera, collembola, pauropoda, protura, coleoptera, symphyla, dipteran larval stages, and diplura rapidly decreased. The bottom of the tillage zone should be at least as deep as sample depths at each of the agricultural sites in the research region. They discovered that some microarthropod taxa were widespread below the tillage zone. In the summer and winter, but not in the spring, changes in the amount of litter in the field led to large changes in the abundance of microarthropods (Gill, 1969). The seasonal change in the density of the collembolan and acarina populations of two pastures was compared in a study of acarina and collembola populations in New Zealand pastures (McMillan, 1969). In most cases, total and partial coefficient correlations were analyzed, and it was shown that temperature and soil moisture had a substantial impact on the individuals of microarthropods. The populations of acarina and collembola were found to be at their highest density

throughout the fall and winter, when temperatures dropped. This indicates that not all of the collembola and acarina's constituent groupings displayed the same pattern of seasonal periodicity. The identical saturation deficit had distinct effects on *Tomocerus minor*, *Orchesella cincta*, and *Isotoma viridis* (Joosse & Groen, 1970). Depending on their preferred levels of humidity in their natural habitats, various species responded differently to the same saturation deficiency number. They believed that desiccation encouraged collembola to exhibit greater locomotor activity, which eventually allowed them to assemble in an ideal humidity environment. In comparison to horticultural environments, the agricultural habitats have studied (Gadaily et al., 2020) a higher population of soil arthropods. The two orders with the greatest number of individuals were araneae and entomobryomorpha, respectively. In a grassland ecosystem, the research of the soil mesofauna (Pillai & Singh, 1977) indicated the existence of two meso faunal peak periods, one in the winter and the other during the rainy season. No matter the sampling zone or season, a collembolan order of microarthropod species dominated the forest floor (Acharya et al., 2020). The 0 - 3 cm layer of a beech wood floor's litter was where oribatid mites were most prevalent, while the 6 - 15 cm layer included 3 - 4% of the entire community, according to a study of oribatid mites over the course of a year. The study also revealed that the depth distributions of oribatids varied with taxa, habitat, and climatic regime, and many species displayed true vertical migrations in response to climatic variables (temperature being of primary significance) and in the hunt for exploitable resources that were available during specific seasons. In five sampling areas of Dalman (Turkey), the vertical distribution of numerous soil microarthropods, including acarina (mites), revealed that trash had the highest population density, while the lowest population was detected in the top ten to fifteen centimeters of the subterranean soil profile (Urhan et al., 2008). In addition, a study on the vertical distribution of soil arthropods in an apple orchard in the Jammu and Kashmiri Shopian region found that the number of individuals per sample was largest in the month of August and the smallest in the month of February. Furthermore, relative abundance indicated that there were 46.15 - 66.66% of individuals in the 0 - 15 cm depth range, followed by individuals in the 16 - 30

cm range at a percentage of 25.92 - 35.24, and the lowest population percentage (12.90 - 21.43%) in the 0 - 45 cm depth range. If dominance is observed, it is noted that the acarina are the most dominating group, followed by the collembolan and hymenoptera, while other groups such as the symphyla, coleopteran, chilapoda, orthoptera, heteroptera, and dermaptera are quite rare. The reason for the acari's dominance is believed to be their unique morphological and physiological adaptations, which include sclerotized exoskeletons, a variety of feeding preferences, and long lifespans (between a few months and two years on average). The fact that springtails reproduce more frequently and have multiple generations in a year may be the reason they predominate in the soil (Sheikh et al., 2017). In Sikkim, the north district had the greatest diversity of collembolan species (39 species, 26 genera, and 8 families), while the south district had the greatest number of species (27 species, 14 genera, and 3 families). In coniferous forest soil, zoogeographical links are less important than climatic and ecological circumstances, according to a lengthy study (14 years) conducted in a generally natural yet little modified ecosystem (Balogh et al., 2008). Growing diversity in the litter enhanced variety as well as abundance and species richness (Coleman 2008). As litter feeders, mesofauna are known to multiply with an increase in OM (Galvan et al., 2008).

In pine forests, temperature affected *Folsomia octoculata* natality and mortality (Takeda, 1984). Seasonal variations in population abundance in temperate forest soils reflect the processes of population growth and reproduction from spring to early winter as well as mortality throughout that time. The recruitment occurred often both during both seasons of the year, resulting in an overlapped generation structure. There was no evidence of aestivation through the dry seasons. Seasonal fluctuations in the number and geographic location of soil microarthropods were investigated in a Japanese pine (*Cryptomeria japonica*) plantation (Naoki Hijii, 1987), with a focus on collembola and acarina in particular. It was discovered that there was a seasonal increase in unevenness indices from July to fall, a time when the soil's top layer had less moisture. According to research on the spatiotemporal impacts of invertebrates on soil processes (Anderson, 1988), macrofauna that consume vast amounts of litter have a significant influence on

decomposition. A variety of factors work together to govern the changing seasons periodicity of soil's mesofauna rather than a single component acting alone (Sinha et al., 1988).

2.9 Sampling Methods for Soil Arthropod Extraction

The first published account of collembolans, sometimes known as swarms of the snow fleas, that were discovered white and hairy, may be found in Aristotle's Historia Animalium (Aristotle et al., 1978). Due to original description of the Micrographia (Grassi, 1887) Diplura, a well-known silverfish, very little research has been done on soil microarthropods to date (Hooke, 2003). The most well-known species of soil microarthropods found in Europe's coastal zone is *Anurida maritima* (a collembola) (Imms & Herdman, 1906). The similar method was used to study a variety of soil microarthropods, including oribatid mites from Indonesia (Berlese, 1913). Different sampling techniques are used for the same objective (Coddington et al., 1996 and Fisher, 1999), with implications for the conclusions drawn and the quality of the generated data. Arthropods can be extracted from soil plus litter samples using tools like a corer or a soil shovel, for instance. While soil corers condense the soil (Meyer, 1996), making it more difficult for the creatures to leave the sample, shovels create a lot of displacement (Longino et al., 2002), which motivates mobile organisms to leave and reduces their apparent abundance in the sample. The diversity of the gathered fauna may be neglected or exaggerated since the variety of the gathered arthropods will vary between the two approaches (André et al., 2002). Based on these diverse results, the researcher will make numerous assumptions. Therefore, it is critical to assess how varied practices affect the species composition, variety, and richness of the arthropods. Three Pristine Forest Reserves and four Cacao Estates provided the first source of soil microarthropods for the flotation method of extraction (Strickland, 1947). However, Raw (1956) was the first person to use the flotation approach to successfully retrieve the most nimble and delicate group of insects. In order to quickly remove numerous collembolans, acari (mites), staphylinids, and spiders from grassland in 1937, Ford employed an upgraded Tullgren's

funnel. The results of this study indicate that soil moisture is essential for the existence of this fauna, and that some species moved into particular grassland zones as a result of the wet and dry nature of those zones. With the help of Berlese-Tullgren funnels, arthropods are typically extracted from soil or litter samples (Walter et al., 1987; MacFadyen, 1961; Rohitha, 1992; Lakly & Crossley, 2000; Bremner, 1990; Haarlov, 1947; MacFadyen, 1953;). At the start of the 20th century, Berlese (1913) may have been the first to research soil microarthropods from Indonesia, notably the oribatid fauna. In such funnels, the sample is positioned above a heat source, such as a light bulb, and beneath a collecting vial holding a lethal solution, such as 70% ethanol. Light from a light bulb has a twofold effect since it heats the sample and pushes photophobic creatures away from the source. As the sample dries, a temperature and humidity gradient forms between its upper and lower surfaces (Haarlov, 1947; Block, 1966). As this gradient decreases, animals are driven into the liquid that is gathering (Coleman et al., 2004). Heat increases the temperature in the funnel, which speeds up drying (Coleman et al., 2004), but it may also scorch organisms beforehand they are collected, reducing estimates of their richness (Walter et al., 1987). While in remote field settings where extraction tasks without light are logistically more advantageous and practical, the creation of the gradient and sample drying are dependent on the room temperature at which the extraction procedures are conducted (Krell et al., 2005). Since both extractions using and without light induce different situations inside the sample, the use of light while extractions might result in the removal of different groups of arthropods and, consequently, a different collection of data (Agosti et al., 2000). Length of arthropod extraction can also have an impact on estimates of diversity. According to the research, extraction times might be as long as 7 days (Bestelmeyer et al., 2000; Oliver & Beattie, 1996; Hasegawa, 1997; Burgess et al., 1999; Chen & Wise, 1999; Walter et al., 1987). Longer extraction times are typically thought to result in more accurate extractions as well a greater proportion of the retrieved fauna (Oliver & Beattie, 1996), but they also reveal the samples to the risk of getting contaminated by foreign organisms. This is because organisms with little mobility need a lot more time to leave the sample. On the other hand, in order to choose an appropriate

extraction period, the environment of birth and stage of development should be taken into account (André et al., 2002). For instance, organisms accustomed to harsh habitats, such as arid regions with high temperature variations, may need longer extraction times than organisms evolved to more moderate conditions. Additionally, different developmental phases of the organisms (Sovik & Leinaas, 2002) or presence during dry or wet seasons (Oliver & Beattie, 1996) may affect how long it takes to gather them from the same habitat. In order to obtain correct data, it is crucial to assess how an appropriate period of extraction varies across origin locations and stages of the focus organism's development. Analysis of the effects of chilling time (Lakly & Crossley, 2000) on the effectiveness of method Tullgren extract of soil mite (Acarina), soil microarthropods move across soil samples in response to gradients in temperature and humidity soil extraction techniques have been examined (Southwood & Henderson, 2009; Mac Fadyen, 1955, 1962; Kevan, 1962 and Murphy, 1962). The approach (Salt & Hollick, 1944), on which the majority of soil washing procedures are based, has the primary drawback of taking a long time to handle each sample. Sieve blocking, which occurs when tiny mineral particles become stuck in the holes, is a problematic aspect of this and other techniques. The authors aimed to prevent this string of sieving operations when they created the mechanical cleaning mechanism. Equipment made of 16 g stainless steel grade 304 is: rotary sieves, Intersieves, rotary sieve baths, washing tables, grass float baths, grass separators, flotation funnels, flotation cans, aeration stirrer, sucti, etc. Prior to extracting the fauna or fine plant material, it was thought advantageous to reduce the amount of material transfer from one container to another. This was done using rotary filters, Intersieves, spinning sieve soaks, cleaning tables, grass floating baths, grass barriers, flotation pipes, funnels, the flotation cans, aeration stirrers, suction columns, and sorting dishes. Minor adjustments would mostly deal with fauna that could possibly float in water. (Wilcocks & Oliver, 1971).

2.10 Morphological identification of soil arthropods

Different soil arthropods at the family, genus, and species levels had been identified morphologically through the work of different workers: arthropod identification (Gibb & Oseto, 2005); arthropods (Mani, 1962, 1968, 1990; Dindle, 1990) to morpho-species level; isoptera (Holmgren, 1906, 1910, 1912); diptera (Johnston & Tiegs, 1921a; Linnaeus, 1789); hemiptera (Stal, 1866); orthoptera (Stal, 1875; Walker, 1870); insects and spiders (Chandra, 2011); millipedes (Golovatch & Wesener, 2016; (Petra & Jason, 2007); ants, bees, ichneumons, chalcids, sawflies (Mayhew, 2007); diptera (Frouz, 1999); thysanura (Escherich, 1903; Hazra & Mandal, 2007); protura (Szeptycki, 2007); diplura (Mandal & Suman, 2013; Singh et al., 2008; Yadav et al., 2009; Yadav, 2018); collembola (Janssens, 2007; Bellinger et al., 2016; Yadav et al., 2018a; Yadav et al., 2018b; Yadav, 2017a, 2017b, 2017c, 2018a; Rusek, 2002; Mandal, 2010a, 2013, 2014; Mandal & Hazra, 2002, 2004, 2009); acarina (Dhooia, 2016); symphyla (Eberhard & Spate, 1995; Clark & Greenslade, 1996); pauropoda (Cedric, 2005). According to research on the taxonomy as well geographical spread of the genera *Anurida* (collembola: family neanuridae) throughout the northern Palaearctic, *Micranurida*, *Cephalachorutes*, as well as *Isotomiella* were flawlessly defined at the generic level by their antennal chaetotaxy, and *Anurida* used antennal characters at the species level. In order to evaluate the value of morphological traits for the identification of species employing molecular markers, (Fрати et al., 1995) looked at the genus *Isotomurus*. Since the taxonomic classification of collembola is entirely based on morphology, molecular techniques are used to study the emergence of the group, and these are intimately linked to morphological ones. In this context, morphological approaches are restricted in two ways: first, in the process of separating taxa clusters, parent species, and color design forms; and second, in a variety of phylogenetic reconstruction aspects. Therefore, molecular techniques are very useful in these grave situations.

2.11 DNA barcoding

A DNA barcoding system (Hebert et al., 2003) for species identification employing the gene for the cytochrome c oxidase unit 1 in mitochondria (cox1 or COI) as a standardized single genetic marker for the identification of animal species. Barcoding using the cox1 gene (Trivedi et al., 2015) is recommended as a benchmark for cryptic taxonomic discovery, or various life stages of the same species. Compared to the other mitochondrial genes, cox1 seems to have a stronger phylogenetic signal (Strüder & Lynn, 2010). Some researchers contend that the cox1 gene's evolution has progressed quickly enough to distinguish between closely related species and study intraspecific diversity (Lin et al., 2015). The cox1 region is quite effective (Oba et al., 2015) at differentiating across arthropod species. A bio informatics analysis of databases (Margam et al., 2010) was performed to show the efficacy of the DNA extraction protocol via the use of universal bar-coding primers unique for the cytochrome C oxidase I gene to recognize various arthropods specimens by means of a Barcode of Life Database (BOLD) database search. DNA barcoding (such as a 658 - bp fragment of the mt dna cytochrome c oxidase unit 1 gene/cox1) is recognized as a major method for swiftly and precisely identifying insects (Ojha & Jalali, 2014).

2.12 The relationship between arthropod diversity and edaphic factors

The importance of animals that live in the soil is crucial for the soil fertility, which is also influenced by the surroundings. According to a study (Ghilarov, 1975), only soil-dwelling animals are involved in the destruction of plant detritus, its penetration into soil, decomposition, humus production, and mixing with mineral particles.

2.12.1 Initial work done on arthropods in relation with soil

Soil animals play an important role in decomposition process was studied primarily by Bornebusch in 1930. In subterranean soil, population of soil collembola was observed (Glasgow, 1939) and was found that microarthropods tend to be aggregated highly in the

soil. In the same year (Jacot, 1939) while studying on reduction of spruce and fir litter by minute animals, it was observed that the larval forms of mites burrow within spruce and fir needles decomposed and softened by fungi and that the mites complete their development in this situation to emerge in the adult stage. The first study on ecological aspect of soil microarthropods in India was done by Trehan in 1945. Although investigation on the ecology of mites and collembolas in the soil was done (Weis-Fogh, 1948), however, the animal community in a beech forest floor of Netherlands (Drift, 1951) was analyzed and found the Astigmata to be a very small group and studies of soil fauna with special reference to collembola was also made (Bellinger, 1954).

2.12.2 With SOM, temperature, moisture, OC, pH, available N, K, P, and S

The main factor affecting soil microarthropods is SOM (Scheu & Schulz, 1996; Fujikawa, 1970; Santos, 1974; Anderson, 1988 and Tripathi et al., 2006). Numerous research (Haarlov, 1960; Christensen, 1970; Davis, 1963; Ilyas & Parwez, 2012; Darlong & Alfred, 1982; Huhta & Milkkonen, 1982) demonstrated a correlation between the population of microarthropods and SOM levels. Collembolans prefer environments that offer a consistent supply of OM (Vreeken - Buijs et al., 1998). When the soil is rich in organic material, such as decomposing vegetation, dung, or animal waste, dozens of species of mites may be discovered in a small space (Hoy, 2008). Acari displayed an erratic fluctuation tendency that showed maxima and minima during the post-winter or pre-monsoon seasons (Ghosh & Mandal, 2017). The main cause of mite population abundance, the oribatida, had a substantial and positive link with the amount of OM and a negative correlation with the soil pH, temperature, and wetness. The relationship between the soil's nutrient concentration and faunal richness was investigated (Kováč et al., 2001). Although severe temperatures in June and July had a negative impact on soil arthropods, soil temperature was strongly and positively linked with abundance (Ali - Shtayeh & Salahat, 2010). In rice fields, the diversity of prevailing microarthropods was maximum from May until September while it was its lowest from January (Zhimomi et al., 2009). Additionally, the primary sources of soil arthropod richness - collembola, mites, ants, and

millipedes - were practically absent in the samples all winter long, resulting in a dramatic fall in number (Sulkava & Huhta, 2003; Asikidis, 1991). On the other hand, a research (Ford, 1935) found that the population increased in December and decreased from January to May. However, temperature preference varies between species (Wallwork, 1970). It was discovered that (Agrell, 1941) on the temperature choices of various species of collembola, the latter have been bestowed with a great flexibility of thermal tolerance because they could withstand a wide range of temperatures between -4°C and -10°C as their lowest point and 35°C - 38°C as their maximum. A study (Gisin, 1943) demonstrated how the presence of a few collembolan species that were known to be sensitive to edaphic conditions might be utilized as a trustworthy index for identifying the type of soil. According to studies on how invertebrates from the soil living in various kinds of soil respond to temperature changes in their vertical migration (Dowdy, 1944), during the fall and winter the invertebrates went deeper into the soil and returned closer to the surface the following spring. This study found that the primary trigger causing vertical movements was temperature. The temperature range that was seen was from 38 to 45 degrees. Low temperatures delayed the frequency at which certain species of *Onychiurus* matured over the course of the winter, either in the form of eggs or in the nymph stage, according to Trehan (1945), who studied the effect of temperature on all three types of *Onychiurus*. The challenging air conditions induced on by dry and chilly spells could also be withstood by collembolans. The duration of each instar, the entire life span, plus the pre-oviposition period were all reduced as the temperature rose under favorable conditions because of a rapid acceleration in the rate of growth. A study (Butcher et al., 1971) found that the variance in mite counts in the forest and cassava plots is explained by soil temperature in 76% and 61% of the cases, respectively. The bioecology about edaphic collembola and acarina was the main topic of the study. High soil temperatures have been demonstrated to stop mites from laying eggs and to kill their sperm, which slows the population expansion of mites. A community of springtails may be affected by outside factors includes temperature, moisture, even predator activity, according to a study (Hagvar, 1995) on fragility in tiny, discrete microarthropod

communities. Animals in the soil are negatively impacted by elevated temperature fluctuation and higher likelihood of frost due to the shorter length of snow cover (Sulkava & Huhta, 2003). Daily fluctuations in soil temperature affected the potential of oribatids to remain alive and reproduce; swings between 5 and 25 °C had severe negative effects, while variations within 10 and 20 °C increased reproduction (Uvarov, 2003). By imitating an extreme summer warming effects of tent warming on web habitats were observed for three years (Coulson et al., 1996). In semi-desert settings, there had been an increase in the number of young oribatid individuals, but no other notable changes had been noted. The recurrent occurrence of *Isotoma viridis* and *Isotoma palustris* over the winter months shown that the population grew in the morning (8 - 10 am) and subsequently declined until evening (6:30 pm). Accordingly, it was believed that the air temperature that was reflected in the coating of snow appeared to control how the animals moved during phototropism. According to research on microarthropods cold tolerance (Cannon & Block, 1988), soil microarthropods appear to be freeze - susceptible and employ variable degrees of supercooling to prevent freezing. Moulting, especially in collembola, may increase a person's ability to supercool, and the role of ice - nucleating pathogens in cold-hardy insects may be important. The seasonal and daily migration of soil animals was primarily caused by variations in light as well as soil moisture. The research presented here (Jacot, 1940) strongly advises against categorizing these organisms merely on the assumption of the powerful or subdominants and instead suggests categorizing them based on their life cycles, dietary patterns, and interpersonal connections. When collembola (a variety of *Folsomia*) was present, the nematode population was dramatically reduced at both medium and high levels of wetness and (Huhta et al., 1998) researched the impact of microclimatic variables on associations among soil faunal communities. Through research on the microflora and associated soil fauna, a pioneer in the ecological study of microarthropods (Hammer, 1944) noted that the soil fauna was somewhat adversely connected with soil moisture and split into two types of communities, moisturephilic and moisturephobic. Soil moisture is the main variable that influences the seasonal variation in microarthropod populations (Asikidis,

1991; Choudhuri, 1990; Bean et al., 1994; Guru et al., 1988; Usher, 1976; Hazra & Choudhuri, 1983; Wallwork, 1970; Vannier, 1987; Mukherjee & Singh, 1970; Choudhuri & Roy, 1972; Whitford, 1989). If the soil didn't have enough organic materials, soil moisture content alone would not be sufficient to encourage an increase in the population of soil fauna (Steinberger et al., 1984). The SOM content, according to a study (Davis, 1963), had an effect on the population of soil microarthropods, but soil moisture had the biggest impact on seasonal changes. The crops increased water consumption and strong growth after fertiliser application (four times) may be the reason of the negative connection (Zhang et al., 2017). The species richness of oribatid mites has been significantly influenced by water content, albeit its impact has changed with the seasons (Noti et al., 2003). Collembolans (71% of the soil litter arthropods) in a deciduous forest stand were substantially more abundant than acarines, whose density was strongly influenced by soil temperature and soil moisture but not by the amount of litter (Vats & Handa, 1988). Similar to this, whereas soil moisture and soil pH did not significantly correlate with abundance, soil temperature and SOM did (Shakir & Ahmed, 2015). Collembola had the highest density and abundance of soil microarthropods, followed by hymenopterans and acari (Abbas & Parweej, 2012). Regarding the collembolan population, soil temperature had a negative correlation ($r = -0.932$, $P < 0.05$), although soil moisture and available N had positive correlations ($r = 0.502$, $P > 0.05$, and $r = 0.656$, $P > 0.05$, respectively). In some situations, perhaps more so than C, the soil's N level can be an important factor (Mitchell et al., 2007). The collembolan population and SOC were shown to have a very strong positive association. There is a direct association between soil carbon content and mite species richness (Scheu & Schultz, 1996). The soil's OC ($r = 0.17$), pH ($r = 0.59$), moisture content ($r = 0.25$), and soil temperature ($r = -0.90$) all showed positive correlations with the soil's arthropod fauna. Soil arthropod populations rise when soil moisture content rises and soil temperature falls (Ogedegbe et al., 2014). In contrast to soil moisture, SOC, phosphate, nitrate, calcium carbonate, pH of the soil, particle size, and soil cover, as well as in some cases obtaining winter maxima, the quantitative and qualitative composition of collembola provided a description of their

seasonal fluctuations and vertical and horizontal distribution patterns. Seasonal variations in the populations of acarina, collembola, diplura, palpigradi, pauropoda, symphyla, and pseudoscorpions were studied in a rose garden in Varanasi (Mukherji & Singh, 1970). It was shown that there was an association among moisture levels, temperature, as well as population dynamics of soil microarthropods if the temperature as well as soil moisture content were both relatively high. The pH and OM of the soil showed only modest variations. This study found that any relationship between these soil characteristics and the population of soil arthropods was challenging to understand. The increase in population density (Choudhury & Roy, 1972) was associated with soil elements including moisture, OC, nitrate, and phosphate, and the majority of the fauna were located in the higher layers of the soil. In May and November, when there are the maximum concentrations of accessible phosphate and OC, an increase in the oribatid population was noted each year (Sanyal, 1982). In contrast to the acarina (mites) population, collembola as a complete was more affected by the pH of the soil (Edward & Lofty, 1974). The pace of decomposition, the number of microorganisms, and soil fertility all decreased in soil that had been treated with H₂SO₄ (Bath, 1980). Collembola, a species of *Folsomia*, was shown to considerably lower the nematode abundance at moderate to elevated levels of wetness when the effect of microclimatic circumstances on soil faunal assemblages was explored (Huhta et al., 1998). The pH gradually drops as a result of prolonged acid deposition, which lessens the soil's capacity to serve as a buffer (Van Straalen, 1998). With the exception of only a few stress response genes (Boer et al., 2010), soil temperature and pH levels had no effect on the transcriptional regulation of *Folsomia candida*. These therapies' physiological effects on *Folsomia candida* may point to intriguing new molecular processes. In their study of the oribatid mites species' preference for particular microenvironments on the floor of a tropical rainforest, the makeup of the power source mesofauna was not influenced (Badejo & Akinwole, 2006) by the habitat sample's location, whether it was in direct sunlight or shade. On the other hand, found that the population densities of soil arachnids were larger in the shaded fields rather than the un-shaded fields (Belfield, 1970). In a study (Dermody et al., 2007)

examined the significant role that raised plots having lots of natural matter, cooling shade, elevated C, and N play in maintaining a variety of soil organisms such as collembola and mites.

2.12.3 With Tillage, Irrigation, Soil Depth, Land Use Changes, Heavy Metals, Fertilisers, Pesticides, Herbicides, Weedicides, Predators, Crop Type,

Few arthropods were detected in the upper 5 cm soil after cultivation, and the majority of forms were concentrated at the lower level, according to research on the arthropod fauna of cultivated soils (Shaddy & Butcher, 1977). As a result, it was discovered that tillage decreased the dimension of the aggregation while watering had little impact on the periodic abundance and accumulation of the soil fauna. The effects of soil tillage on soil animals are varied and to varying degrees, and they can even be detrimental to different taxa and soil invertebrates to the point where the dominant species changes. In addition, after tillage and other agricultural practices, several ecological groupings and species were entirely eradicated (Ghilarov, 1975). When studying how cultivation affected the population of soil microarthropods, (Edward & Lofty, 1973) plowing had a generally positive effect on the circumstances that were typical of arable land. The seasonal changes of the oribatid mite population were impacted by soil agriculture (Jeleva, 1970). The number of oribatid mites has peaked as long as conditions are favorable for species that live in deep soil layers. Diplura collembola, pauropoda, psocoptera, protura, coleoptera, symphyla, dipteran larvae, and acarina, population densities rapidly dropped with increasing depth. The number of soil insects was found to decline with increasing depth (Strickland, 1947), and it was discovered that they did not travel past 7 inches. According to a study (Birch & Clerk, 1953), the density of various types of spaces in the soil heterogeneity of solid soil was the cause of the diversity of the defined soil fauna. The size, form, and scarcity of food supplies were likely variables in the spatial arrangement of the collembolan fauna, as suggested by an investigation (Haarlov, 1960) on the vertically distribution of collembola with acarina (mites) in relation to soil structure. There is a drop in springtail and mite populations (Watenova, 1964) with

increasing soil depth. This was linked to reasons including a decrease in porosity, carbon dioxide evolution, soil carbon contents, and the quantity of roots present in each horizon. The susceptibility of soil-dwelling collembola in high carbon dioxide levels was examined (Zinkler & Platthaus, 2013). Soil that has trapped gas in it may have places where the percentage of carbon dioxide is high. *Folsomia candida* have the potential to replace other collembola species as the most common one in these habitats since it has evolved to survive for extended periods of time in them. Animals can withstand 10% of carbon dioxide over six weeks at a time or up to 25% for an hour, according to a claim. Additionally, some of the microarthropod taxa were widely distributed below the tillage zone. As a result, all agricultural cultivation sites should have sampling that goes at least as deep as the tillage zone (Price & Benham, 1977). Land use changes: the highest population was found in forest soil, followed by locations with grassland and crops (Singh, 1975) respectively. In grassland compared to arable land, the soil fauna's distribution and population density were more steady (Buckle, 1921). But when the plant grew in both places, the soil fauna grew as well *Tomocerus onichiurus* and *Tipula* larvae, as well as certain beetles from the family catheridae, were found in a study (Blacke, 1931) of soil and litter inhabited by an animal community in a deciduous forest. This discovery was consistent with the fact that there were less soil creatures on the area of land with a high concentration of herbs and shrubs. As a result, population shifts coincided with changes that had an adverse effect on the substratum, which was affected by high temperatures and increasing moisture. In water-logged and burnt forest areas (Vlug & Borden, 1973), there was no seasonal change in the overall density for soil microarthropods or association between the population density and edaphic variables, indicating that none of the two included deaths occurred. When human involvement within the collembola species was identified in a study (Huther, 1983), it was discovered that the species *hypogastrura* was the dominating taxon on the surface. One month after the blaze was put out, the surface population density was larger than in the prehistoric forest, but mite dominance and collembolan absence from the soil had changed. Within one year upon the burning, the total insect population was equivalent to that of the

ancient forest. but the corresponding collembola population displayed clear differences. In an unburned forest with 50,000 individuals spread across 44 species, the impacts of post-fire succession on surface-dwelling collembola was investigated (Tamm, 1986). The fire significantly altered the habitat because it significantly increased the ground vegetation's carbon content, destroying the top soil's raw humus in the process. Epizootic springtail mortality from fire was particularly high. The number of individual collembola caught in the burned area was down to 20% in April, seven months after the fire. Some epigial collembolans in environments with arable land may tolerate lengthy droughts, it was discovered when researchers examined the effects of drought on springtails (Alvarez et al., 1999). It was discovered that particular kinds of surface - living organisms having restricted habitat ranges were less adversely harmed by the drought after studying the effects of drought on acarina and collembola in addition to their recovery after the drought. After the drought, species with wide habitats tended to recover more quickly. According to Lindberg & Bengtsson (2005), collembolan species generally recovered more quickly than acarina. Collembolans then acarina undergo a stage of passivity during being submerged, and their eggs emerge once the water recedes, according to Tamm's studies on the existence of grounded soil microarthropods in areas susceptible to flooding. Microarthropods contributions to the processes of mineralization and decomposition were examined (Seastedt, 1984). As opposed to 50,000 m² in tropical forest soils, discovered that there were approximately 300,000 m² of soil arthropods in temperate forest soils. In an investigation (Strickland, 1947) using the floatation method of extraction, it was discovered that the flora had a bigger impact on the size of the insect population in the soil than the kind of soil. Acarina (mites) were discovered to be the main animals that lived in the earth and the litter in every location. When the populations of soil- dwelling microarthropods in banana, citrus, fodder, and fallow fields were compared, it was discovered that they ranged in density from 1698 to 20,377 m². The most prevalent group across all habitats was the acarina, which made up 45.6 - 71.8 % of the entire soil fauna. A banana field with high levels of calcium carbonate, OM, and soil moisture yielded the most collembola. In various settings, collembola population

densities ranged from 11.9% - 41.7%. The collembolan was found to have a favorable correlation with oribatei and an unfavorable association with prostigmata. According to collembola quantitative makeup, some species population growth was confined to particular habitats. In soils with a high proportion of OM, collembola and oribatids dominated, while prostigmata dominated in soils with a lower proportion of OM (Singh & Pillai, 1975). The variety and quantity of soil arthropods are impacted by changes in plant both quantity and quality as well as soil physicochemical characteristics (Lakshmi et al., 2020). The most important factor for estimating species diversity and a major ecological variables in studies of crucial biotic processes and links for biodiversity conservation is the number of soil-based arthropod species associated with various sorts of vegetation (crops or plants) (Lupardus et al., 2021). A study about the investigations of *Gamasina* mites in natural and man - affected soils (Salmane, 2003) in Latvia for a total of 22 naturally occurring and human-influenced habitats included data from various seasons and years. The study examined species dominance, average species density, and species diversity. The overall parameters in this study that were discussed above demonstrated that the number of mites and species density both lower in areas where humans had an impact than in areas where they had not. Trends were only used on natural areas and not on conventional agricultural farmlands, therefore this lengthy study may be more useful in context of habitat change. According to a thorough study on the impacts of drought in Swedish coniferous woods (Lindberg et al., 2002), long-term precipitation shortage reduces the diversity and abundance of oribatid mite groups. Lindberg also looked at the community's long-term consequences of the draft and how long regeneration would take; even three years after the intervention, he was unable to compare results between treated and untreated control sites. In addition, he noted that compared to collembola or mesostigmata, oribatid mites were more sensitive and had significantly more moderate regeneration capabilities. They also looked at whether diversity was negatively impacted by drought. According to a research (Alvarez et al., 1999) on the impact of drought on springtails, some epigial collembolans in systems with arable land may withstand prolonged drought. The population of Colombia, however,

could be affected in certain ways by the expected climate changes as a result of these discoveries. It was investigated how depleted uranium affected the function and functional diversity of soil microbes (Meyer et al., 1998). They discovered that slower degradation was a result of the usage of depleted uranium, which reduced bacterial functional diversity. Only four metals i.e. Cr, Fe, Mn, and Al were found in organic farm soils in a comparison of heavy metal accumulation and soil arthropod diversity, whereas eight metals i.e. Cu, Zn, Cr, Fe, Ni, Mn, Al, and Mo were found in conventional farm soil (Saxena et al., 2020). A gradient study was conducted on microarthropods and Enchytraeidae (Oligochaeta) in a naturally lead-contaminated soil (Hagvar & Abrahamsen, 1990), and it was discovered that anthropogenic activities may have persistent and long-lasting effects on collembola, though springtails can become tolerant to metals with long-term (centuries) exposure. Additionally, they discovered that species numbers declined along a gradient with rising Pb content. High - quality food and metal toxicity to collembola were found to be trade-offs, and it was hypothesized that Cu diminished or altered the microbial flora, which in turn reduced the number of species and quantity of collembola when Cu was introduced to the soil (Filser et al., 1995). Due to their recent evolutionary history and low level of environmental change tolerance, some soil microarthropods have the potential to be very good indicators of heavy metal pollution (Janssen et al., 2006). Heavy metals like Cu, Zn, and Pb are present in high concentrations in chemical fertilizers like superphosphate, copper sulphate, and iron sulphate (Gimeno et al., 1996), and they have a detrimental effect on the diversity of soil arthropods (Skubala et al., 2004; Tyokumbur, 2016; Manu et al., 2017; Barrios, 2007). However, the overall number of soil oribatids was unaffected by the use of fertilizers (Jeleva, 1970). Both organic and inorganic fertilizers have a positive impact on the amount of collembola. The first had a direct impact by providing food, and the latter had an indirect impact by having an impact on the growth of plants and bacteria. Additionally, the number of species that can withstand the rigors of cultivation rises as a result of fertiliser treatment and crop rotation. Additionally, during the cultivation of jute, paddy, and wheat, the impacts of various NPK dosages were reflected in their population

dynamics (Mitra et al., 1983). Farm manure was found to boost the population of invertebrates in arable soil (Morris, 1922). According to research on collembola and mites in plots fertilized with various kinds of green manure (Axelsen and Kristensen, 2000), collembola was found to be particularly prevalent in soil and leaf litter. They are widespread in most terrestrial environments. In pine woods in India and Japan, on moorland in England, and in dry meadows in Norway, springtail densities greater than 105 m² have been discovered. Collembola are highly prevalent in organically farmed agricultural soils. Acarina (mites) and collembola, two types of soil microarthropods, are negatively impacted by pollutants like aldrin and endosulphan, according to an intriguing study (Joy & Chakravorty, 1991). Since the addition of OM would have had favorable impacts on the chemical and physical characteristics of the soil, an increase might have been anticipated (Korentajer, 1991). When pesticides were applied to crops to control small mammals like rats, mice, moles, and voles, the non-target species (soil arthropods) were also harmed (Reganold et al., 1987). On leaves without insecticides, the population of mites prospering was compared to that on leaves treated with insecticides (Fujikawa, 1972). 40 different kinds of mature oribatid mites total 781 in number were collected. Nine of the forty species examined were common, pesticide or not. Of the nine species, *Oppia* was among the most widespread. In contrast to clean locations, soil contamination by a range of toxins may affect the diversity of species within the collembolan community, as seen by the effect of a sulfonylurea herbicide upon soil microarthropods. According to variations in the overall rate of development of springtails (collembola) beneath the influence of herbicides, studies on *Folsomia candida* only give direct information about the effects of chemical on *Folsomia candida* (Chernova et al., 1995). Long-term use of inorganic weedicides has resulted in a considerable decline in both agricultural output and collembola population. The effects of inorganic weedicides were seen to be less pronounced during paddy cultivation, which may be related to the high moisture content and spasmodic rains that diluted their effects (Mitra et al., 1983). Atrazine decreases fertility and consequently affects reproduction in a laboratory research (Mola et al., 1987) on the impacts of the weedicide on a particular kind of collembola.

Although the collembolans in the investigation were able to breed once more a month later, this effect is just momentary. Because a change in altitude may alter the soil chemistry, humus forms, and flora, the species composition of the soil microarthropod communities also changed (Loranger et al., 2001) and diversity increased with elevation (Migliorini & Bernini, 1999). In a study on *Sminthurus viridis* (the Lucerne flea), (Mac Lagan, 1932) looked into how the flea's ability to prey on *Coccinella*, *Philonthes*, and *Staphylinides* affected its ability to survive. The results (Behan - Pelletier, 1999) showed that families with parthenogenetic breeding (*Tectocephus* sp., Oppidae) were resistant to disturbances. As a result, they eat a variety of foods and contribute in a variety of ways to the structure of the food chain. As a result, they interact strongly with their surroundings (such as castorage) and heavy metal build - up, which is crucial for the establishment of soil structure as the processes that lead to its degradation. It's said that soil microarthropod populations were unable to react fast to short - term, intense shocks because of their slow growth, limited fecundity, and low metabolic rate. According to research on the biodiversity of collembola and their ecological function (Rusek, 1998), since soil - dwelling collembola frequently consume decomposer species, they had mostly been linked with the detritus - based food system. In a microbially based soil food web, (Mikola & Setala, 1998) analyzed productivity and trophic-level biomasses and discovered no or little impact from predators on consumers in soil systems. Although predators may indirectly affect the pace at which microorganisms are devoured, the microflora can counteract this by changing the rate at which biomass is turned over. It was found that collembola consume a variety of resources in their natural environments, such as fungi, bacteria, moss, pollen grains, spores, decaying plants, while debris, by examining the dietary styles for the collembolan *Onychiurus sinensis* for mold expanding into holm oak litter (*Quercus rotundifolia* Lam.). Along with this finding, it was also noted that *Sminthurus viridis* growth, development, and fecundity are influenced by variables such as temperature, soil moisture, and pH. In the maize production system, the impact of various management techniques (such as plowing and the weedicide atrazine) on the population dynamics of acarina and collembola was investigated (Moore et al.,

1984). The soil had a high moisture content and was quite fertile. They contrasted their findings with those of their counterparts from grasslands. Acarina and collembola were found to have increased in June, reaching their maximum in July for acarina and in August for collembola. Regarding seasonal variations, the trends in these soil creatures' natural population levels exhibit a considerable degree of variety. It was noted that a change in the pre - existing plant cover indicated a secondary impact of cultivation on population dynamics. Within a single horizon and soil type, such a change in vegetation cover altered the composition of the soil animal population. The quality of SOM was also altered by the shift in vegetation cover, which in turn had an impact on the faunal makeup. The need for increased research on soil fauna in India was prompted by the knowledge and significance of soil fauna, particularly microarthropods (Zodinpuii & Lalthanzara, 2019). Oribatid mites were found practically everywhere on earth in both terrestrial and freshwater ecosystems, and because of this, they can be very important in the field of indication research (Gergócs & Hufnagel, 2009; Gergócs et al., 2010; Hufnagel et al., 2011). Numerous factors, including ecological diversity, density, biochemical composition, geographic expanse, physiological and chemical features (such as weather and climate), effectiveness, and biological interactions, influence the number of species present in soil (Wagner, 2019). Due to their high rate of reproduction and diversity, arthropods are relatively resilient to pollution, urbanization, industry, change, and habitat loss (Baardsen et al., 2021). In the districts of Haryana state, there is still a dearth of understanding regarding the diversity and abundance of these arthropod, which are essential to the soil ecosystem. With these considerations in mind, the current study has been created to more thoroughly comprehend the seasonal change of soil arthropods in the number and diversity of farming and nonfarming land in the Haryana region of India.

2.13 Current Status of soil arthropods studies

Nevertheless, we are far from knowing all species currently living on the planet, particularly in highly diverse tropical regions and in megadiverse groups (Arthropoda).

For instance, there are around one million named insect species currently recognized as valid, while estimates of the real number vary from around five million (Stork 2018) to as many as 30 million species (Erwin 1982). Other groups, even if not as diverse as insects, are even less known. Such is the case of mites, with roughly 50,000 recognized species, and estimates of real diversity above one million (Stork 2018). But even knowing and studying the already described species is a major task that requires considerable time and expertise as most of these groups lack specialized taxonomists able to identify and delimit species (Engel et al. 2021). This, in turn, increases the biases of study toward some groups, while others suffer further neglect.

Agricultural professionals can influence the composition and diversity of their soil arthropod communities through management decisions such as insecticide and fertilizer use (Geisen et al., 2019) or crop rotation types (Elmqvist et al., 2023). Management practices that increase soil arthropod biodiversity in agricultural soils can improve the provision of ecosystem services to support crop growth (Bender et al., 2016) and influence aboveground interactions (Haase et al., 2008).

Higher levels of nitrogen in the environment (from, for example, fertilizers and livestock) affect not only plants, but also soil invertebrates and insects. The diversity of roundworms decreases in areas with high nitrogen input and the numbers of some arthropods decline. However, other arthropod species benefit from excess nitrogen (Gallego-Zamorano et al., 2023).

2.14 Research Gap

The aforementioned analysis makes it clear that numerous studies have been conducted both domestically and internationally on the distribution, density, and seasonal abundance of arthropod communities in various habitats in connection to climatic, edaphic, and biological parameters. However, ecological research on soil microarthropods in Haryana has not been done to the extent necessary to draw firm conclusions about their seasonality

and distribution. Moreover, investigators in many instances concentrated and restricted their study to a particular ecosystem and also to a specific group of arthropods and often failed to single out a factor(s) responsible for bringing out the changes in density, distribution, and population structure of soil microarthropods. They occasionally neglected to examine the interactions between various biotic and abiotic elements present in soil and their potential effects on the community of arthropods. In light of this challenge, the current author has investigated both farming and non-farming land in Haryana.

2.15 Hypothesis

The goal of the current study was to examine how edaphic conditions affected the diversity and distribution of soil arthropods. Arthropod variation was also thought to be related to changes in the life cycle of a given crop field, as well as to a particular crop field and particular terrain type in non - farming areas.

2.16 Objectives

1. Physical and chemical factors of soil for a period of two years from its inception.
2. Arthropod diversity of soil in different farming (sugarcane, rice, wheat, and jowar) and non-farming (forest and industrial) areas
3. Identification of arthropods through morphological and/or molecular techniques
4. Seasonal distribution and correlation of the arthropod's diversity with different edaphic factors

MATERIALS AND METHODOLOGY

CHAPTER 3: MATERIALS AND METHODOLOGY

3.1 Study Area

Haryana is a landlocked state in North India, located between 27°39' and 30°35' N latitude and 74°28' to 77°36' E longitude (NIDM). It is 700 to 900 feet above sea level and is quite hot in the summer (about 45°C/113°F) and pleasant in the winter. May and June are the hottest months, while December and January are the coldest. Forests cover 1,553 km² out of a total area of 44,212 km², while agricultural land accounts for 6,549 ha.

The whole study was based on agricultural fields and non-agricultural land systems as described (Table 3.1).

For the study, two agricultural zones were selected:

1. Agricultural Zone I: Karnal (KR), Kaithal (KT), and Yamunanagar (YN)
2. Agricultural Zone II: Sirsa (SI), Hisar (HI), and Rohtak (RO) - of Haryana is purposefully selected for farming land as it has better irrigation facilities, severe agriculture options, more coverage of the percentage area, and based on the highest (followed by the second highest) production of crops in the respective districts, the following sites have been selected for the present study:

Non-farming land - adjoining forest land and outskirts of textile industrial areas (FT and IL, respectively) of Haryana has been chosen for the present study.

Table 3.1: Description of study fields

S. No.	Study Area	Location	History
1	Sugarcane field, Yamunanagar	Between 29° 55': 30° 31' north latitudes and 77° 00': 77° 35' east longitudes	Growing sugarcane from last 3 years; Fertilizer used (Kisan urea / IFFCO / Shaktiman) only once in June-July; No pesticide was used; Loamy soil.
2	Sugarcane field, Karnal	Between north latitudes 29° 25'05" and 29° 59'20" and east longitudes 76° 27'40" and 77° 13'08"	Growing wheat, potato, and rice from last 2 years; Fertilizers used were Urea, Dhaya and Sugar which were used 4 times randomly; No pesticide was used; Loamy soil (well suited for cultivation as the plant roots get enough water and nutrients for their growth and development).
3	Rice field, Karnal	Between north latitudes 29° 25'05" and 29° 59'20" and east longitudes 76° 27'40" and 77° 13'08"	Alternative rice – wheat cropping was done; Fertilizers used were Urea and DAP (DAP after 10 days while Urea after 25 days of sowing); No pesticide was used; Loamy soil.
4	Rice field, Kaithal	Between the latitudes 29° 31' and 30° 12' north and the longitudes 76° 10' and 76° 42' east	Alternative rice – wheat cropping was done; Fertilizers used were Urea and DAP (DAP after 10 days while Urea after 25 days of sowing); No pesticide was used; Loamy soil
5	Wheat field, Sirsa	Between 29° 13': 29° 59' north latitudes and 74° 30': 75° 7' east longitudes	Rice – wheat cropping was done from last 2-3 years; DAP was used at the time of sowing while urea (2 times) 20-25 days after application of DAP and second time 5-10 before harvesting; Zn spray with salty pentacene was used as pesticide; Loamy soil.
6	Wheat field, Hisar	Between the north latitudes 28° 56'00": 29° 38'30" and east	Wheat – Lady's finger cropping was done from last 3 years; Organic farming was done with no use of fertilizers and pesticides but poultry water as

		longitudes 75 ⁰ 21' 12": 76 ⁰ 18' 12"	irrigation water; Loamy soil.
7	Jowar field, Rohtak	Between latitudes 28 ⁰ 40' and 29 ⁰ 05' north and longitudes 76 ⁰ 13' and 76 ⁰ 51' east	Wheat – cropping was done here from last two years; Fertilizers used were DAP and Urea (DAP after 10 days while Urea after 25 days of sowing); No pesticide was used; Loamy soil.
8	Forest Land, Panipat	Between 29 ⁰ 23' 7.4004" north latitudes and 76 ⁰ 58' 2.7768" east longitudes	An area of Reh, Kallar (common/ local names for saline soil); Occupied with Poa grass from last 15 years; No fertilizer and pesticide were used.
9	Outskirts of Textile Land, Panipat	Between 29 ⁰ 23' 7.4004" north latitudes and 76 ⁰ 58' 2.7768" east longitudes	N.A.

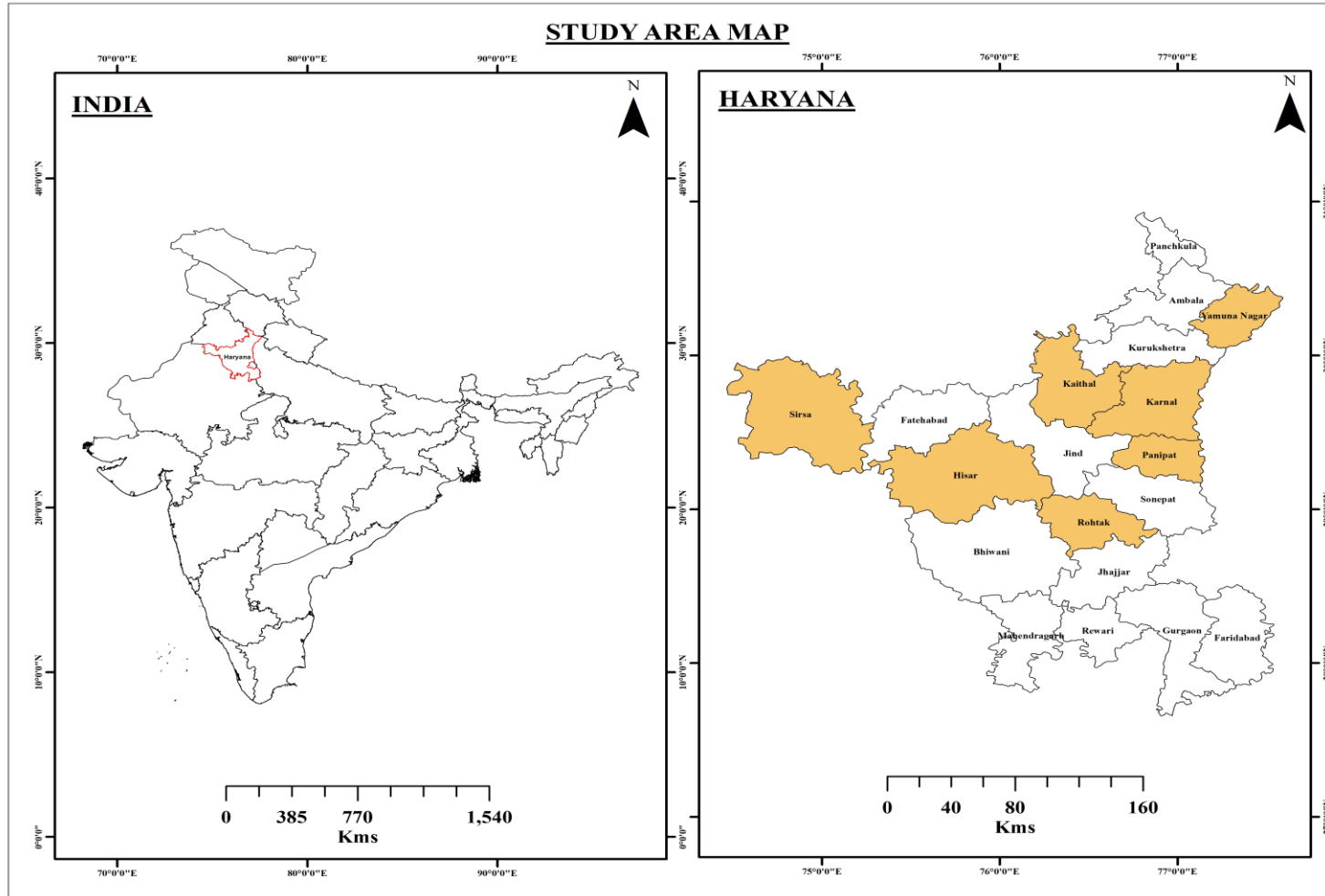


Figure 3.1: Map showing Study Area

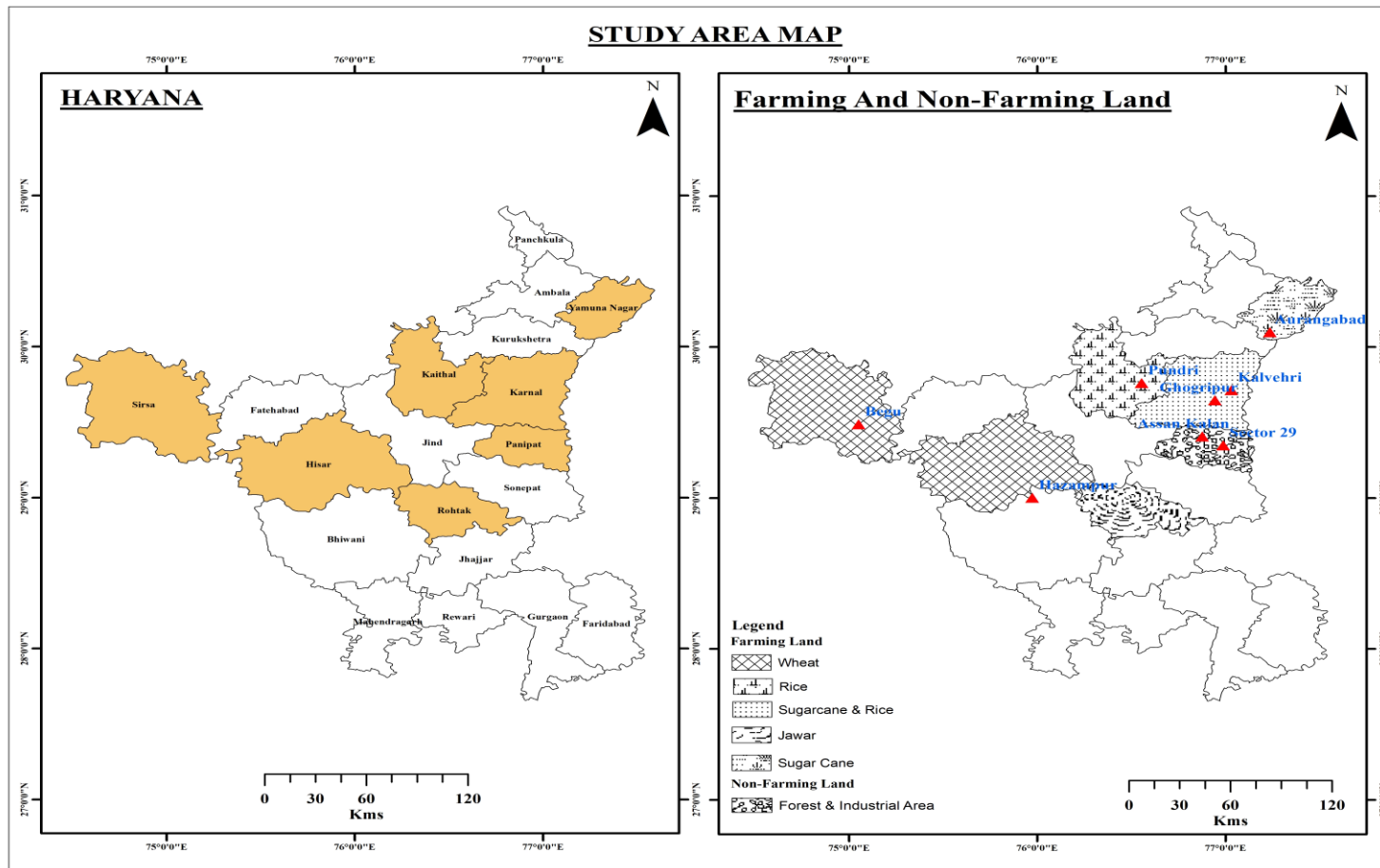


Figure 3.1: Map showing Study Area



(1) Sugarcane field, Yamunanagar



(2) Sugarcane field, Karnal

Figure 3.2: Study fields



(3) Rice field, Karnal



(4) Jowar field, Rohtak

Figure 3.2: Study fields

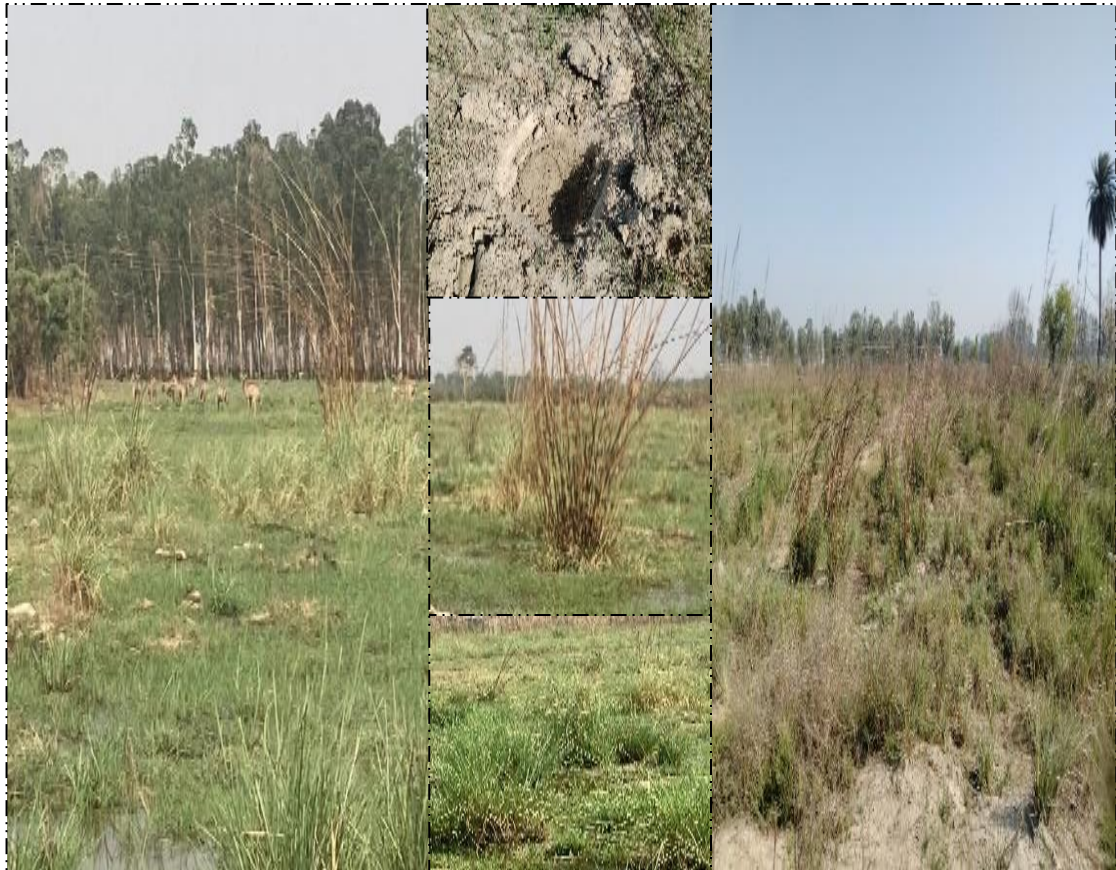


(5) Wheat field, Sirsa



(6) Outskirts of Textile land, Panipat

Figure 3.2: Study fields



(7) Forest land, Panipat

Figure 3.2: Study fields

3.2 Sampling of Soil

To obtain an evenly thick slices of soil from the surface of the ground to the ploughing depth from every sample location in the current investigation, surface litter was removed away with a shovel. With a shovel, a V - shaped trench was created in the sampling location to a depth of approximately 15 cm in order to remove a 2 - 3 cm slice of dirt. The sample was scooped up with a shovel or spade and placed on a newspaper, plastic sheet, chart, or bucket, where all subsamples were thoroughly mixed, collected by the quarter method, and packed in labelled packets. Soil samples

were taken from a depth of 15 cm during each sampling. The sampling took place between November 2020 and October 2022. The dirt was gathered from five separate places (250 gms) on the plot. They were then combined to form 1.25 kilogram per plot. This process was then done three times on three different fields of the same crop. Collected soil samples were immediately stored in labelled plastic bags with appropriate sample information (e.g., project, date, plot, variate) in the laboratory at 4°C for arthropod extraction and estimation of soil parameters such as soil temperature, soil moisture, soil pH, EC, OC content, OM content, soil available P, N, K, and metal analysis.

3.3 Extraction of soil arthropods

The extraction of arthropods from the soil has been considered one of the most important and intricate problems in soil zoology. From time-to-time, soil zoologists followed different methods and techniques to extract soil fauna from the collected soil samples. In the present investigation, soil arthropod extraction from taken soil samples was done by the Berlese - Tullgren funnel method (Berlese, 1913). The device was made up of six funnels placed in two rows (three funnels in each row) and lit by a 60 W incandescent lamp. Because of this arrangement, soil arthropods travel to the damp section of the soil sample (away from the light). The whole apparatus is mounted on a plywood board set in a wooden framework resembling a rack where the collecting vials (tubes) are tightly fitted. The vials contain a mixture of 70% ethyl alcohol and glycerine in the proportion of 20:1 for collecting as well as preserving the specimen. The extraction continued for 72 - 96 hours, after which the material was ready for identification.

3.4 Analysis of physical-chemical parameters of soil

Various edaphic factors were quantitatively analyzed by means of standard laboratory methods:

3.4.1 Soil Temperature

A soil thermostat (Gardman soil thermometer) was inserted into the soil of the testing plot at a depth of 15 cm to measure the soil temperature.

3.4.2 Soil Moisture

10g of soil was dried in a beaker over a burner for 15 minutes at 100 °C, chilled in the shadow, and weighed in a weighing scale to determine soil moisture content. The weight loss reflected the moisture content, which may be translated to a percentage using the following formula (Santhanam et al., 1989):

$\text{Moisture content (\%)} = \frac{I - F}{I} \times 100$ <p>Where, I = initial weight of sample (g)</p> <p>F = final weight of sample (g)</p>
--

3.4.3 Soil pH

According to Misra (1968), the pH is determined using a dilute suspension of soil with a water in a 1:5 ratio. 50 ml of distillation water was added to 25 g of air - dried and powdered soil in a beaker. An electromagnetic stirrer is used to thoroughly stir the mixture for 60 minutes. By inserting the electrode of a digital pH meter in a newly stirred suspension, the pH was measured.

3.4.4 Soil EC (Corwin & Lesch, 2005)

A 50 gram soil sample was mixed with 100 ml of tap water and swirled for 20 minutes with a glass rod until a paste formed (slurry method). Now, with the help of a funnel and filter, paper paste is filtered in a conical flask. Now filtered water is shifted in the silica crucible, and the electrode is calibrated at 0.00. Three concordant readings were taken, and finally the mean was taken as the final result. Also, can be calculated as:

$EC = pH \times 10$

3.4.5 SOC Content (Walkey & Black, 1934)

The Walkey Black Wet Oxidation Method (1934) was used to calculate the OC content of soil sample. 1 gram of dry and finely powdered dirt was placed in a 500 ml conical flask for this approach. 10 ml of standard $K_2Cr_2O_7$ solution and 20 ml of concentrated sulfuric acid were added and gently swirled together. The flask was left to stand in the dark for 30 minutes. The mixture was then mixed with 200 mL of distilled water, 10 mL of orthophosphoric acid, and 1 mL of diphenylamine (an indicator). Titrated against a standard ferrous ammonium sulphate solution, 0.5 mL at a time, until the colour changed to green. The precise end point could not be determined because this occurred with little or no warming. Another 1 ml of normal $K_2Cr_2O_7$ solution was added to determine the exact end point, and the titration was completed by adding ammonium ferrous sulphate solution dropwise until the last trace of violet colour gone. For control, a similar blank titration was performed without soil.

3.4.6 SOM Content (Walkey & Black, 1934)

To calculate the percentage of OM in soil, the OC content was estimated first following the rapid titration method of the Walkley Black Wet Oxidation Method (1934). The result thus obtained was multiplied by a factor of 1.724 (the Von Bemmelen factor). So,

$$\% \text{ of OM} = \% \text{ of OC} \times 1.724$$

3.4.7 Soil Available N (Jackson, 1962)

The Jackson (1962) method was used to calculate N. In this experiment, 0.1 g of soil was placed in the digestion tube, and 1 ml of concentrated H_2SO_4 was added. It was stored overnight before being digested for 30 minutes at $300^\circ C$. Following digestion, 1 ml of H_2O_2 was added to increase the material's clarity. Then, to the extract, add 11 mL of purified water. This extract was used to determine total N. The Kjeldahl apparatus method was used to determine the total N content of a soil sample. In a

Kjeldahl flask, 5 mL of extract was placed on the distillation unit. After adding 10 mL of NaOH, attach the extract flask to the distillation unit. A 100 ml flask was filled with 5 ml of boric acid and a few drops of indicator (methylene red). The conical flask was removed when the distillate reached a volume of 40ml to 50ml. The conical flask's contents were then treated with 0.01N standard H₂SO₄ until the pink end point was reached.

3.4.8 Soil Available P (Murphy & Riley, 1962)

The Murphy & Riley (1962) approach (adding a mixed reagent including antimony K tartrate, ammonium molybdate, sulfuric acid and ascorbic acid, to a neutral) was also used to evaluate solution P.

3.4.9 Soil Available K (TNAU-2016)

The soil was shaken with Morgan's reagent, which contained sodium acetate and acetic acid, to extract available potash. The extract treated with sodium cobalt nitrite and alcohol results in turbidity, the colour of which corresponds to the concentration of potash. First, we place 5 g of soil in a test tube and add 10 cc of Morgan's reagent to it. We will now dilute 2 mL of filtrate to 10 mL. In a suitable Nessler's cylinder, combine 2 mL alcohol, 6 drops sodium cobalt-nitrite solution, and 2 mL diluted extract (1:5) and shake. Compare the turbidity created by the same treatment of a typical potassium chloride solution. Cooling kept the temperature below 20°C throughout the trial (TNAU - 2016).

3.4.10 Soil Metal Analysis

The soil was analyzed for Fe, Zn, Mn, and Cu heavy metals via a sky-ray instrument, the AAS6000 (Atomic Absorption Spectrometer).

3.5 Identification of soil microarthropods

The soil sample extracted microarthropods were preserved in ethyl alcohol with a concentration of 70%. Most soil microarthropods were recognized up to the order

level using an array of taxonomic keys. To detect soil microarthropods, an optical stereomicroscope (OLYMPUS, CX - 21) was utilized in binocular form. Most soil microarthropods have been identified at 40X magnification. Final identification up to the level of genera and species has been done by Zoological Survey of India scientists. For collembolans, specimens were sent to Scientist Mandal. For acarina, specimens were sent to Scientist Shelley Acharya. For spiders, send them to Scientist Souvik Sen. For diptera as well as thysanuran, specimens were sent to Dr. Meenakshi Bharti from Punjab University. A list of microarthropods has been prepared on the basis of their report, which is far from complete. The generic and specific status of some of the groups, such as Collembola, Acarina, Araneae, Diptera, and Thysanura, has remained undetermined.

3.6 Diversity Indices

Species temporal diversity (popularly known as the Shannon Weiner Diversity Index), Simpson's Index of Dominance, and species richness, (Krebs, 1989) were employed to quantify species diversity.

3.6.1 Species Relative Abundance (Williams, 1964)

Species Relative Abundance tells as how common or rare a species is in comparison to other species in a given location or population.

The following formula will be used to compute relative abundance: $n_i / N \times 100$

Where n_i represents the number of soil arthropods of a specific species and N represents the total number of soil arthropods recorded.

3.6.2 Relative Frequency (Phillips, 1959)

The following formula should be used to evaluate the relative frequency of species:

$$RF\% = \text{species frequency } A \times 100$$

3.6.3 Species Diversity Index (Krebs, 1985)

Species Diversity Index considers both the number of species present and their dominance or evenness in respect to one another.

Shannon-Wiener Index computed species diversity:

$$H' = -\sum_{i=1}^S P_i \log_2 P_i,$$

where $P_i = n_i/N$.

H' = species diversity index.

n_i = total number of 'i' species individuals in the sample

N = total number of individuals in the sample from all species.

S = total number of species.

3.6.4 Species Dominance Index (Simpson, 1949)

Simpson (1949) calculated the index of dominance using the formula:

$$C = \sum_{i=1}^S (n_i/N)^2$$

Where C = the Index of Dominance.

n_i = total number of 'i' species individuals in the sample

N = total number of individuals in the sample from all species.

S = total number of species.

3.6.5 Species Richness Index (Margalef, 1968)

The number of species detected in a sample is measured by species richness. The following formula was used to calculate the index of species richness proposed by Margalef (1968):

$$D = S - 1 \log N$$

Where D = the indicator of species variety.

S = total number of species.

N = total number of people

3.6.6 Species Evenness Index (Pielou, 1966)

Pielou (1966) created the following formula to calculate the index of evenness:

$$E = H' \log_2 S.$$

Where E = the index of evenness.

H' = the Shannon-Wiener index.

S = the total number of species.

3.7 Statistical Analysis

Data from physicochemical analyzes of soil and extracted soil arthropods were statistically analyzed independently for each site to determine correlation and regression coefficients, among other things. The mean abundance and relative abundance were used to conduct community analysis at the sample unit level.

The data of soil variables and arthropod population densities of soil for each site were analyzed using linear correlation and ANOVA (one-way analysis) (Mandal & Suman, 2014).



(a) Soil sample drying



(b) Soil sample packing with labels

Figure 3.3: Methodology section



(c) Temperature measurement at fields



(d) Berlese – Tullgren funnel set up

Figure 3.3: Methodology section



(e) Collection of arthropods sample wise



(f) Apparatus for soil physicochemical analysis

Figure 3.3: Methodology section

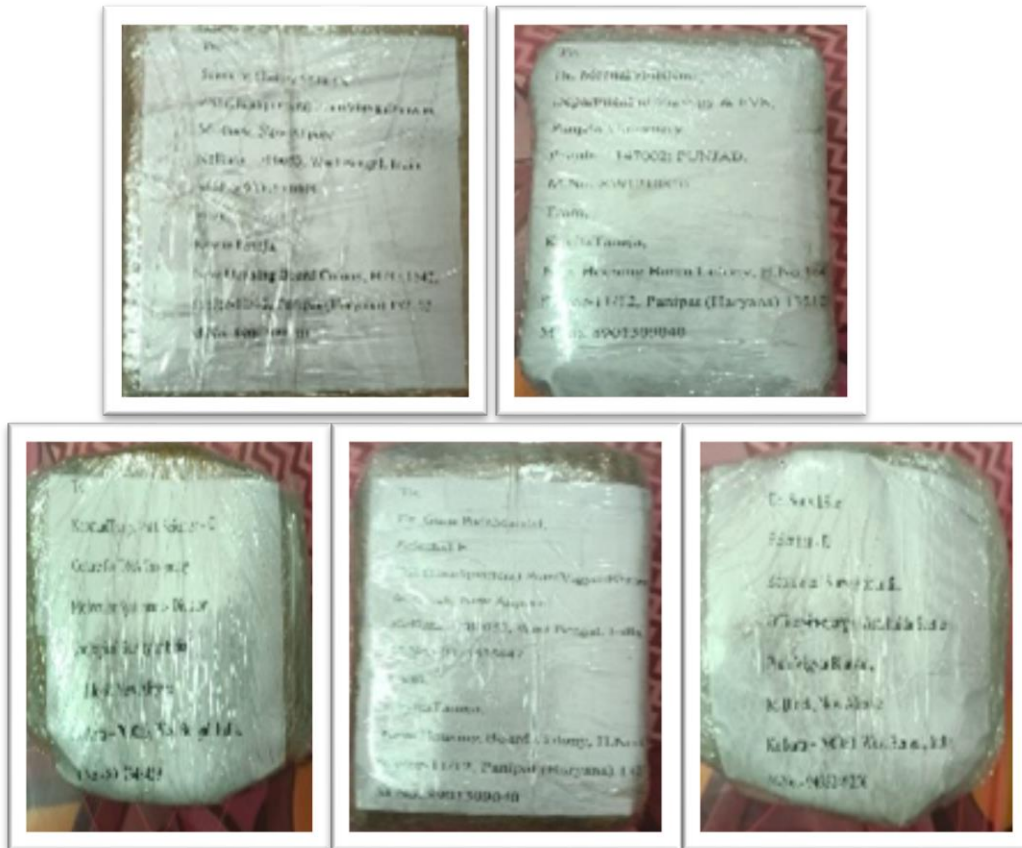


(g) Apparatus for metal analysis



(h) Screened vials ready for identification

Figure 3.3: Methodology section



(f) Couriers ready to dispatch

Figure 3.3: Methodology section

RESULTS AND DISCUSSION

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Seasonal fluctuation of edaphic factors

During the study period (November 2020 - October 2022), the seasonal fluctuation of edaphic factors exhibited a more or less similar pattern (Figure 4.1 - 4.9 ; Table A.1 - A.18). June was the month with the highest recorded soil temperature and it attained the base line in the month of January during both years (Figure 4.1,c - 4.9,c ; Table A.1 - A.18). The soil in all the sampling fields was alluvial in nature. Soil moisture ranged 5.1 % - 20.3 % (Figures 4.1,a - 4.9,a ; Table A.1 - A.18), pH 6.2 - 8.2 (Figures 4.1,d - 4.9,d ; Table A.1 - A.18), EC 0.81 mS/m - 1.9 mS/m (Figures 4.1,e - 4.9,e ; Table A.1 - A.18), OC 0.1 % - 0.69 % (Figures 4.1,b - 4.9,b ; Table A.1 - A.18), OM 0.16 % - 1.11 % (Figures 4.1,b - 4.9,b ; Table A.1 - A.18), available N 103.45ppm - 577.00 ppm (Figures 4.1,f - 4.9,f ; Table A.1 - A.18), K 8.6 kg/ac - 155 kg/ac (Figures 4.1,g - 4.9,g), P 5.7 kg/ac - 90.01 kg/ac (Figures 4.1,g - 4.9,g ; Table A.1 - A.18), S 6.5ppm -133ppm (Figures 4.1,f - 4.9,f ; Table A.1 - A.18), Zn 0.65ppm - 2.3ppm (Figures 4.1,h - 4.9,h ; Table A.1 - A.18), Fe 0.75ppm - 6.9ppm (Figures 4.1,h - 4.9,h ; Table A.1 - A.18), Cu 0.12ppm - 0.98ppm (Figures 4.1,h - 4.9,h ; Table A.1 - A.18), Mn 2.002ppm - 5.4ppm (Figures 4.1,h - 4.9,h ; Table A.1 - A.18). When observed at the individual field cover of Sugarcane, Yamunanagar ranged in soil temperature 18°C - 41°C (Table A.1 ; Figure 4.2,c) in the preceding year (2020 - 21), while in the succeeding year (2021 - 22), it ranged 20°C - 45°C (Table A.2 ; Figure 4.2,c). Similarly, moisture 6.1% - 12.2% (Table A.1 ; Figure 4.2,a) in preceding year while in succeeding year 5.1% - 13.5% (Table A.2 ; Figure 4.2,a) ; OC 0.18% - 0.67% (preceding year) while 0.28% - 0.71% (succeeding year) (Table A.1 - A.2 ; Figure 4.2,b); OM 0.29% - 0.94% (p) and 0.39% - 0.78% (s) (Table A.1 - A.2 ; Figure 4.2,b); pH 6.5 - 7.9 (p) and 6.9 - 7.7 (s) (Table A.1 - A.2 ; Figure 4.2,d) ; EC 0.85 mS/m - 1.7 mS/m (p) and 0.85 mS/m - 1.41 mS/m (s) (Table A.1 - A.2 ; Figure 4.2,e); available N 255.1 ppm - 577.6 ppm (p) 255.1 ppm - 543.1 ppm (s) (Table A.1 - A.2 ; Figure 4.2,f); S 8.72 ppm - 123 ppm (p) and 33.03 ppm - 103 ppm (s) (Table A.1 - A.2 ; Figure 4.2,f) ; P 37.3 kg/ac - 70 kg/ac (p) and 11.02 kg/ac - 29.6 kg/ac (s) (Table A.1 - A.2 ; Figure 4.2,g) ; K 9.4 kg/ac - 34 kg/ac (p) and 9.4 kg/ac - 31 kg/ac (s) (Table A.1

- A.2 ; Figure 4.2,g); Zn 0.65 ppm - 1.4 ppm (p) and 0.75 ppm - 1.43 ppm (s) (Table A.1 - A.2 ; Figure 4.2,h); Fe 1.41 ppm - 3.3 ppm (p) and 1.01 ppm - 2.9 ppm (s) (Table A.1 - A.2 ; Figure 4.2,h); Cu 0.12 ppm - 0.75 ppm (p) and 0.22 ppm - 0.65 ppm (s) (Table A.1 - A.2 ; Figure 4.2,h); Mn 2.8 ppm - 4.1 ppm (p) and 3.09 ppm - 4.01 ppm (s) (Table A.1 - A.2 ; Figure 4.2,h). In the case of Sugarcane field, Karnal, soil temperature ranged 19 °C - 46 °C in the preceding year, while in the succeeding year it ranged 19 °C - 45 °C (Table A.3 - A.4 ; Figure 4.1,c). Similarly, moisture ranged 7.1% - 17.5% in the preceding year while in the succeeding year it ranged 9.7% - 18.1% (Table A.3 - A.4 ; Figure 4.1,a); OC ranged 0.18% - 0.67% (p) and 0.28% - 0.83% (s) (Table A.3 - A.4 ; Figure 4.1,b); OM ranged 0.29% - 0.94% (p) and 0.39% - 0.83% (s) (Table A.3 - A.4 ; Figure 4.1,b); pH ranged 6.6 - 7.8 (p) and 6.2 - 7.8 (s) (Table A.3 - A.4 ; Figure 4.1, d); EC 0.87 mS/m - 1.9 mS/m (p) and 0.81 mS/m - 1.31 mS/m (s) (Table A.3 - A.4 ; Figure 4.1,e); available N 155.1 ppm - 477.6 ppm (p) and 255.1 ppm - 448.3 ppm (s) (Table A.3 - A.4 ; Figure 4.1,f); S 6.5 ppm - 120 ppm (p) and 6.5 ppm - 90.9 ppm (s) (Table A.3 - A.4 ; Figure 4.1,f); P 10.1 kg/ac - 36.91 kg/ac (p) and 18.2 kg/ac - 38.12 kg/ac (s) (Table A.3 - A.4 ; Figure 4.1,g); K 8.6 kg/ac - 19.8 kg/ac (p) and 11.3 kg/ac - 29.8 kg/ac (s) (Table A.3 - A.4 ; Figure 4.1,g); Zn 0.85 ppm - 1.15 ppm (p) and 0.75 ppm - 1.27 ppm (s) (Table A.3 - A.4 ; Figure 4.1,h); Fe 0.95 ppm - 8.1 ppm (p) and 0.75 ppm - 6.9 ppm (s) (Table A.3 - A.4 ; Figure 4.1, h); Cu 0.21 ppm - 0.71 ppm (p) and 0.31 ppm - 0.74 ppm (s) (Table A.3 - A.4 ; Figure 4.1,h); Mn 2.1 ppm - 3.94 ppm (p) and 2.002 ppm - 4.08 ppm (s) (Table A.3 - A.4 ; Figure 4.1,h). In the case of Rice field, Karnal, the soil temperature ranged 31 °C - 45 °C in the preceding year, while in the succeeding year it ranged 31 °C - 45 °C (Table A.5 - A.6 ; Figure 4.3,c). Similarly, moisture 8.1 % - 15.2 % in preceding year while in succeeding year 7.1 % - 14.2 % (Table A.5 - A.6 ; Figure 4.3,a); OC 0.41 % - 0.53 % (p) and 0.32 % - 0.43 % (s) (Table A.5 - A.6 ; Figure 4.3,b); OM 0.71 % - 0.87 % (p) and 0.61 % - 0.77 % (s) (Table A.5 - A.6 ; Figure 4.3,c); pH 6.8 - 7.2 (p) and 6.7 - 7.1 (s) (Table A.5 - A.6 ; Figure 4.3,d); EC 1.1 mS/m - 1.3 mS/m (p) and 1.1 mS/m - 1.4 mS/m (s) (Table A.5 - A.6 ; Figure 4.3,e); available N 439.6 ppm - 543.1 ppm (p) and 309.6 ppm - 443.1 ppm (s) (Table A.5 - A.6 ; Figure 4.3,f); S 14 ppm - 20.39 ppm (p) and 15.44 ppm - 21.01 ppm (s) (Table A.5 - A.6 ; Figure 4.3,f); P 8.4 kg/ac - 13.71 kg/ac (p) and 7.4 kg/ac -

12.91 kg/ac (s) (Table A.5 - A.6 ; Figure 4.3,g); K 13.3 kg/ac - 24 kg/ac (p) and 14.3 kg/ac - 26 kg/ac (s) (Table A.5 - A.6 ; Figure 4.3,g); Zn 0.9 ppm - 1.12 ppm (p) and 0.89 ppm - 1.14 ppm (s) (Table A.5 - A.6 ; Figure 4.3,h); Fe 1.31 ppm - 2.03 ppm (p) and 1.41 ppm - 2.3 ppm (s) (Table A.5 - A.6 ; Figure 4.3,h); Cu 0.12 ppm - 0.52 ppm (p) and 0.15 ppm - 0.51 ppm (s) (Table A.5 - A.6 ; Figure 4.3,h); Mn 2.8 ppm - 3.9 ppm (p) and 2.89 ppm - 3.7 ppm (s) (Table A.5 - A.6 ; Figure 4.3,h). In the case of Rice field, Kaithal, the soil temperature ranged 32 °C - 41 °C in the preceding year while in the succeeding year it ranged 30 °C - 42 °C (Table A.7 - A.8; Figure 4.4,c). Similarly, moisture 10 % - 16.1 % in preceding year while in succeeding year 9.7 % - 18.1 % (Table A.7 - A.8 ; Figure 4.4,a); OC 0.43 % - 0.56 % (p) and 0.50 % - 0.59 % (s) (Table A.7 - A.8 ; Figure 4.4,b); OM 0.79 % - 0.98 % (p) and 0.82 % - 0.94 % (s) (Table A.7 - A.8 ; Figure 4.4,b); pH 7.5 - 8.1 (p) and 7.8 - 8.2 (s) (Table A.7 - A.8 ; Figure 4.4,d); EC 0.93 mS/m - 1.11 mS/m (p) and 0.92 mS/m - 1.16 mS/m (s) (Table A.7 - A.8 ; Figure 4.4,e); available N 332 ppm - 417.2 ppm (p) and 312 ppm - 403.1 ppm (s) (Table A.7 - A.8 ; Figure 4.4,f); S 12 ppm - 19.39 ppm (p) and 15 ppm - 20.39 ppm (s) (Table A.7 - A.8 ; Figure 4.4,f); P 10.4 kg/ac - 14.91 kg/ac (p) and 9.4 kg/ac - 13.91 kg/ac (s) (Table A.7 - A.8 ; Figure 4.4,g); K 14.73 kg/ac - 24 kg/ac (p) and 13.3 kg/ac - 26 kg/ac (s) (Table A.7 - A.8 ; Figure 4.4,g); Zn 0.89 ppm - 1.22 ppm (p) and 0.79 ppm - 1.25 ppm (s) (Table A.7 - A.8 ; Figure 4.4,h); Fe 1.41 ppm - 2.3 ppm (p) and 1.31 ppm - 2.03 ppm (s) (Table A.7 - A.8 ; Figure 4.4,h); Cu 0.12 ppm - 0.31 ppm (p) and 0.20 ppm - 0.32 ppm (s) (Table A.7 - A.8 ; Figure 4.4,h); Mn 2.7 ppm - 3.21 ppm (p) and 2.75 ppm - 3.52 ppm (s) (Table A.7 - A.8 ; Figure 4.4,a). In the case of Wheat field, Sirsa, the soil temperature ranged 19°C - 28°C in the preceding year, while in the succeeding year it ranged 18°C - 34°C (Table A.9 - A.10 ; Figure 4.5,c). Similarly, moisture increased 12.9% - 20.3% in the preceding year, while in the succeeding year it increased 13.9% - 18.3% (Table A.9 - A.10 ; Figure 4.5,a); OC 0.26% - 0.44% (preceding year) while 0.34% - 0.54% (succeeding year) (Table A.9 - A.10 ; Figure 4.5,b); OM 0.50% - 0.65% (p) and 0.60% - 0.73% (s) (Table A.9 - A.10 ; Figure 4.5,b); pH 7.1 - 7.5 (p) and 6.8 - 7.1 (s) (Table A.9 - A.10 ; Figure 4.5,d); EC 0.9 mS/m - 1.2 mS/m (p) and 0.91mS/m - 1.26 mS/m (s) (Table A.9 - A.10 ; Figure 4.5,e); available N 206.9 ppm - 379.3 ppm (p) and 306.9 ppm - 479.3 ppm (s) (Table A.9 - A.10 ; Figure 4.5,f

); S 8.03 ppm - 16.3 ppm (p) and 9.15 ppm - 26.3 ppm (s) (Table A.9 - A.10 ; Figure 4.5,f); P 30.00 kg/ac - 66.00 kg/ac (p) and 40.00 kg/ac - 90.01 kg/ac (s) (Table A.9 - A.10 ; Figure 4.5,g); K 100 kg/ac - 141 kg/ac (p) and 90 kg/ac - 131 kg/ac (s) (Table A.9 - A.10 ; Figure 4.5,g); Zn 0.8 ppm - 1.35 ppm (p) and 0.75 ppm - 1.23 ppm (s) (Table A.9 - A.10 ; Figure 4.5,h); Fe 1.11 ppm - 2.6 ppm (p) and 1.4 ppm - 2.8 ppm (s) (Table A.9 - A.10 ; Figure 4.5,h); Cu 0.17 ppm - 0.80 ppm (p) and 0.37 ppm - 0.78 ppm (s) (Table A.9 - A.10 ; Figure 4.5,h); Mn 3.7 ppm - 4.5 ppm (p) and 3.5 ppm - 4.15 ppm (s) (Table A.9 - A.10 ; Figure 4.5,h).

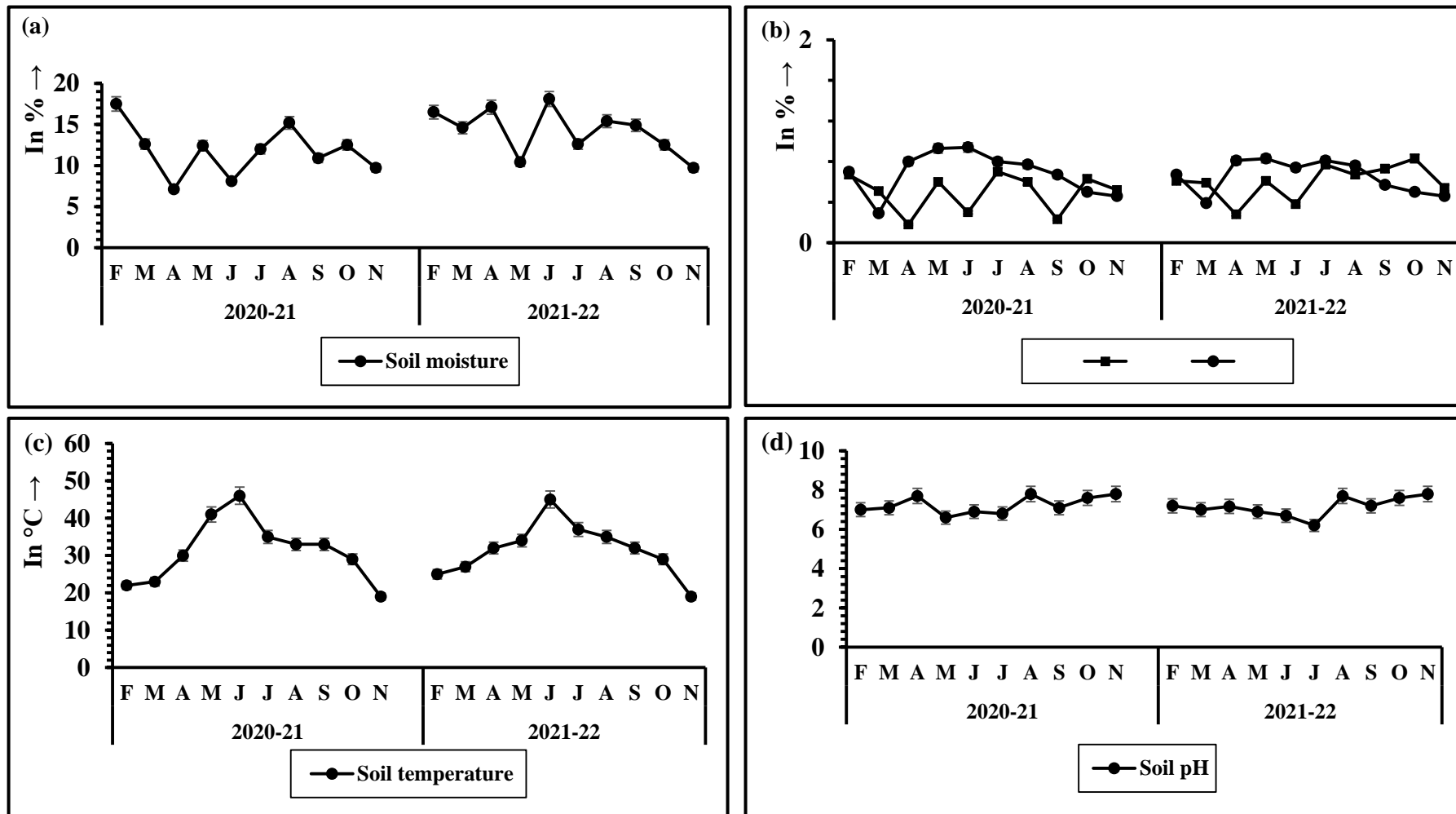


Figure 4.1: Seasonal variation of edaphic factors in Sugarcane field, Karnal

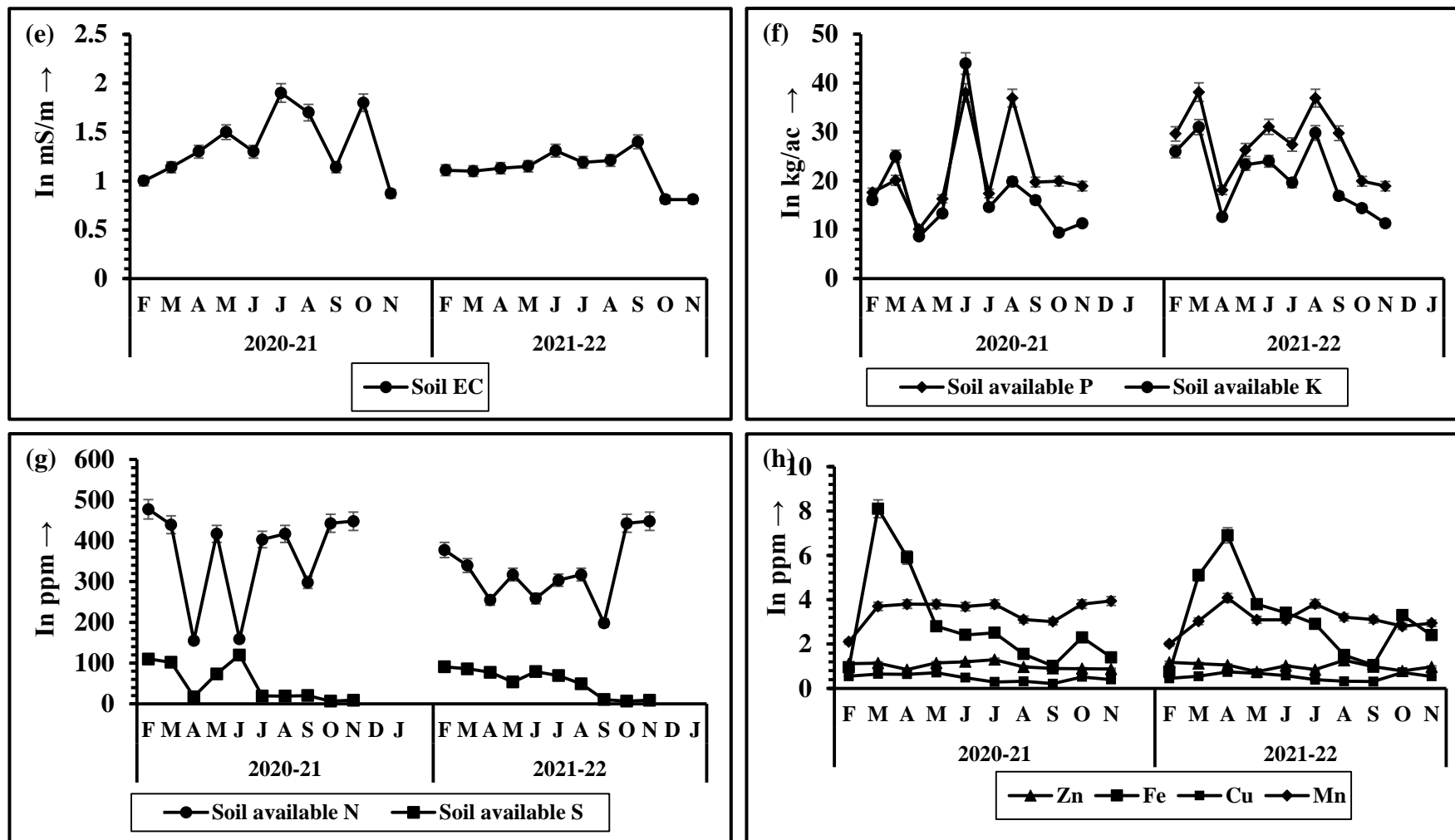


Figure 4.1: Seasonal variation of edaphic factors in Sugarcane field, Karnal

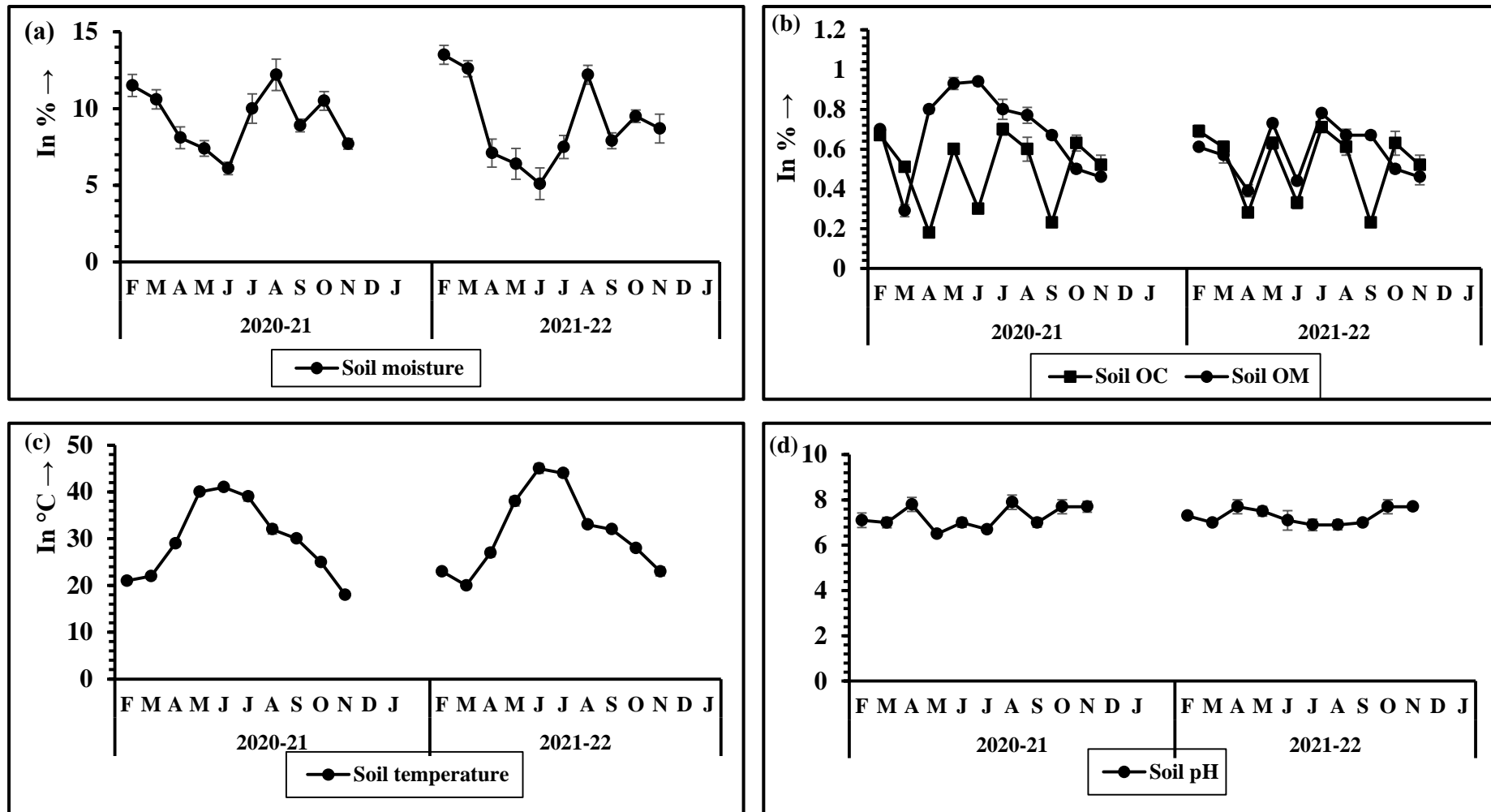


Figure 4.2: Seasonal variation of edaphic factors in Sugarcane field, Yamunanagar

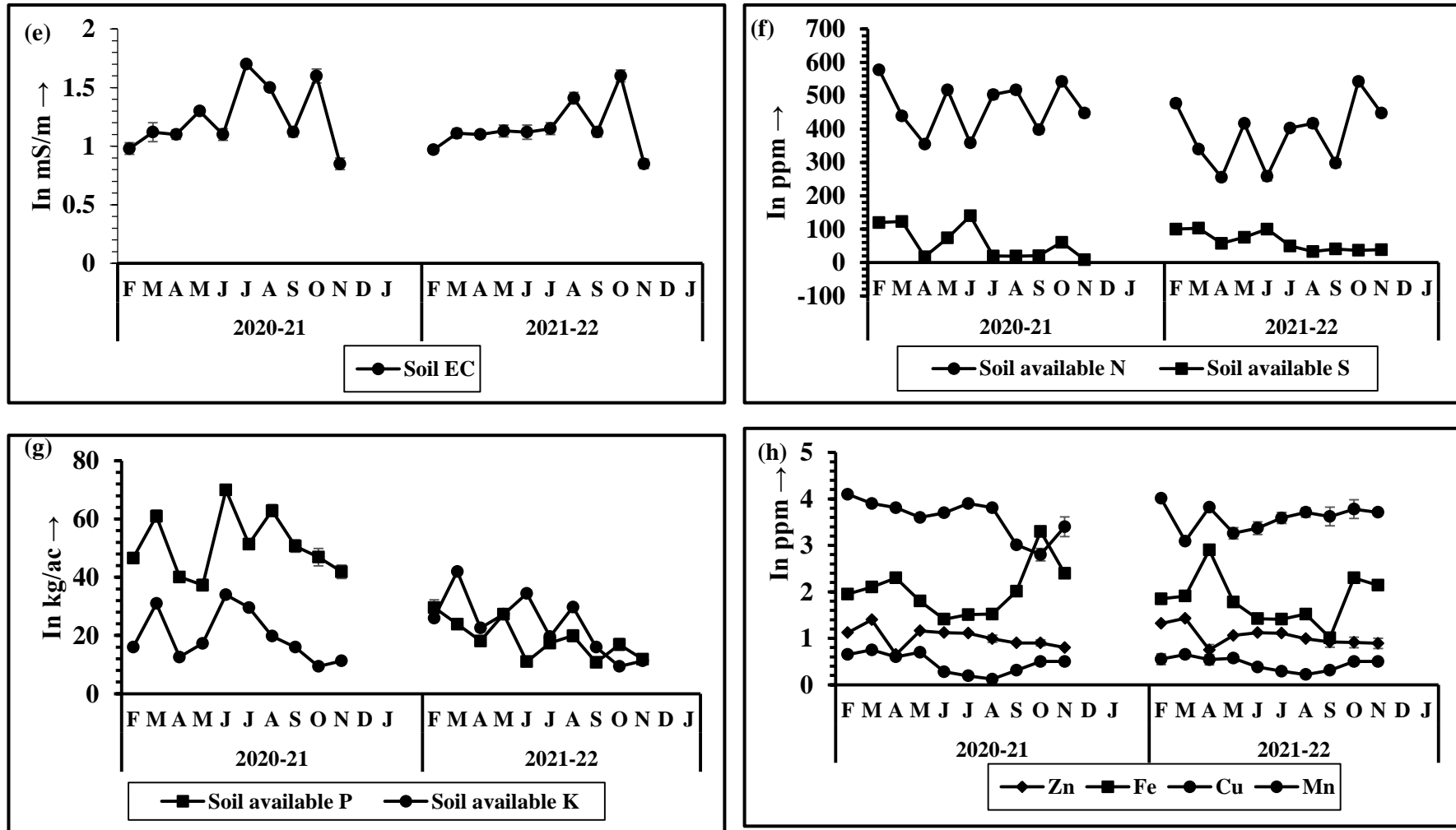


Figure 4.2: Seasonal variation of edaphic factors in Sugarcane field, Yamunanagar

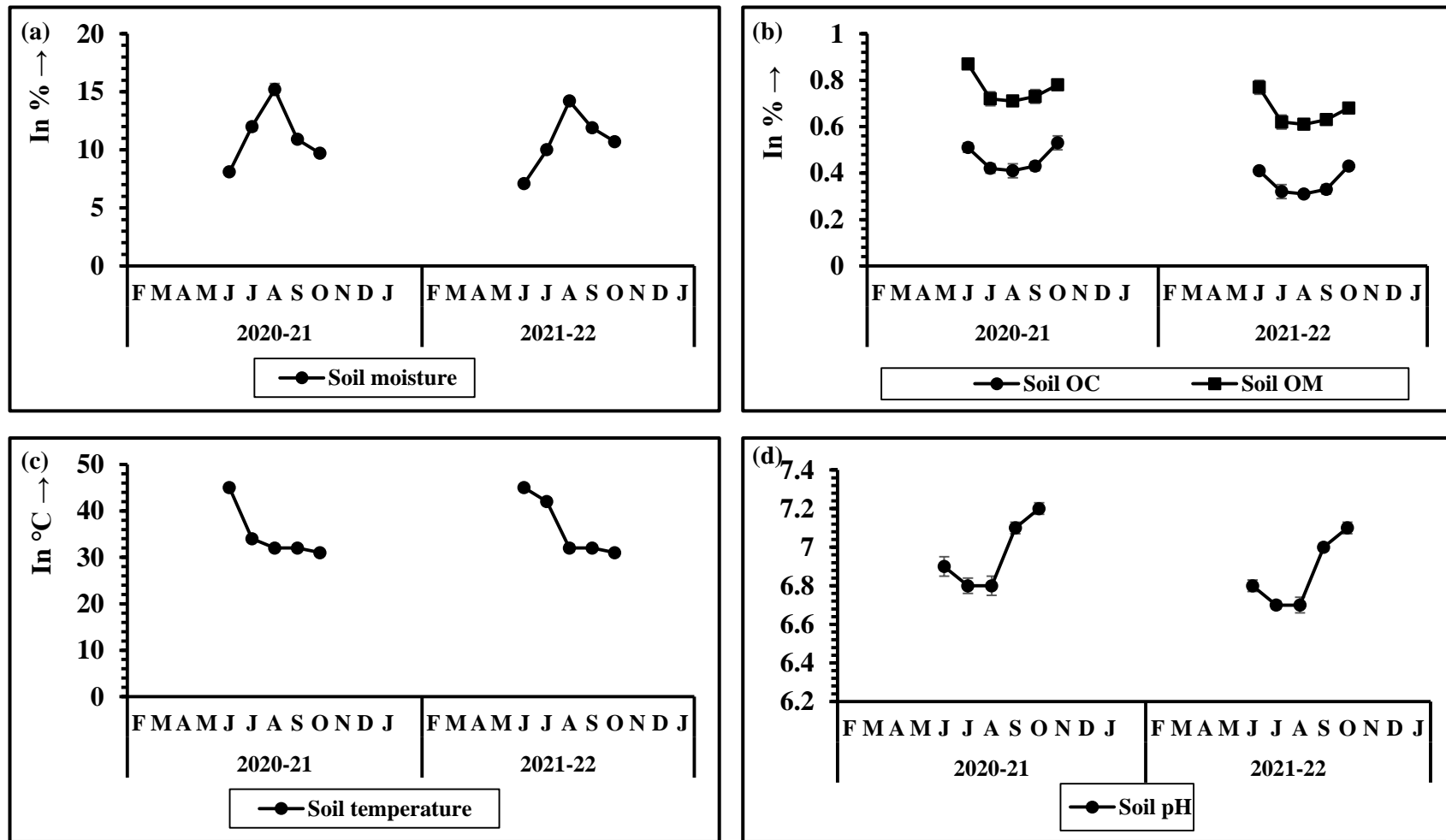


Figure 4.3: Seasonal variation of edaphic factors in Rice field , Karnal

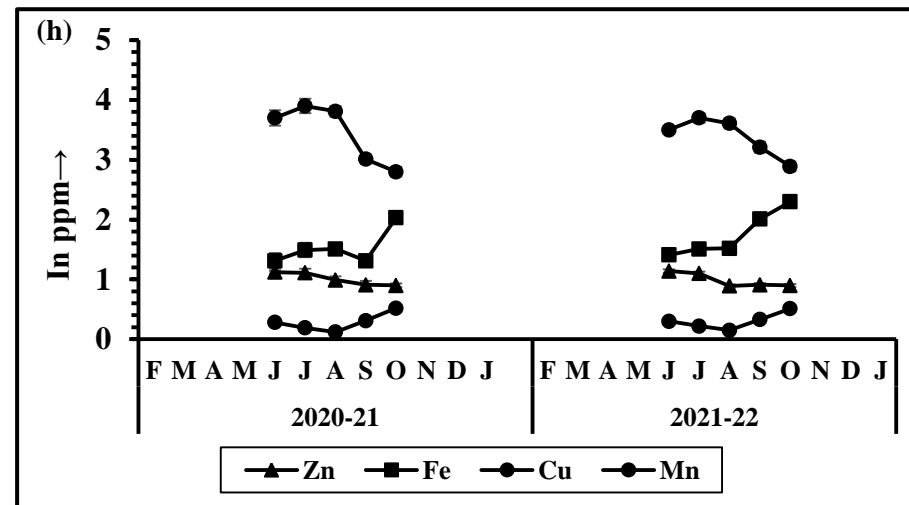
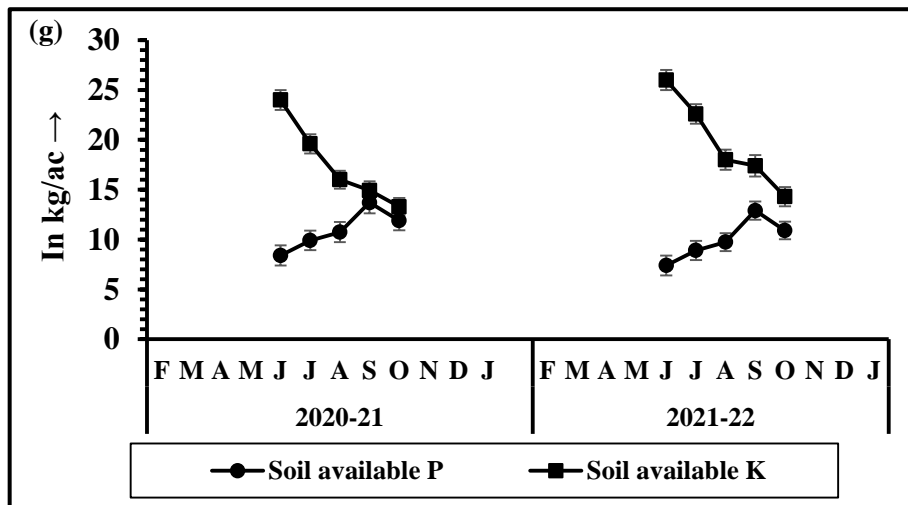
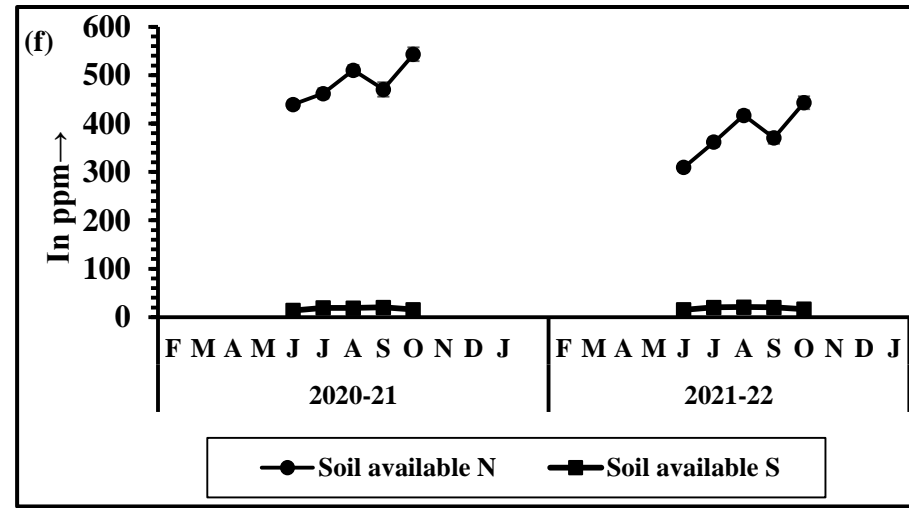
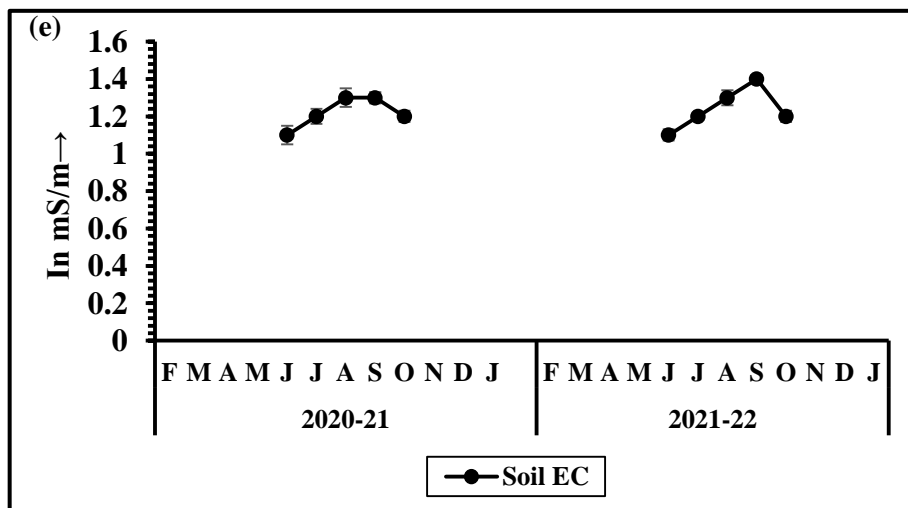


Figure 4.3: Seasonal variation of edaphic factors in Rice field, Karnal

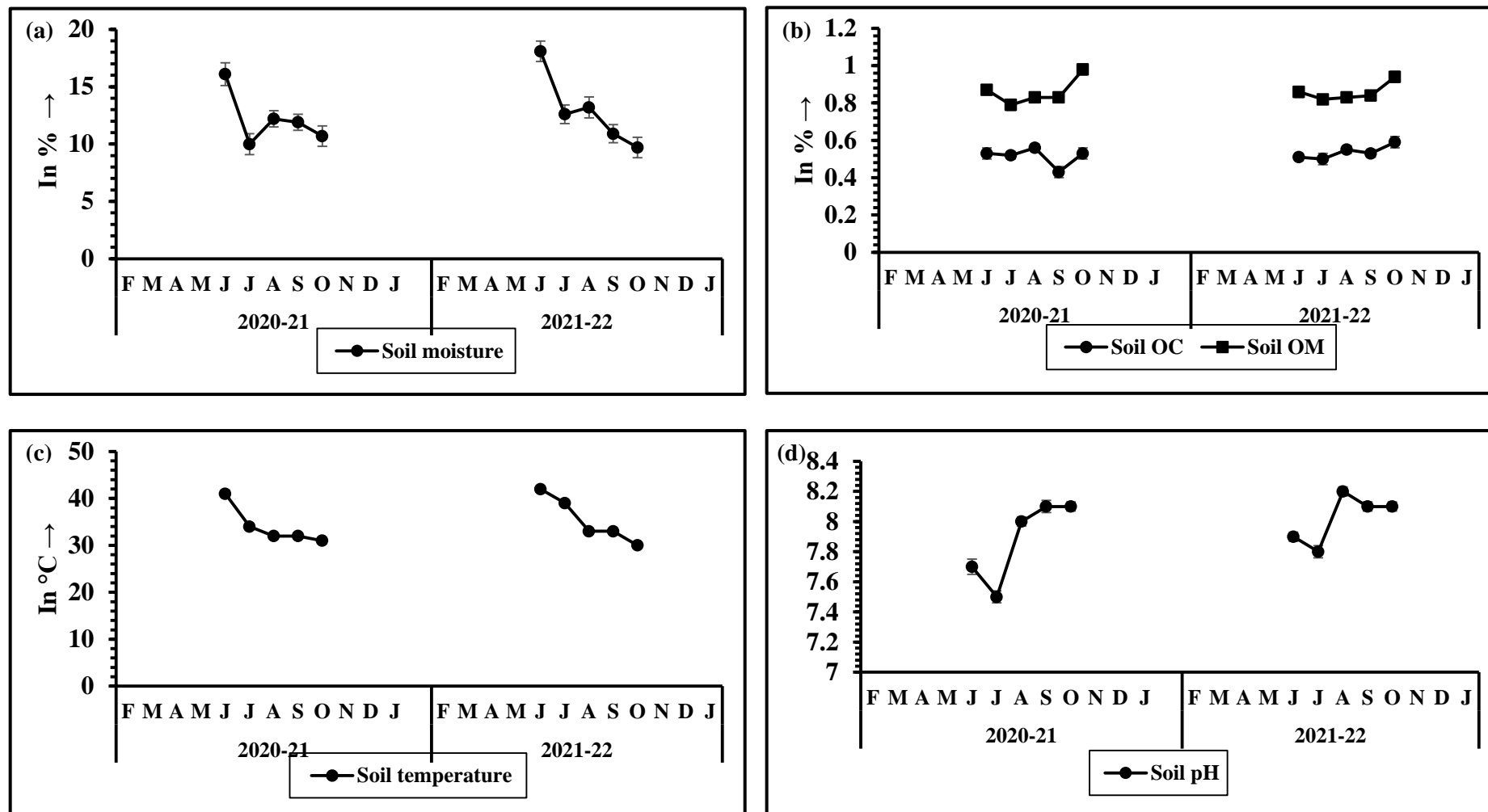


Figure 4.4: Seasonal variation of edaphic factors in Rice field, Kaithal

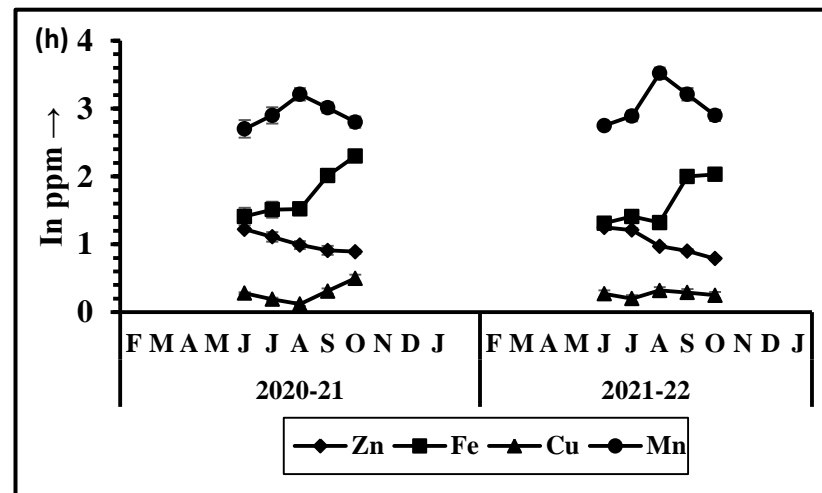
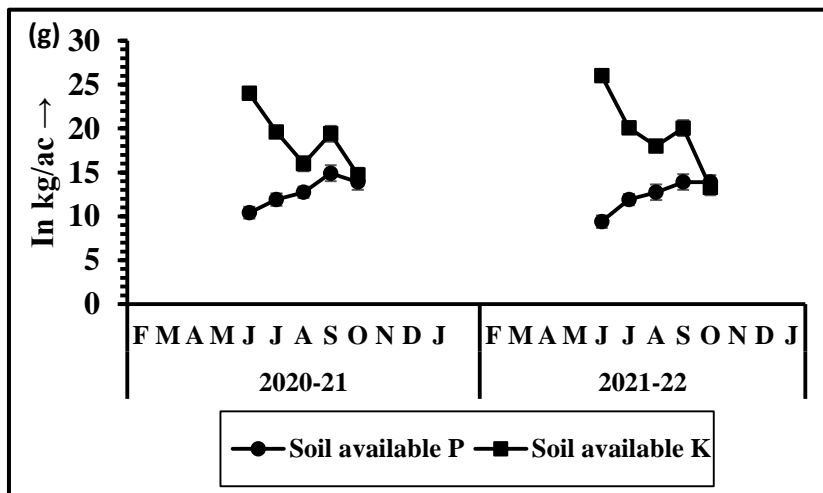
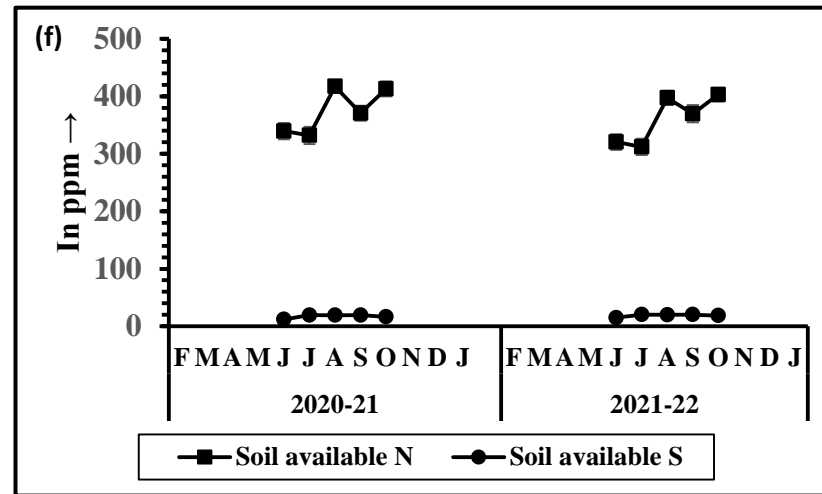
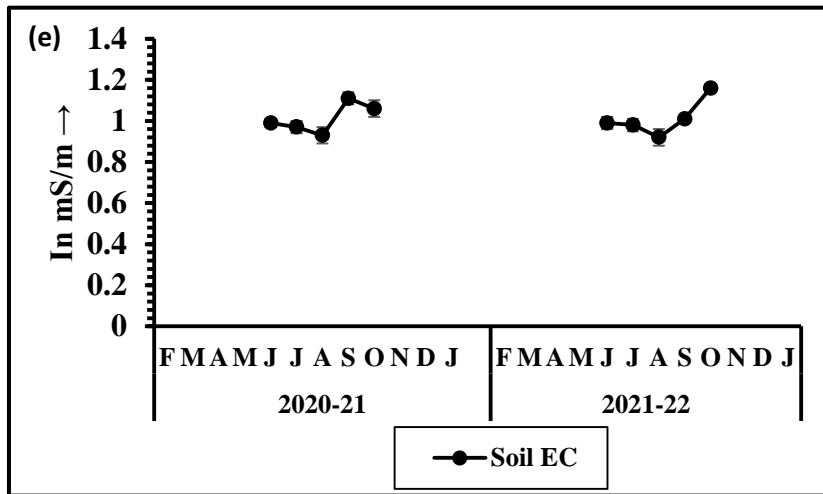


Figure 4.4: Seasonal variation of edaphic factors in Rice field, Kaithal

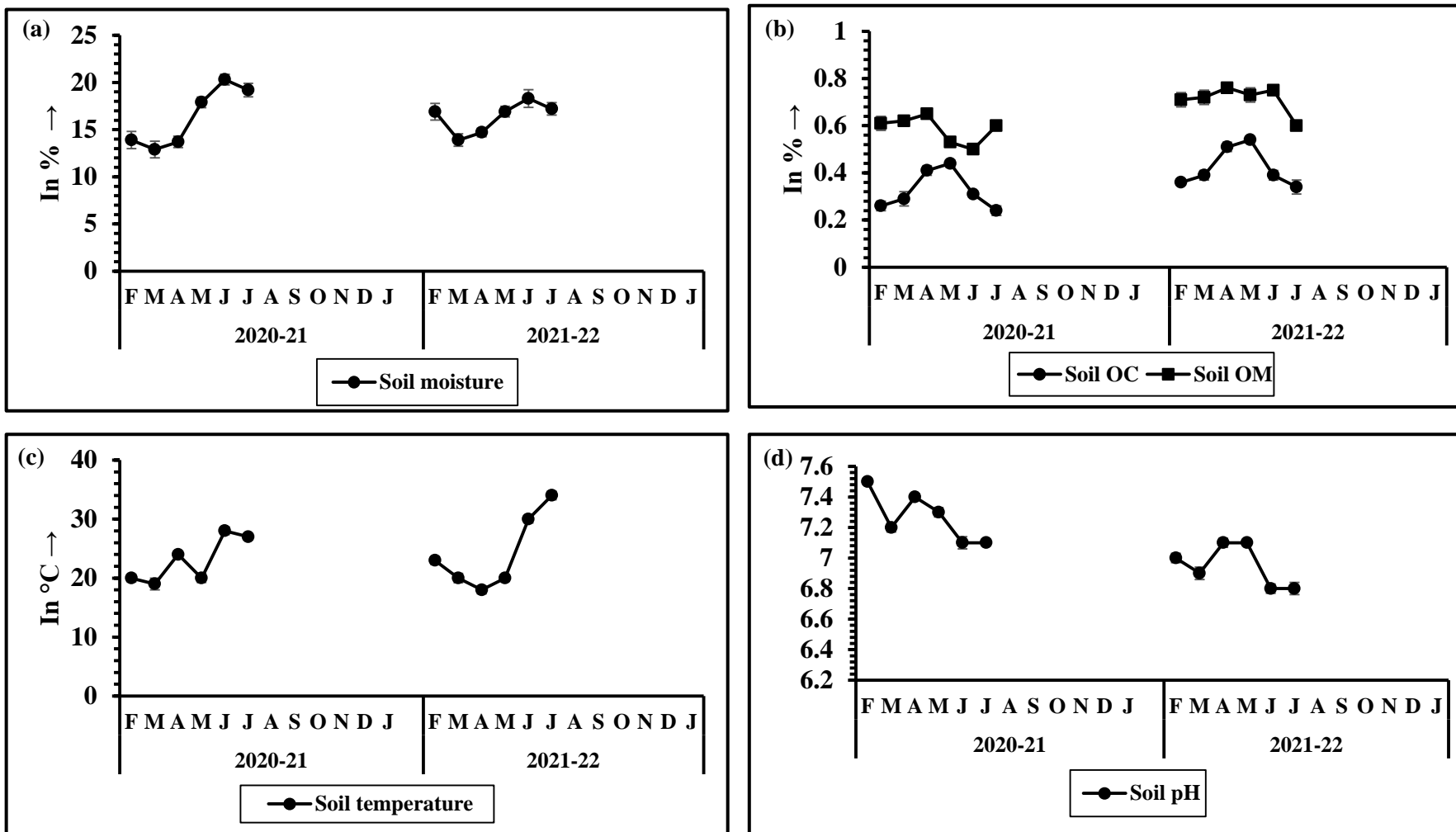


Figure 4.5: Seasonal variation of edaphic factors in Wheat field, Sirsa

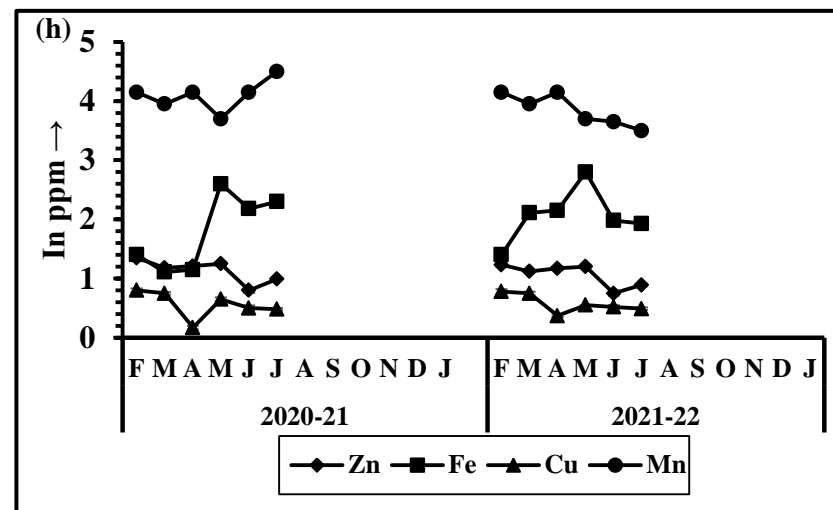
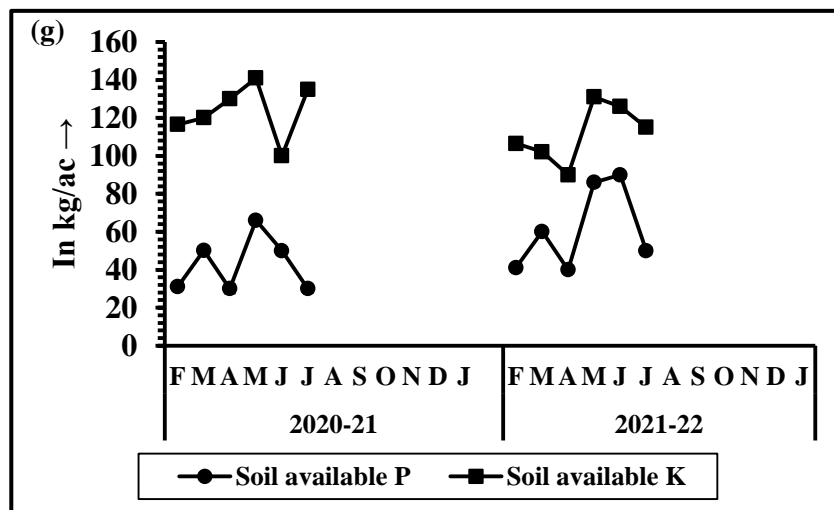
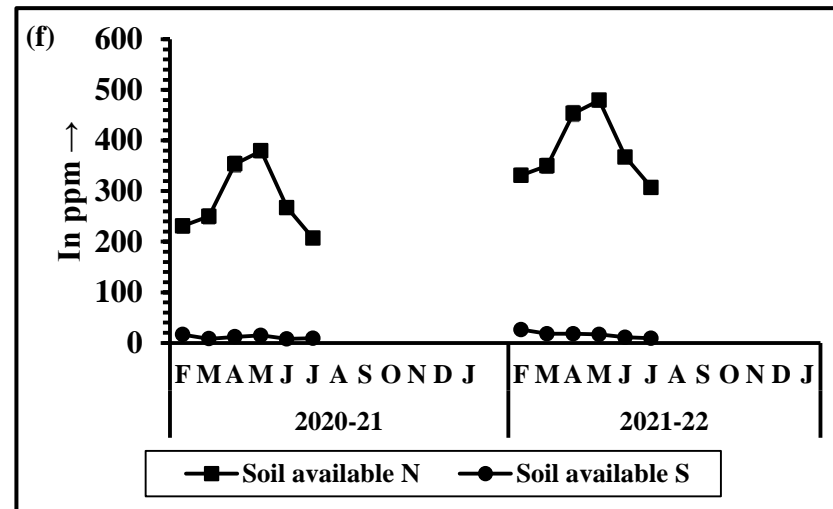
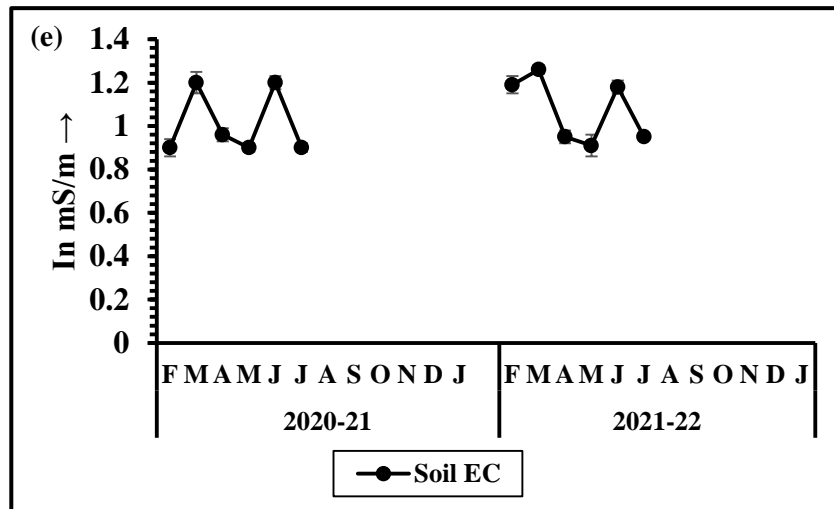


Figure 4.5: Seasonal variation of edaphic factors in Wheat field, Sirsa

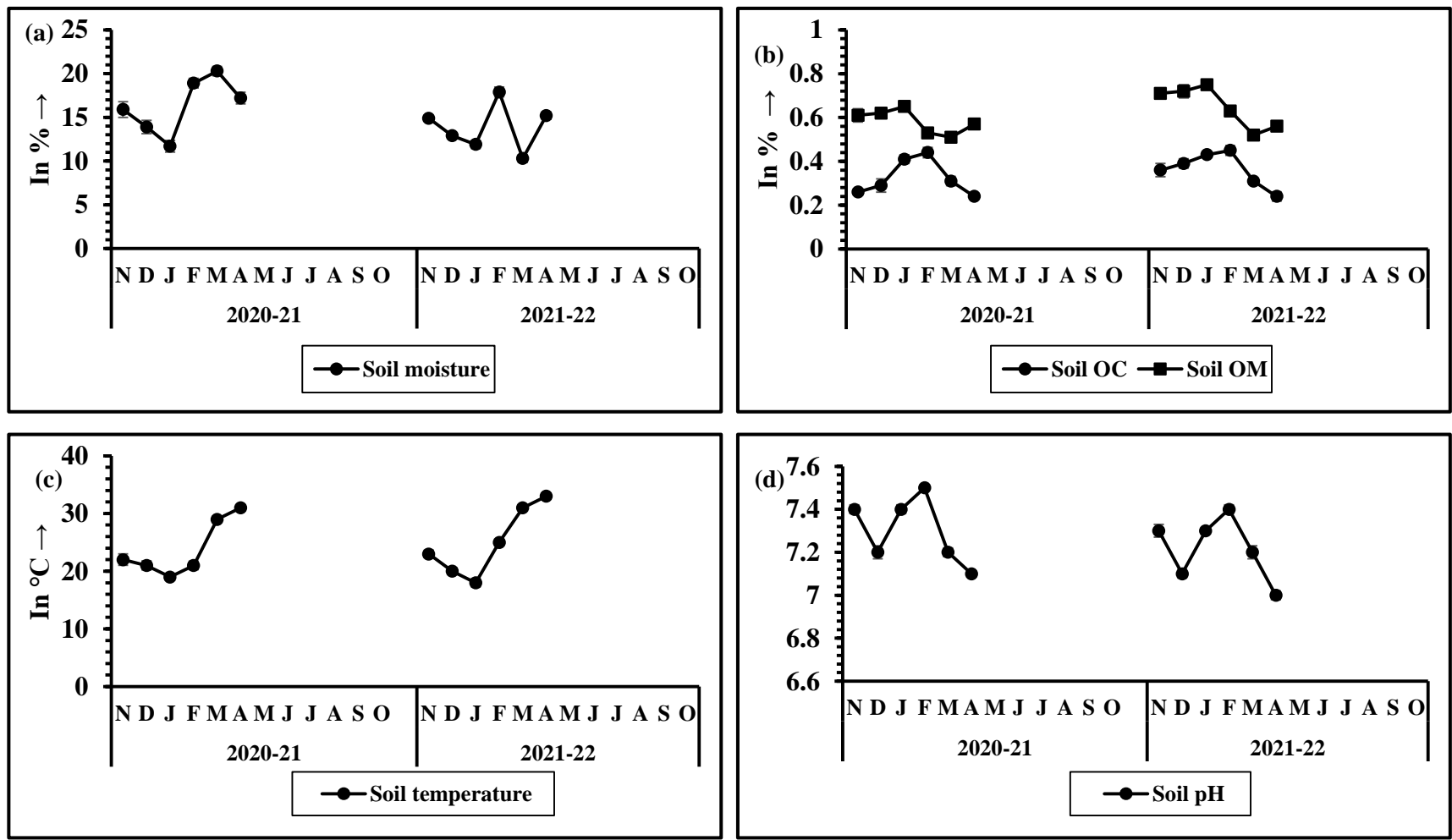


Figure 4.6: Seasonal variation of edaphic factors in Wheat field, Hisar

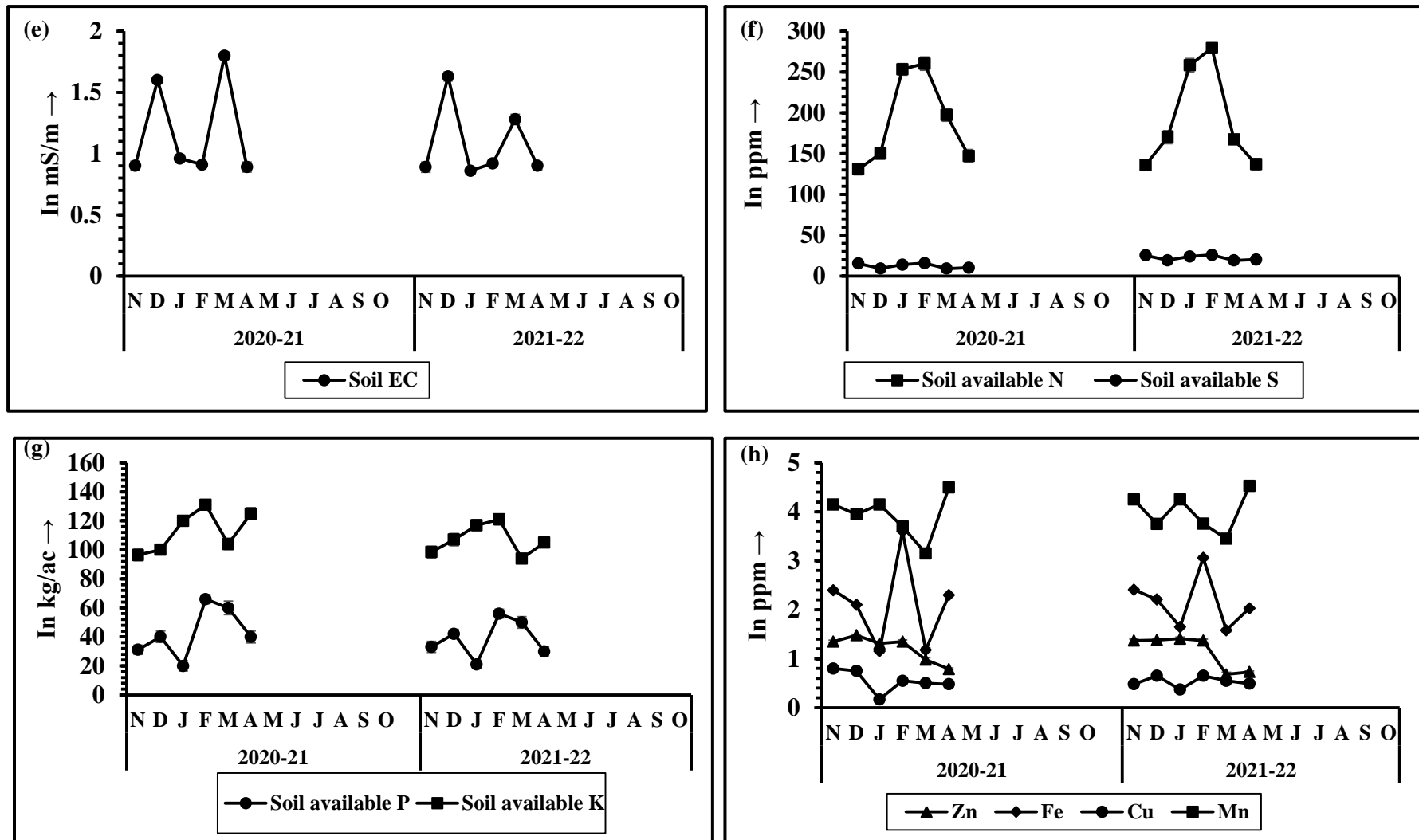


Figure 4.6: Seasonal variation of edaphic factors in Wheat field, Hisar

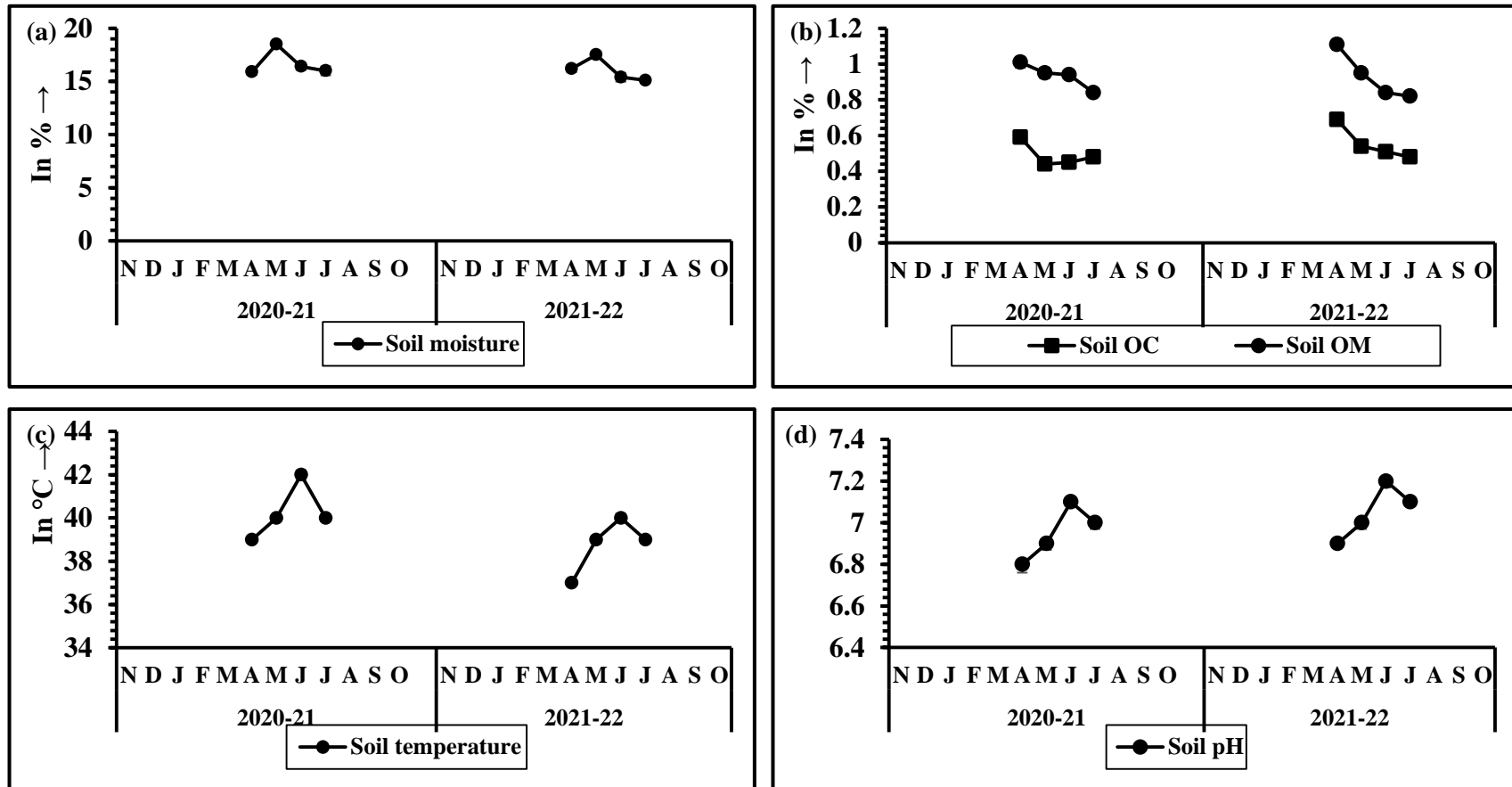


Figure 4.7: Seasonal variation of edaphic factors in Jowar field, Rohtak

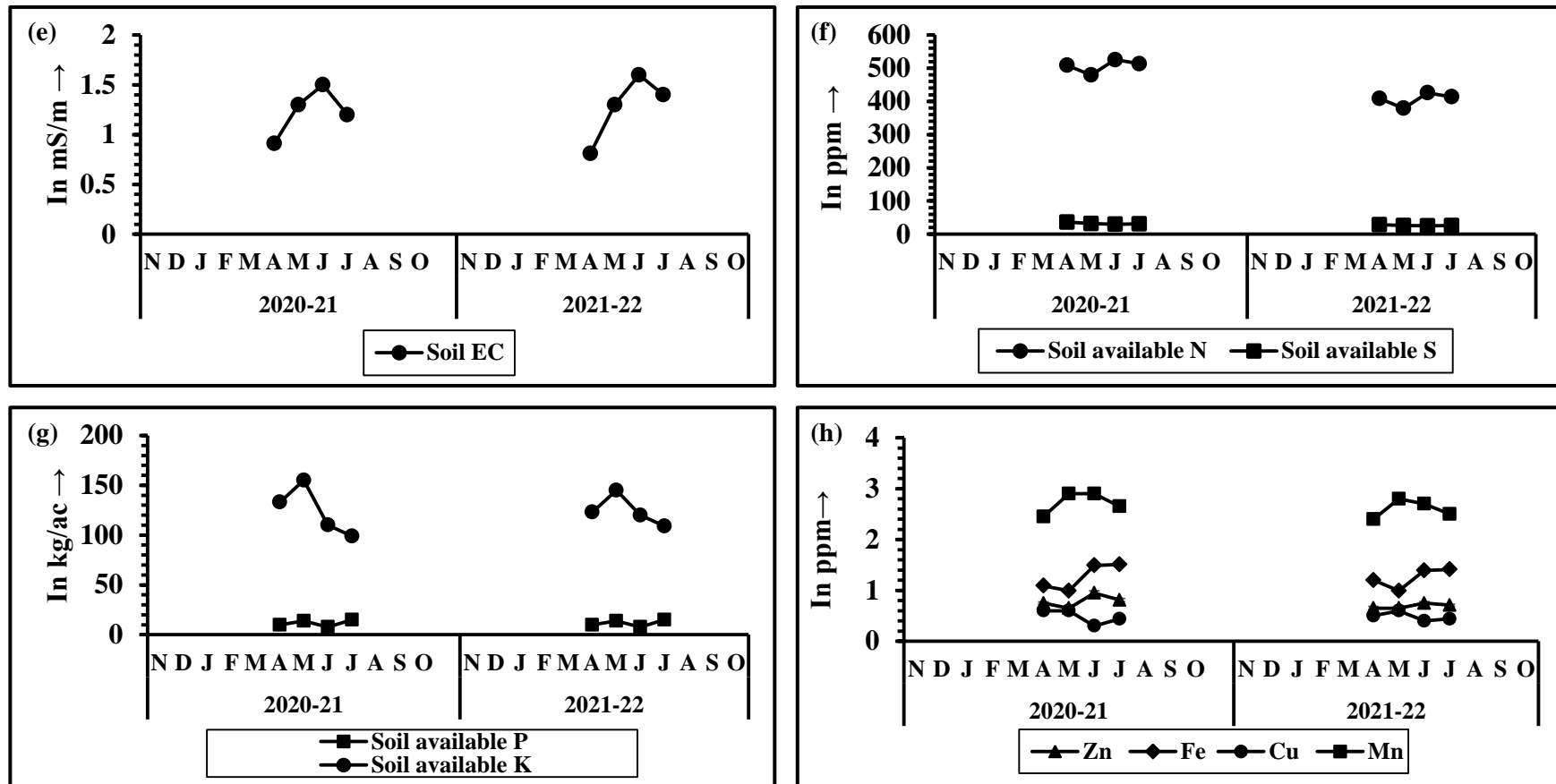


Figure 4.7: Seasonal variation of edaphic factors in Jowar field, Rohtak

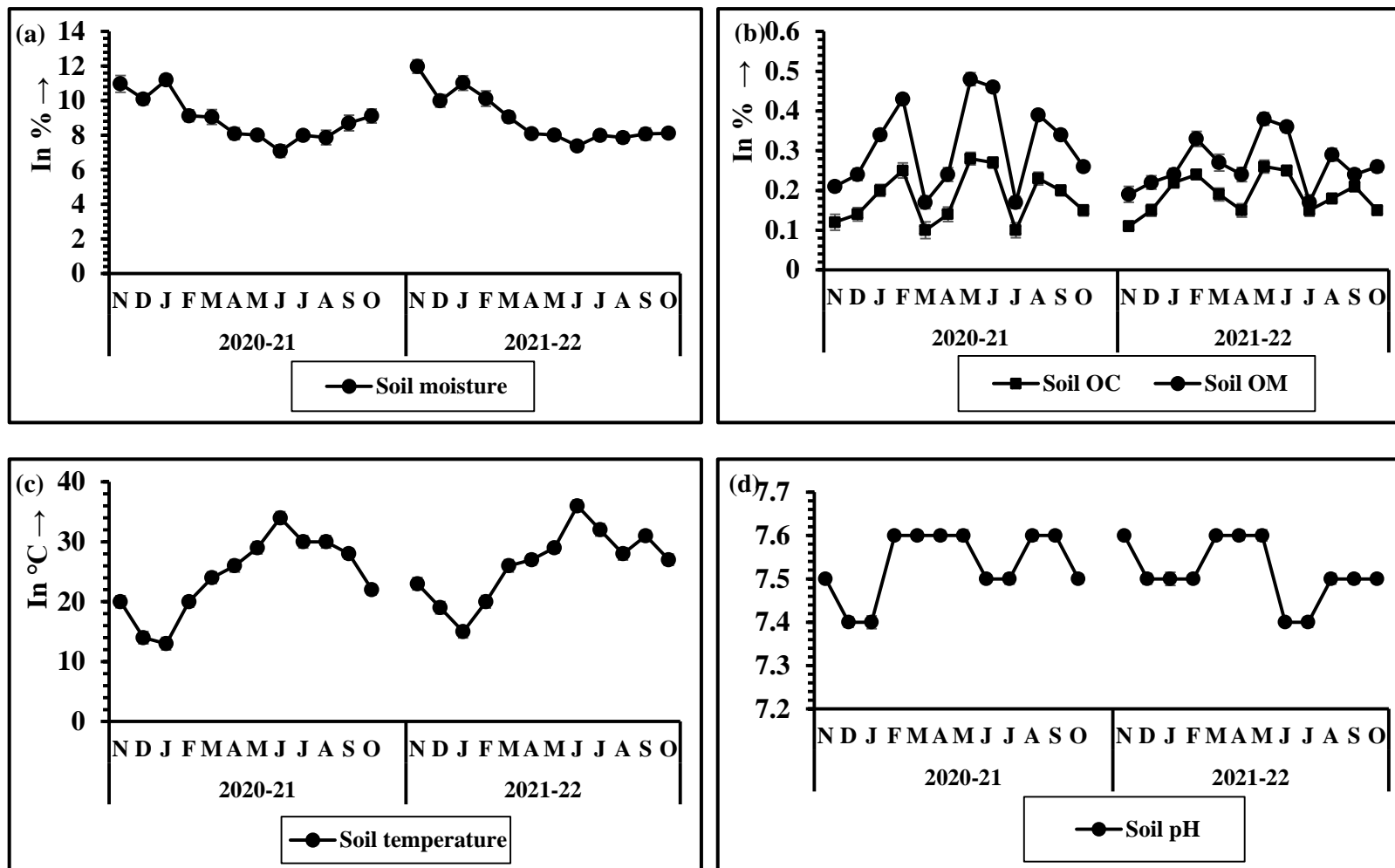


Figure 4.8: Seasonal variation of edaphic factors in Forest land, Panipat

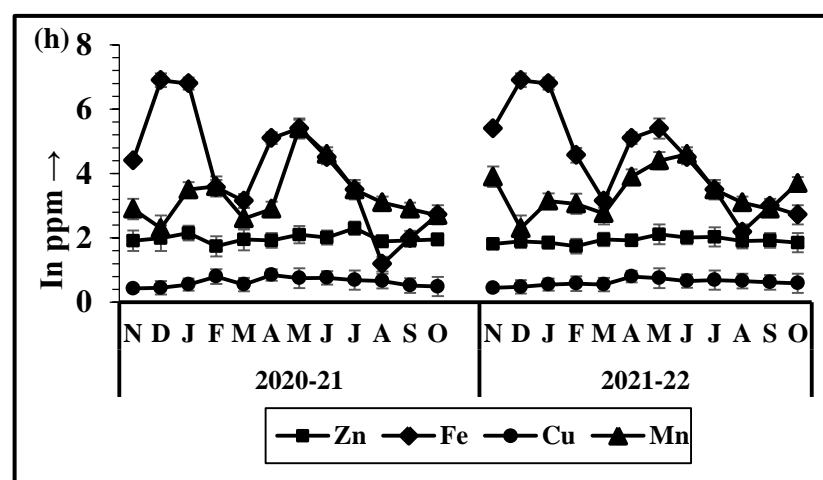
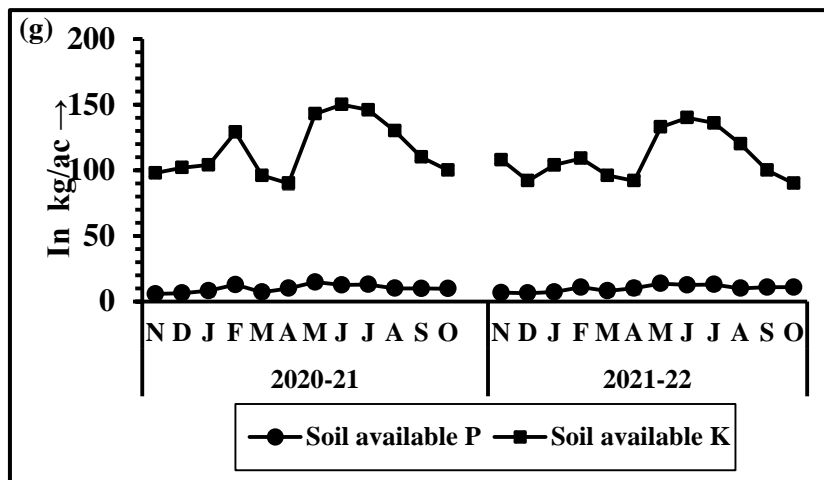
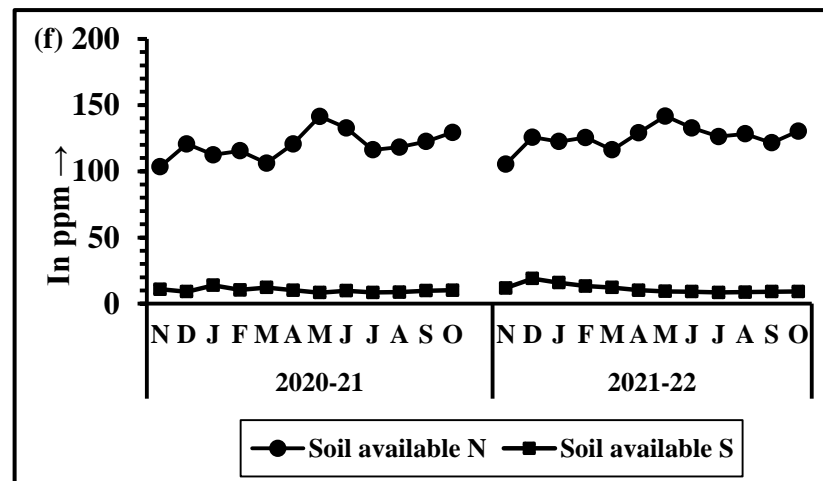
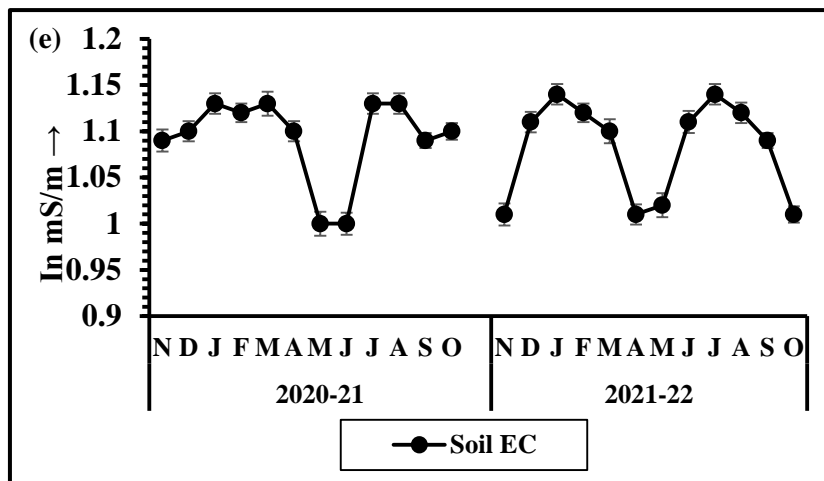


Figure 4.8: Seasonal variation of edaphic factors in Forest land, Panipat

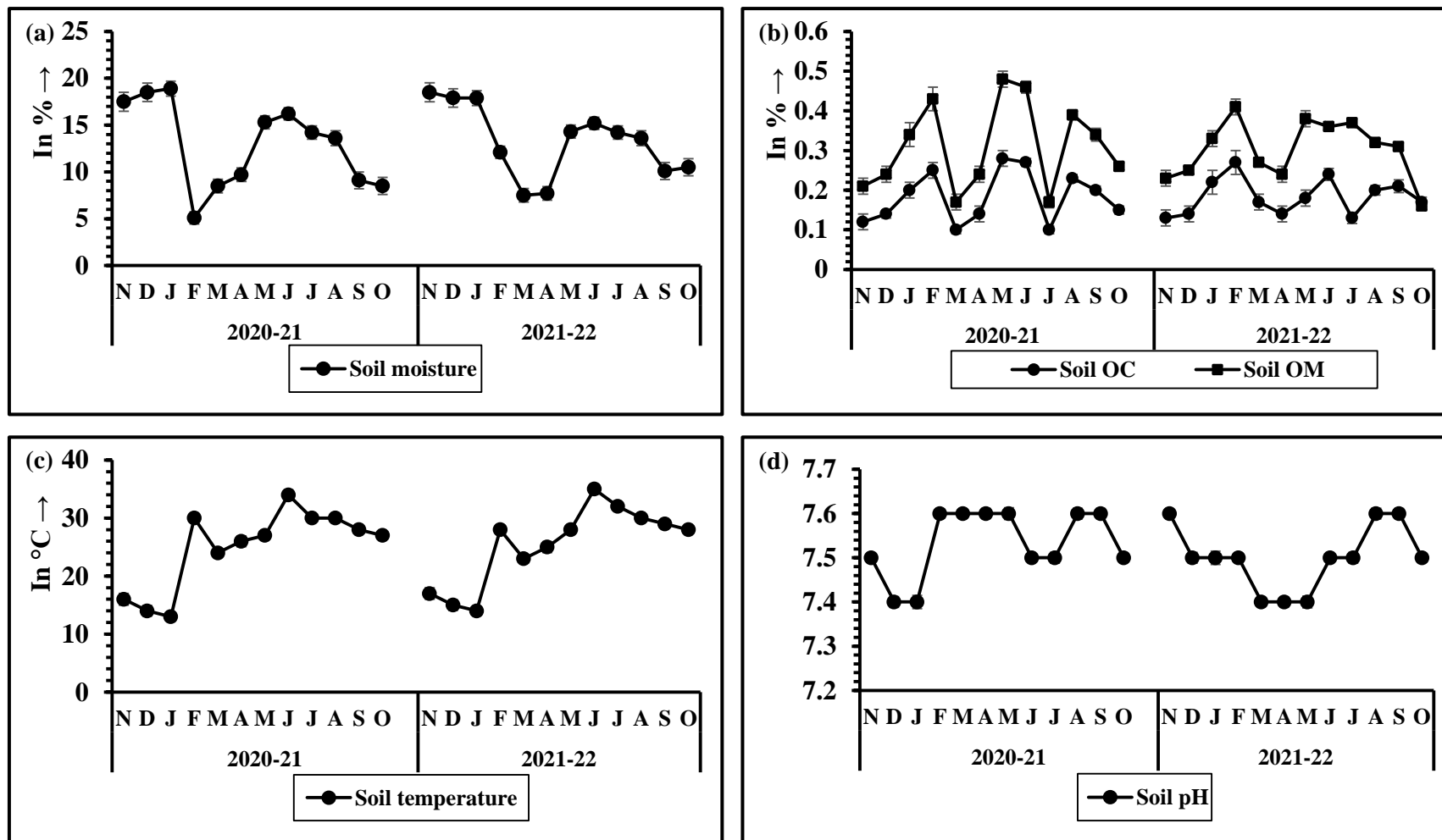


Figure 4.9: Seasonal variation of edaphic factors in Outskirts of Textile land, Panipat

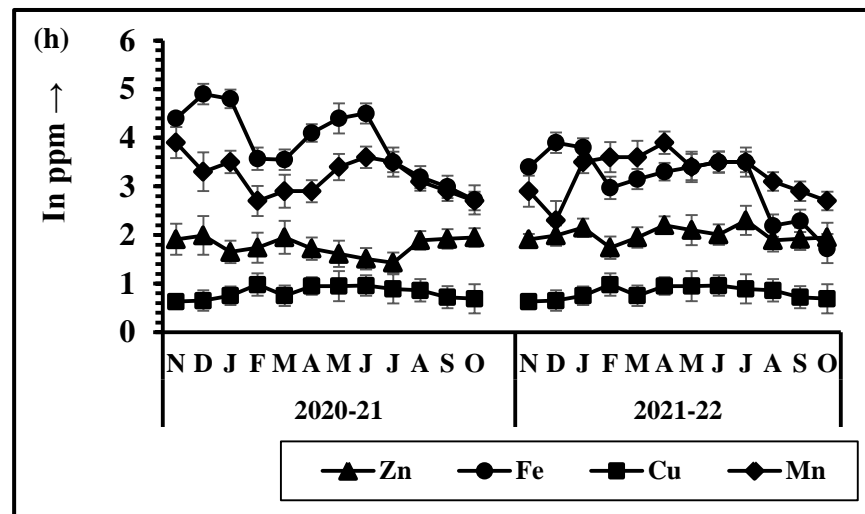
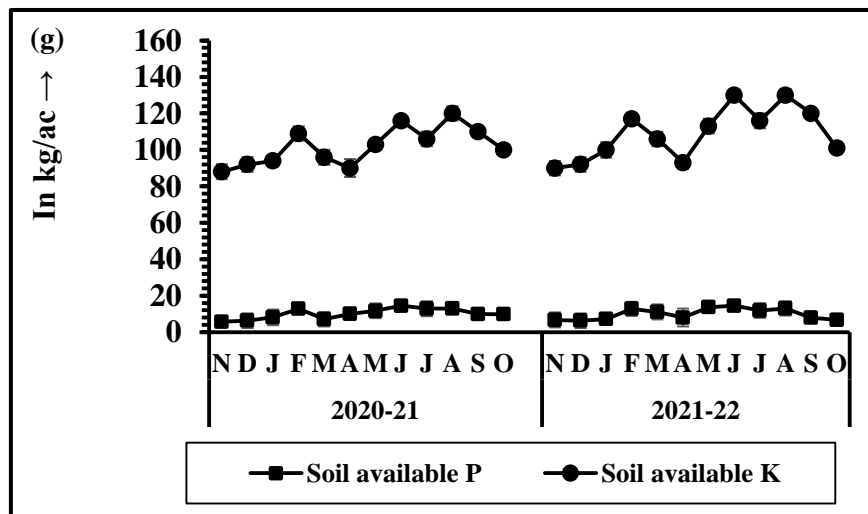
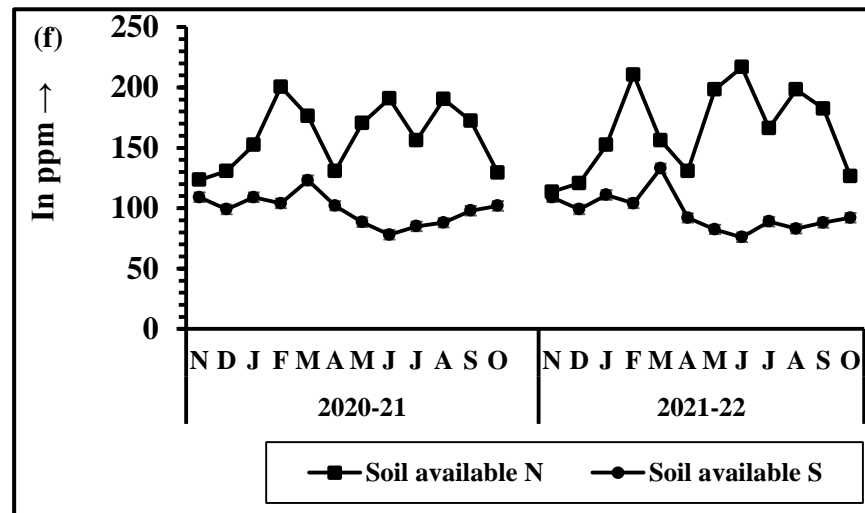
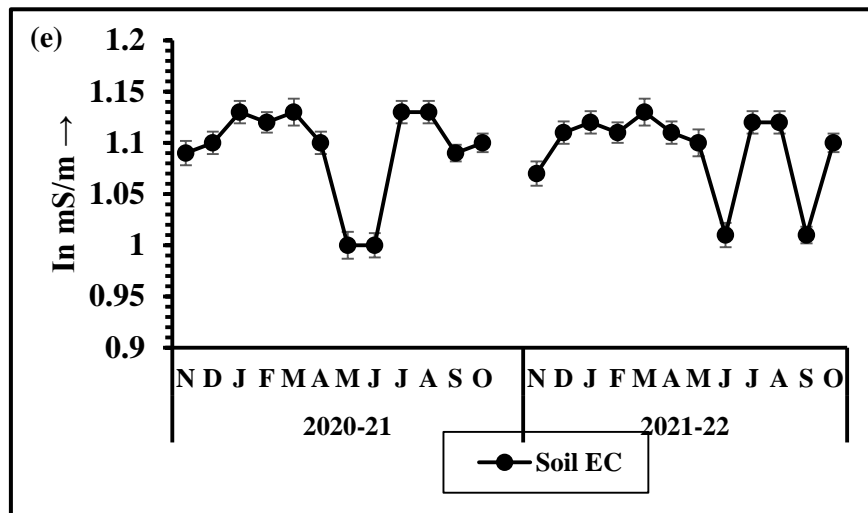


Figure 4.9: Seasonal variation of edaphic factors in Outskirts of Textile land, Panipat

In the case of Wheat field, Hisar, the soil temperature ranged 19°C - 31°C in the preceding year, while in the succeeding year it ranged 18°C - 33°C (Table A.11 - A.12 ; Figure 4.6,c). Similarly, moisture 11.7 % - 20.3 % in preceding year while in succeeding year 10.3 % - 17.9 % (Table A.11 - A.12 ; Figure 4.6,a); OC 0.26 % - 0.44 % (preceding year) while 0.24 % - 0.45 % (succeeding year) (Table A.11 - A.12 ; Figure 4.6,b); OM 0.51 % - 0.65 % (p) and 0.52 % - 0.75 % (s) (Table A.11 - A.12 ; Figure 4.6,b); pH 7.1 - 7.5 (p) and 7.1 - 7.4 (s) (Table A.11 - A.12 ; Figure 4.6,d); EC 0.89 mS/m - 1.8 mS/m (p) and 0.86 mS/m - 1.63 mS/m (s) (Table A.11 - A.12 ; Figure 4.6,e); available N 131 ppm - 260.3 ppm (p) and 136 ppm - 279.3 ppm (s) (Table A.11 - A.12 ; Figure 4.6,f); S 9.03 ppm - 15.73 ppm (p) and 19.03 ppm - 25.73 ppm (s) (Table A.11 - A.12 ; Figure 4.6,f); P 20 kg/ac - 66 kg/ac (p) and 21 kg/ac - 56 kg/ac (s) (Table A.11 - A.12 ; Figure 4.6,g); K 96.5 kg/ac - 131 kg/ac (p) and 94 kg/ac - 121 kg/ac (s) (Table A.11 - A.12 ; Figure 4.6,g); Zn 0.79 ppm - 1.48 ppm (p) and 0.68 ppm - 1.41 ppm (s) (Table A.11 - A.12 ; Figure 4.6,h); Fe 1.15 ppm - 3.6 ppm (p) and 1.65 ppm - 3.06 ppm (s) (Table A.11 - A.12 ; Figure 4.6,h); Cu 0.48 ppm - 0.80 ppm (p) and 0.37 ppm - 0.65 ppm (s) (Table A.11 - A.12 ; Figure 4.6,h); Mn 3.15 ppm - 4.5 ppm (p) and 3.45 ppm - 4.53 ppm (s) (Table A.11 - A.12 ; Figure 4.6,h). In the case of Jowar field, Rohtak, the soil temperature ranged 39 °C - 42 °C in the preceding year, while in the succeeding year it ranged 37 °C - 40 °C (Table A.13 - A.14 ; Figure 4.7,c). Similarly, moisture 15.9 % - 18.5 % in preceding year while in succeeding year 15.1 % - 17.5 % (Table A.13 - A.14 ; Figure 4.7,a); OC 0.44 % - 0.59 % (preceding year) while 0.48 % - 0.69 % (succeeding year) (Table A.13 - A.14 ; Figure 4.7,b); OM 0.84 % - 1.01 % (p) and 0.82 % - 1.11 % (s) (Table A.13 - A.14 ; Figure 4.7,b); pH 6.8 - 7.1 (p) and 6.9 - 7.2 (s) (Table A.13 - A.14 ; Figure 4.7,d); EC 0.91 mS/m - 1.50 mS/m (p) and 0.81 mS/m - 1.63 mS/m (s) (Table A.13 - A.14 ; Figure 4.7,e); available N 479.3 ppm - 525.8 ppm (p) and 379.3 ppm - 425.8 ppm (s) (Table A.13 - A.14 ; Figure 4.7,f); S 30.06 ppm - 36.41 ppm (p) and 25.06 ppm - 28.41 ppm (s) (Table A.13 - A.14 ; Figure 4.7,f); P 7.6 kg/ac - 15.01 kg/ac (p) and 7.6 kg/ac - 15.01 kg/ac (s) (Table A.13 - A.14 ; Figure 4.7,g); K 99 kg/ac - 155 kg/ac (p) and 109 kg/ac - 145 kg/ac (s) (Table A.13 - A.14 ; Figure 4.7,g); Zn 0.65 ppm - 0.95 ppm (p) and 0.65 ppm - 0.75 ppm (s) (Table A.13 - A.14 ; Figure 4.7, h); Fe 0.99 ppm - 1.51 ppm (p) and 0.99 ppm - 1.41 ppm (s)

(Table A.13 - A.14 ; Figure 4.7,h); Cu 0.3 ppm - 0.6 ppm (p) and 0.4 ppm - 0.6 ppm (s) (Table A.13 - A.14 ; Figure 4.7,h); Mn 2.45 ppm - 2.9 ppm (p) and 2.4 ppm - 2.8 ppm (s) (Table A.13 - A.14 ; Figure 4.7,h). In the case of Forest land, Panipat, soil temperature ranged 13°C - 34°C in the preceding year, while in the succeeding year it ranged 15°C - 36°C (Table A.15 - A.16 ; Figure 4.8,c). Similarly, moisture ranged from 7.08% - 11.2% in the preceding year and 7.38% - 11.97% in the succeeding year (Table A.15 - A.16 ; Figure 4.8,a); OC ranged 0.1% - 0.27% in the preceding year and 0.11% - 0.26% in the succeeding year. (Table A.15 - A.16 ; Figure 4.8,b); OM 0.17 % - 0.48 % (p) and 0.17 % - 0.38 % (s) (Table A.15 - A.16 ; Figure 4.8,b); pH 7.4 - 7.6 (p) and 7.4 - 7.6 (s) (Table A.15 - A.16 ; Figure 4.8,d); EC 1.0 mS/m - 1.13 mS/m (p) and 1.01 mS/m - 1.14 mS/m (s) (Table A.15 - A.16 ; Figure 4.8,e); available N 103.45 ppm - 141.4 ppm (p) and 105.45 ppm - 141.74 ppm (s) (Table A.15 - A.16 ; Figure 4.8,f); S 90 ppm - 150 ppm (p) and 90 ppm - 140 ppm (s) (Table A.15 - A.16 ; Figure 4.8,f); P 8.4 kg/ac - 13.9 kg/ac (p) and 8.5 kg/ac - 19.08 kg/ac (s) (Table A.15 - A.16 ; Figure 4.8,g); K 5.7 kg/ac - 14.7 kg/ac (p) and 6.3 kg/ac - 13.7 kg/ac (s) (Table A.15 - A.16 ; Figure 4.8,g); Zn 1.74 ppm - 2.3 ppm (p) and 1.74 ppm - 2.3 ppm (s) (Table A.15 - A.16; Figure 4.8,h); Fe 1.19 ppm - 6.9 ppm (p) and 2.19 ppm - 6.9 ppm (s) (Table A.15 - A.16; Figure 4.8,h); Cu 0.43 ppm - 0.85 ppm (p) and 0.45 ppm - 0.80 ppm (s) (Table A.15 - A.16 ; Figure 4.8,h); Mn 2.3 ppm - 5.4 ppm (p) and 2.3 ppm - 4.6 ppm (s) (Table A.15 - A.16 ; Figure 4.8,h). In the case of the Outskirts of textile land, Panipat, the soil temperature ranged 14°C - 35°C in the preceding year, while in the succeeding year it ranged 13°C - 34°C (Table A.17 - A.18 ; Figure 4.9,c). Similarly, moisture 5.1 % - 18.9 % in preceding year while in succeeding year 7.5 % - 18.5 % (Table A.17 - A.18 ; Figure 4.9,a); OC 0.1 % - 0.28 % (preceding year) while 0.13 % - 0.27 % (succeeding year) (Table A.17 - A.18 ; Figure 4.9,b); OM 0.17 % - 0.48 % (p) and 0.16 % - 0.41 % (s) (Table A.17 - A.18 ; Figure 4.9,b); pH 7.4 - 7.6 (p) and 7.4 - 7.6 (s) (Table A.17 - A.18 ; Figure 4.9,d); EC 1.00 mS/m - 1.13 mS/m (p) and 1.01 mS/m - 1.13 mS/m (s) (Table A.17 - A.18 ; Figure 4.9,e); available N 123.45 ppm - 200.51 ppm (p) and 113.45 ppm - 216.76 ppm (s) (Table A.17 - A.18 ; Figure 4.9,f); S 78 ppm - 123 ppm (p) and 76 ppm - 133 ppm (s) (Table A.17 - A.18 ; Figure 4.9,f); P 7.1 kg/ac - 14.5 kg/ac (p) and 6.3 kg/ac - 14.5 kg/ac (s) (Table A.17 - A.18 ; Figure 4.9,g); K 88 kg/ac - 120

kg/ac (p) and 90 kg/ac - 130 kg/ac (s) (Table A.17 - A.18 ; Figure 4.9, g) ; Zn 1.43 ppm - 1.99 ppm (p) and 1.74 ppm - 2.33 ppm (s) (Table A.17 - A.18 ; Figure 4.9,h) ; Fe 2.72 ppm - 4.9 ppm (p) and 1.72 ppm - 3.9 ppm (s) (Table A.17 - A.18 ; Figure 4.9,h) ; Cu 0.63 ppm - 0.96 ppm (p) and 0.63 ppm - 0.98 ppm (s) (Table A.17 - A.18 ; Figure 4.9,h) ; Mn 2.7 ppm - 3.9 ppm (p) and 2.3 ppm - 3.9 ppm (s) (Table A.17 - A.18 ; Figure 4.9,h).

4.2 Soil arthropod diversity and distribution

The overall fauna of soil micro-arthropods (Tables 4.49 - 4.51) showed that their abundance in the first year, i.e., 2020 - 21, was approximately double (736 in number) when compared with the second year fauna (399 in number). When individual taxa were analyzed, approximately the same pattern (double in the preceding year or half in the succeeding year) was observed (Tables 4.1 - 4.48). e.g., abundance of collembola (Table 4.49) in the preceding year was 325 and in the succeeding year was observed as 187; mites (Table 4.50) (294, 174); diptera (Table 4.51) (51, 13); thysanuran (Table 4.51) (28, 9); and araneae (Table 4.51) (38, 16). When we compared the arthropod community in terms of relative abundance (Tables 4.49 - 4.51), collembolan found 45.11 % of total soil arthropods, followed by mites (41.23%), diptera 5.63%, araneae 4.75%, and thysanuran 3.25%. Overall observed species abundance (Tables 4.49 - 4.51) showed the collembolan genus *Isotomurus* sp.2 with the maximum abundance (68), followed by the mite genus *Epilohmannia minuta aegyptica* (65) and *Schelorbates thermophilus* (57), and so on. Out of 79 observed taxa, 37 are identified, while 42 remain unidentified (Tables 4.49 - 4.52).

Regarding the variety of soil arthropods, the chosen fields were listed in the increasing order of the same: outskirts of Textile Land, Panipat (0, 0) < Forest land (Tables 4.47 - 4.48), Panipat (4, 4) < Rice field (Tables 4.17 - 4.18), Karnal (7, 7) < Rice field (Tables 4.23 - 4.24), Kaithal (8, 8) < Jowar field (Tables 4.41 - 4.42), Rohtak (10, 8) < Wheat field (Tables 4.29 - 4.30), Sirsa (10, 11) < Wheat field (Tables 4.35 - 4.36), Hisar (12, 13) < Sugarcane field (Tables 4.11 - 4.12), Karnal (17, 12) < Sugarcane field (Tables 4.5 - 4.6), Yamunanagar (21, 20). In terms of Shannon diversity index (H), the following increasing order was found: Outskirts of Textile

Land, Panipat (-, -) < Forest land (Tables 4.47 - 4.48), Panipat (1.21, 1.21) < Rice field (Tables 4.17 - 4.18), Karnal (1.38, 1.83) < Rice field (Tables 4.23 - 4.24), Kaithal (1.85, 1.78) < Jowar field (Table 4.41 - 4.42), Rohtak (2.22, 1.99) < Wheat field (Table 4.29 - 4.30), Sirsa (2.05, 2.16) < Wheat field (Table 4.35 - 4.36), Hisar (2.26, 2.30) < Sugarcane field (Table 4.11 - 4.12), Karnal (2.36, 2.14) < Sugarcane field (Table 4.5 - 4.6), Yamunanagar (2.76, 2.77). In terms of Dominance Index, follow the sequence: Outskirts of Textile Land, Panipat (-, -) < Forest land (Table 4.47 - 4.48), Panipat (0.7292, 0.7167) < Rice field (Table 4.17 - 4.18), Karnal (0.76890, 0.8456) < Rice field (Table 4.23 - 4.24), Kaithal (0.8447, 0.8184) < Wheat field (Table 4.29 - 4.30), Sirsa (0.8668, 0.8865) < Sugarcane field (Table 4.11 - 4.12), Karnal (0.8893, 0.8815) < Wheat field (Table 4.35 - 4.36), Hisar (0.8943, 0.8976) < Jowar field, Rohtak (0.8959, 0.9137) < Sugarcane field (Table 4.5 - 4.6), Yamunanagar (0.9319, 0.9384). In terms of the Richness Index, the following are listed in increasing order: Rice field (Table 4.17 - 4.18), Karnal (0.7708, 1.4906) < Rice field (Table 4.23 - 4.24), Kaithal (1.659, 1.9107) < Wheat field (Table 4.29 - 4.30), Sirsa (1.9147, 2.3459) < Jowar field, Rohtak (2.0153, 2.5247) < Wheat field (Table 4.35 - 4.36), Hisar (2.4155, 2.6351) < Sugarcane field (Table 4.11 - 4.12), Karnal (3.0778, 2.6161) < Sugarcane field (Table 4.5 - 4.6), Yamunanagar (3.8942, 4.091). In terms of Evenness Index: Sugarcane field (Table 4.11 - 4.12), Karnal (0.8342, 0.8629) < Forest land (Table 4.47 - 4.48), Panipat (0.8697, 0.87) < Rice field (Table 4.23 - 4.24), Kaithal (0.8912, 0.8564) < Wheat field (Table 4.29 - 4.30), Sirsa (0.8901, 0.9002) < Wheat field (Table 4.35 - 4.36), Hisar (0.911, 0.8955) < Sugarcane field (Table 4.5 - 4.6), Yamunanagar (0.908, 0.9254) < Jowar field, Rohtak (0.9654, 0.9583) < Rice field (Table 4.17 - 4.18), Karnal (0.9938, 0.9392). In terms of Simpson's Index (D): Sugarcane field (Table 4.5 - 4.6), Yamunanagar (0.0681, 0.0616) < Jowar field, Rohtak (0.1041, 0.0863) < Wheat field (Table 4.35 - 4.36), Hisar (0.1057, 0.1024) < Sugarcane field (Table 4.11 - 4.12), Karnal (0.1107, 0.1185) < Wheat field (Table 4.29 - 4.30), Sirsa (0.1332, 0.1135) < Rice field (Table 4.23 - 4.24), Kaithal (0.1553, 0.1816) < Rice field (Table 4.17 - 4.18), Karnal (0.2342, 0.1544) < Forest land (Table 4.47 - 4.48), Panipat (0.2708, 0.2833).

Overall collembolan taxa (Table 49) showed the following sequence in terms of species numerical abundance: *Isotomurus* sp.2 (68) [Figure 4.10, (g)] > Genus 1, Family 3: Neanuridae (53) [Figure 4.10, (e)] > Genus 1, Family 2: Tullbergiidae (43) [Figure 4.10, (d)] > Genus 1, Family 1: Sminthuridae (42) [Figure 4.10, (o)] > *Proisotoma minuta* (40) [Figure 4.10, (i)] = Genus 1, Family Isotomidae (40) [Figure 4.10, (j)] > *Cyphoderus* sp. (35) [Figure 4.10, (n)] > *Cryptopygus* sp.1 (33) [Figure 4.10, (h)] > Genus 3, Family Isotomidae (31) [Figure 4.10, (l)] > Genus 2, Family 1: Hypogastruridae (28) [Figure 4.10, (b)] > Genus 2, Family Isotomidae (25) [Figure 4.10, (k)] > Genus 3, Family 1: Hypogastruridae (23) [Figure 4.10, (c)] > Genus 4, Family Isotomidae (19) [Figure 4.10, (m)] > *Isotomurus* sp.1 (17) [Figure 4.10, (f)] = Genus 1, Family 1: Hypogastruridae (17) [Figure 4.10, (a)]. Similarly, mite taxa (Table 50) showed the sequence in terms of species numerical abundance: *Epilohmannia minuta aegyptica* (65) [Figure 4.11, (l)] > *Scheloribates thermophilus* (57) [Figure 4.11, (j)] > *Scheloribates curvialatus* (50) [Figure 4.11, (i)] > *Rhizoglyphus echinopus* (43) [Figure 4.11, (n)] > *Protoribates magnus* (41) [Figure 4.11, (k)] > *Bdella* sp. (36) [Figure 4.11, (c)] > *Histiostoma feroniarum* (32) [Figure 4.11, (a)] > *Mahunkania hallensis* (27) [Figure 4.11, (d)] > *Acarus gracillis* (23) [Figure 4.11, (m)] = *Trachyoribates ovulum* (23) [Figure 4.11, (h)] > *Mahunkania secunda* (20) [Figure 4.11, (e)] > *Trachygamasus medianus* (18) [Figure 4.11, (f)] = *Eotetranychus Carapini* (18) [Figure 4.11, (b)] > *Cosmolaelaps indicus* (17) [Figure 4.11, (g)]. In the case of other soil arthropods (Table 51), Genus 1 of Family 1: Linyphiidae [Figure 4.12, (j)] had the highest observed abundance (54), followed by specimen 2 of the Order Diptera (32) [Figure 4.12, (b)], Specimen 1 of the Order Thysanuran (25) [Figure 4.12, (e)], Specimen 4 of the Order Diptera (15) [Figure 4.12, (d)], Specimen 3 of the Order Diptera (12) [Figure 4.12, (c)], Specimen 1 of the Order Diptera (5) [Figure 4.12, (a)], Specimen 3 of the Order Thysanuran (4) [Figure 4.12, (g)], Specimen 5 of the Order Thysanuran (4) [Figure 4.12, (i)], and Specimen 2 of the Order Thysanuran [Figure 4.12, (f)]. When individual fields were compared, not all the species were found in all the fields, and not all the taxa were found throughout the sampling period of a specific field. Only collembolan and mites were present in the majority of soil arthropods (Tables 4.1 - 4.48). In some fields (Sugarcane and Rice), total arthropods as well as individual taxa (Tables 4.1 - 4.2, 4.7

- 4.8, 4.13 - 4.14, and 4.19 - 4.20) show peak in the summer season (May - July), while at other fields (Wheat and Jowar), the same (Tables 4.25 - 4.26, 4.31 - 4.32) show peak in the winter season (December - February). When species composition and their relative frequency were studied field-wise, it was found that in the preceding year, i.e., during 2020 - 2021, the Sugarcane field, Yamunanagar (Tables 4.1 - 4.6), was observed with 5 collembolans, 5 mites, 1 diptera, 1 araneae, 1 thysanura, and 8 unidentified taxa. Out of 5 collembolans, Genus 3 of Hypogastruridae Family of Poduromorpha Order was observed with 06.470 relative frequency, Genus 2 of Isotomidae Family of Entomobryomorpha Order with 10.000 relative frequency, Genus 1 of Isotomidae Family of Entomobryomorpha Order with 4.117 relative frequency (r.f.), *Isotomurus* sp.1 of Isotomidae Family of Entomobryomorpha Order with 5.294 r.f., and *Proisotoma minuta* of Isotomidae Family of Entomobryomorpha Order with 5.882 r.f. Out of 5 mites, *Trachygamasus medianus* of Parasitidae Family of Mesostigmata Order with 5.882 r.f., *Eotetranychus carapini* of Tetranychidae Family of Trombidiformes Order with 5.294 r.f., *Schelorbitates curvialatus* of Schelorbitatidae Family of Sarcoptiformes Order with 7.0588 r.f., *Mahunkania hallensis* of Pygmephoridae Family of Trombidiformes Order with 4.117 r.f., *Bdella* sp. of Bdellidae Family of Trombidiformes Order with 4.705 r.f. Genus 2 of Diptera of Insecta with 12.352 r.f., Genus 1 of Linyphiidae of Euchelicerata with 7.0588 r.f., and Specimen 1 of Thysanura of Insecta with 12.352 r.f., while Unidentified Specimen (22), Unidentified Specimen (23), Unidentified Specimen (25), Unidentified Specimen (29), Unidentified Specimen (31), Unidentified Specimen (32), Unidentified Specimen (33) and Unidentified Specimen (35) were observed with 1.176, 0.588, 1.176, 1.176, 1.176, 1.176, 1.176, 1.176 and 1.176 r.f. respectively.

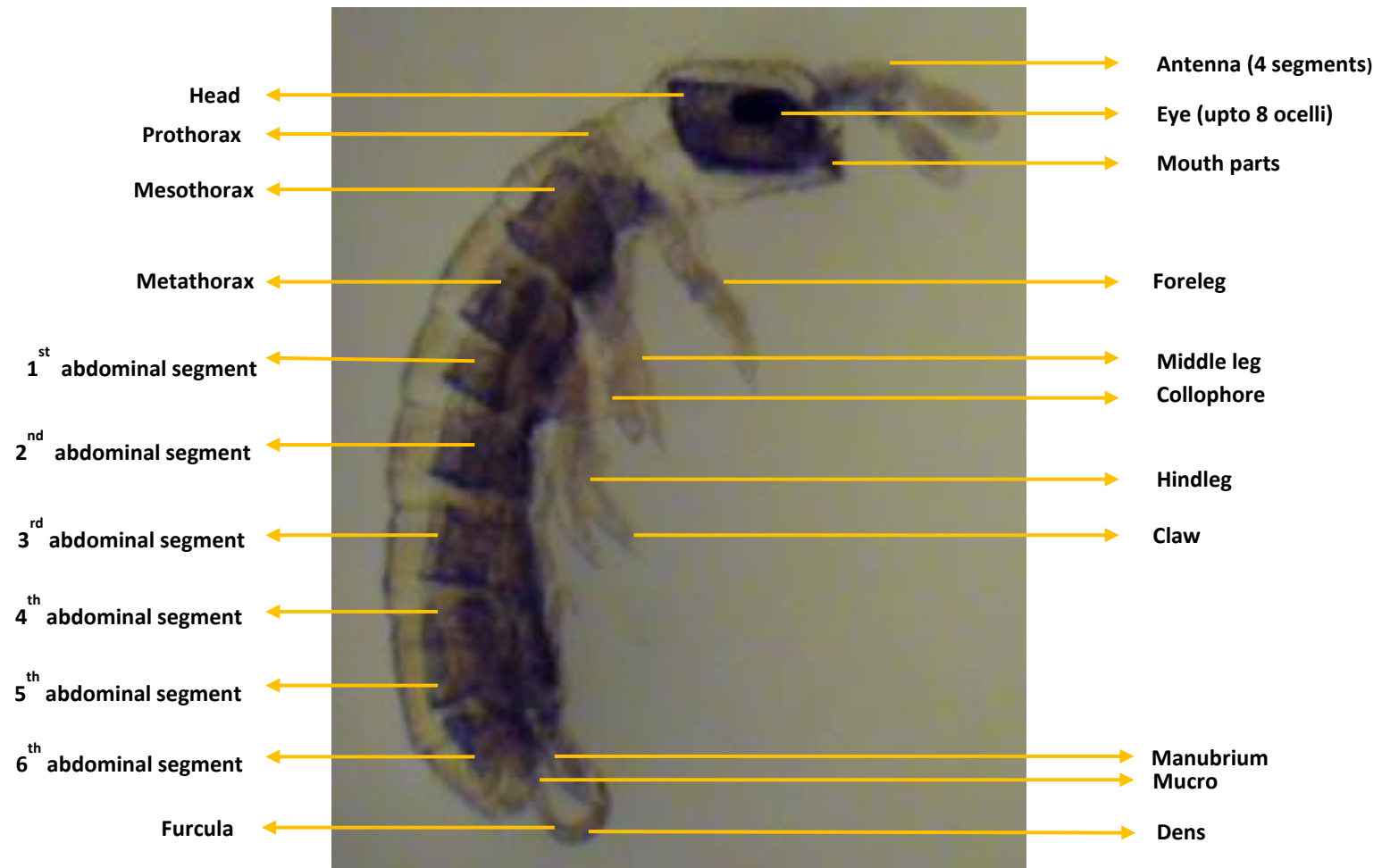


Figure 4.10 Generalized labelled diagram of *Proisotoma minuta*

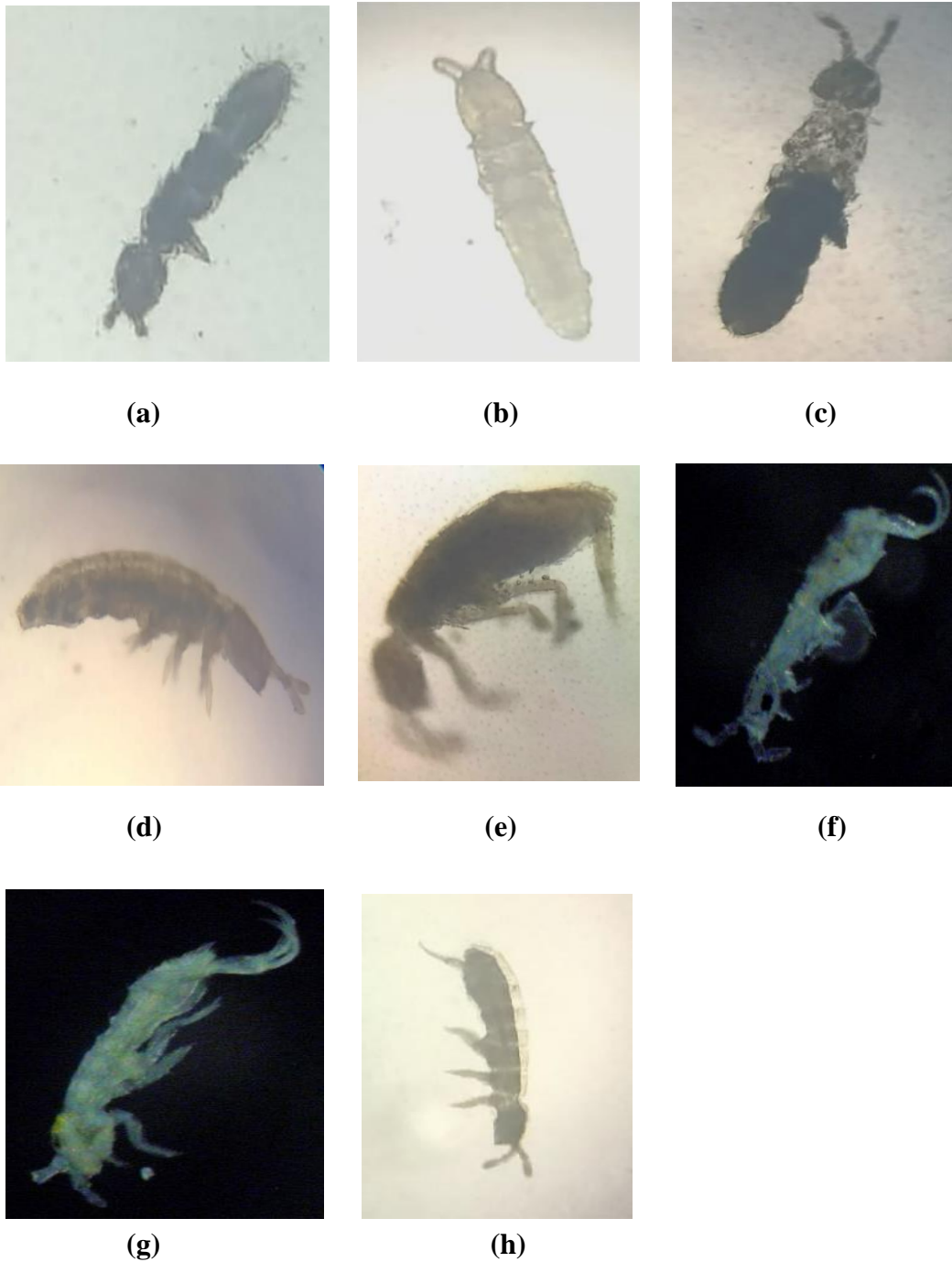


Figure 4.10: (a) Collembolans (a) Genus 3 (Family 1: Hypogastruridae; Order1-Poduromorpha); (b) Genus 2 (Family 1: Hypogastruridae; Order1-Poduromorpha); (c) Genus 1 (Family 1: Hypogastruridae; Order1-Poduromorpha); (d) Genus 1 (Family 2: Tullbergiidae; Order1-Poduromorpha); (e) Genus 1 (Family 3: Neanuridae; Order1-Poduromorpha); (f) *Isotomurus* sp.1 (Family 1: Isotomidae; Order2- Entomobryomorpha); (g) *Isotomurus* sp.2 (Family 1: Isotomidae; Order2- Entomobryomorpha) (h) *Cryptopygus* sp.1 (Family 1: Isotomidae; Order2- Entomobryomorpha)

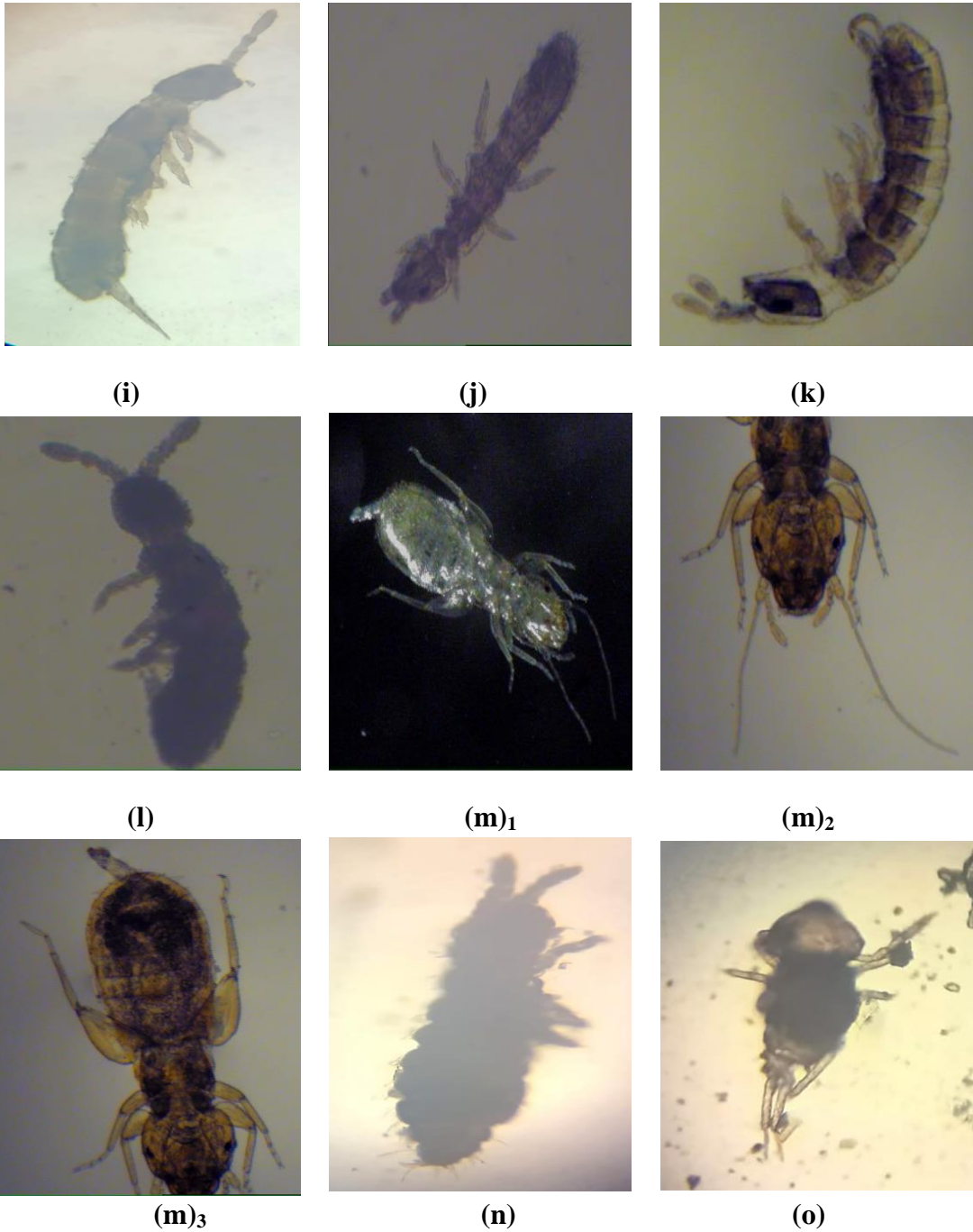


Figure 4.10: (a) Collembolans (i) *Proisotoma minuta* (Family 1: Isotomidae; Order2- Entomobryomorpha); (j) Genus 1 (Family 1: Isotomidae; Order2- Entomobryomorpha); (k) Genus 2 (Family 1: Isotomidae; Order2- Entomobryomorpha); (l) Genus 3 (Family 1: Isotomidae; Order2- Entomobryomorpha); (m) Genus 4 (Family 1: Isotomidae; Order2- Entomobryomorpha); (n) *Cyphoderus* sp. (Family 2: Paronullidae; Order2- Entomobryomorpha); (o) Genus 1 (Family 1: Sminthuridae; Order3 – Symphypleona)

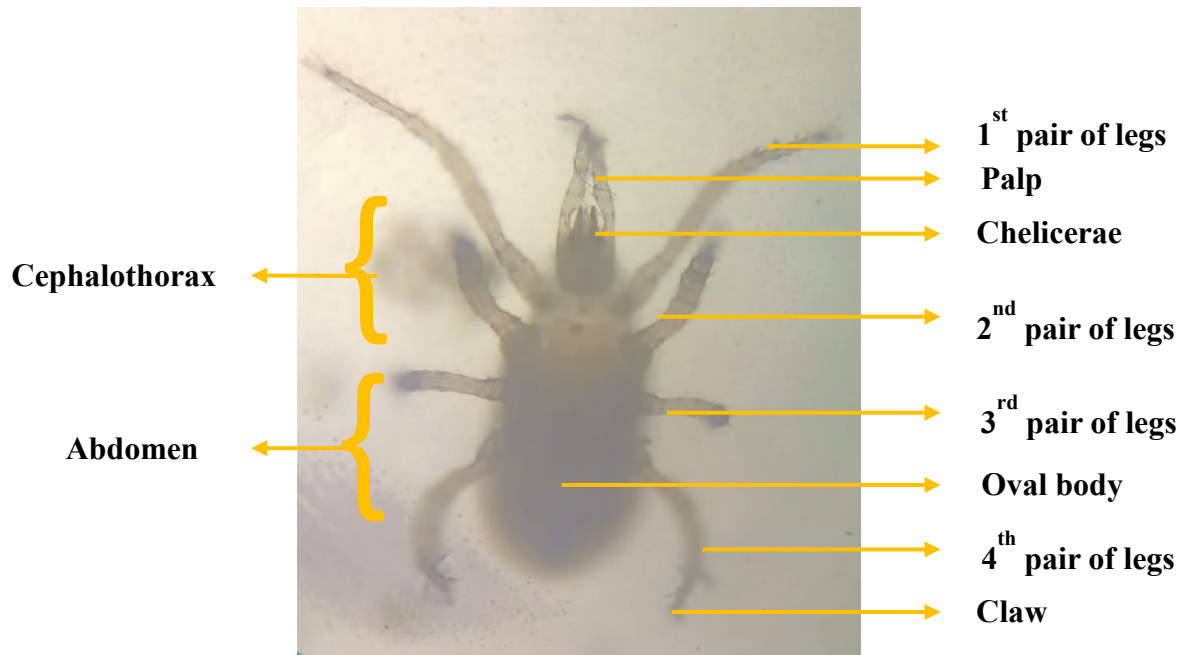


Figure 4.11: Generalized labelled diagram of *Cosmolaelaps indicus*

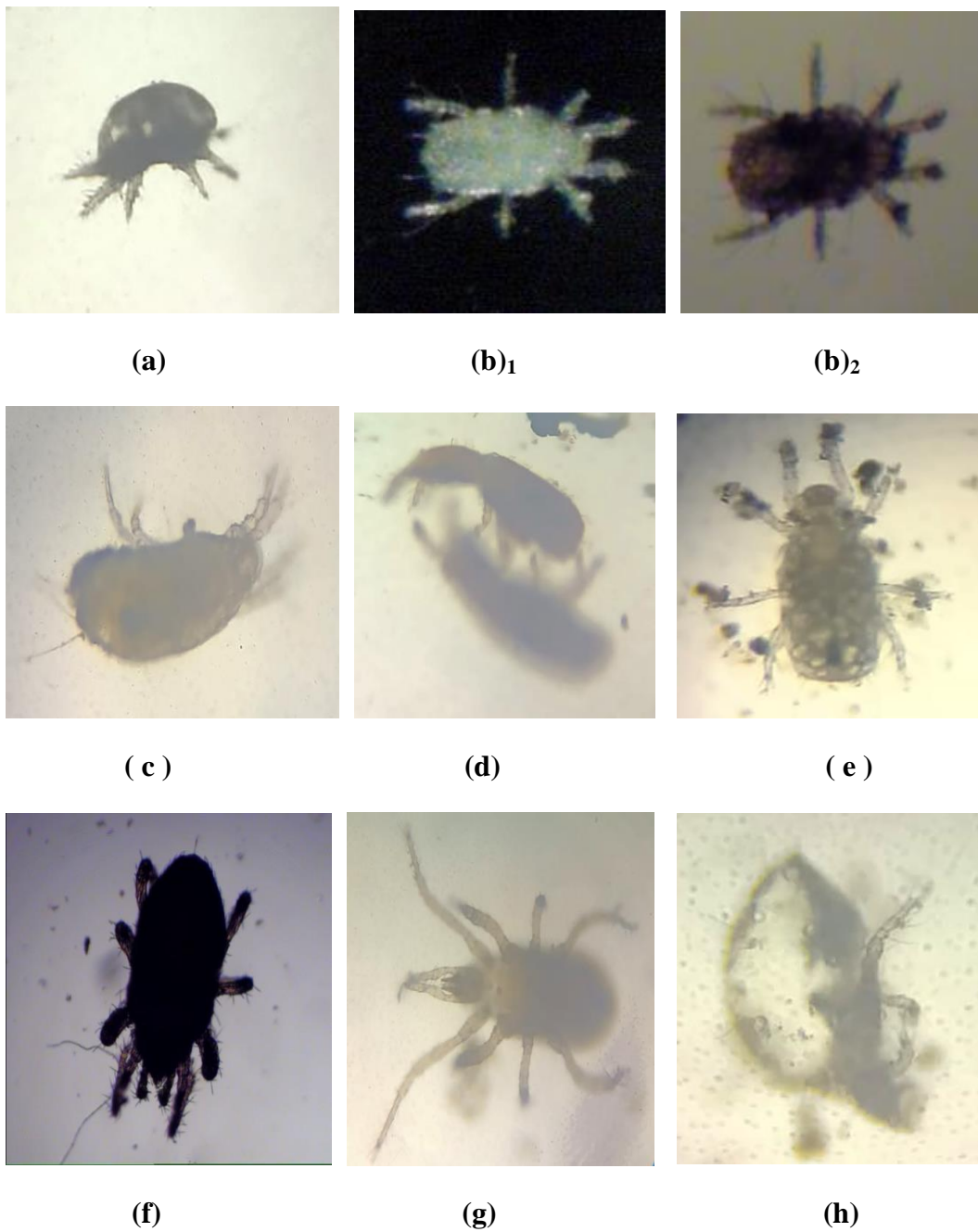


Figure 4.11: (a) Acarina (a) *Histiotoma feroniarum*; (b) *Eotetranychus Carapini*; (c) *Bdella sp.*; (d) *Mahunkania hallensis* (e) *Mahunkania secunda*; (f) *Trachygamasus medianus*; (g) *Cosmolaelaps indicus*; (h) *Trachyoribates ovulum*



Figure 4.11: (a) Acarina (i) *Scheloribates curvialatus*; (j) *Scheloribates thermophilus*; (k) *Protoribates magnus*; (l) *Epilohmannia minuta aegyptica*; (m) *Acarus gracillis*; (n) *Rhizoglyphus echinopus*

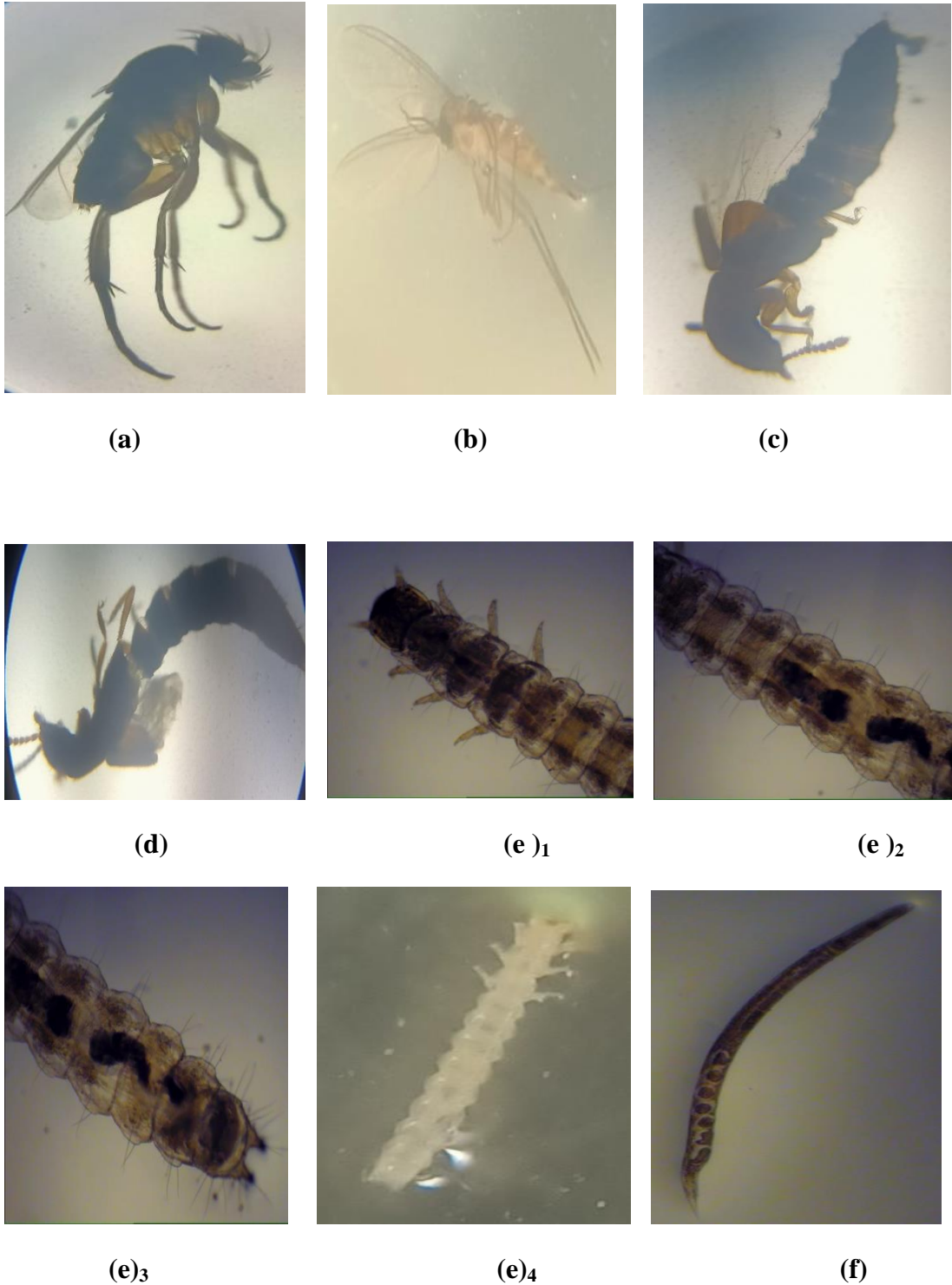


Figure 4.12: Diptera, Thysanura and Aranea (a) Genus 1/ Diptera order/ Insecta class; (b) Genus 2/ Diptera order/ Insecta class; (c) Genus 3/ Diptera order/ Insecta class; (d) Genus 4/ Diptera order/ Insecta class; (e) Genus 1/ Thysanura order/ Insecta class; (f) Genus 2/ Thysanura order/ Insecta class



(g)



(h)



(i)₁



(i)₂



(j)

Figure 4.12: Diptera, Thysanura and Aranea (g) Genus 3/ Thysanura order/ Insecta class; (h) Genus 4/ Thysanura order/ Insecta class; (i) Genus 5/ Thysanura order/ Insecta class; (j) Genus 1/ Linyphiidae family/ Araneae order/ Euchelicerata class.



(1)



(2)



(3)



(4)



(5)



(6)



(7)



(8)



(9)

Figure 4.13: Unidentified specimens serial-wise



(10)



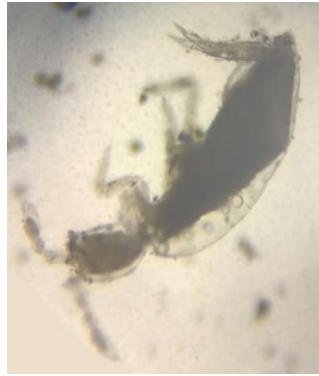
(11)



(12)



(13)



(14)



(15)



(16)



(17)



(18)

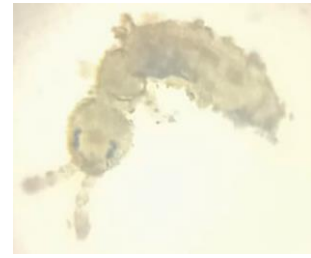
Figure 4.13: Unidentified specimens serial-wise



(19)



(20)



(21)



(22)



(23)



(24)



(25)



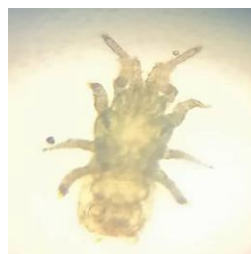
(26)



(27)



(28)



(29)



(30)

Figure 4.13: Unidentified specimens serial-wise



(31)



(32)



(33)



(34)



(35)



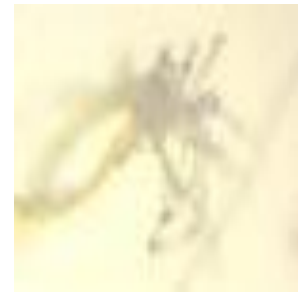
(36)



(37)



(38)



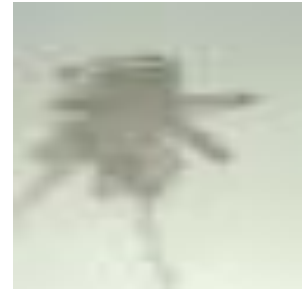
(39)



(40)




(41)



(42)

Figure 4.13 (d): Unidentified specimens serial-wise

4.2.1 Reports of species identified by ZSI

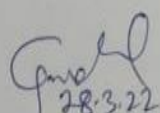

 भारत सरकार
 GOVERNMENT OF INDIA
Zoological Survey of India
 M-Block, New Alipore, Kolkata - 700053
 IDENTIFICATION REPORT
APTERYGOTA SECTION

Identification Report No: 224
 ZSI Lot No. 27/2022

Dated: 28.03.2022
 Received from: Dr. Joydeep Dutta
 Prof. and Head, Deptt. of Zoology
 Lovely Professional University,
 Phagwara, Punjab

Sender's No.	Family/Genus/Species	Received	Retained	Returned	Remarks
	Family Isotomidae				
Vial No. C12:	<i>Isotomurus</i> sp.	lex on slide			Specimen damaged
Vial No. C15:	<i>Isotomurus</i> sp.	lex on slide			Specimen damaged
Vial No. C14:	<i>Cryptopygus</i> sp.	lex on slide			Specimen damaged

Specimens are completely damaged in other vials.


 28.3.22
 (Dr. G.P. Mandal)

Sc - 'E' & O/C, Apterygota section

Figure 4.14: Collembolan (report) identified by Dr. Mandal from ZSI, Kolkata dated 28-3-2022



भारत सरकार
GOVERNMENT OF INDIA
Zoological Survey of India
M-Block, New Alipore, Kolkata – 700053
IDENTIFICATION REPORT
APTERYGOTA SECTION

Identification Report No: 229
ZSI Lot No. 79/2022

Dated: 15.11.2022
Received from: Dr. Joydeep Dutta
Professor & Head,
Department of Zoology,
LPU University, Punjab.

Sender's No.	Family/Genus/Species	Received	Retained	Returned	Remarks
	Class: Collembola				
	Order: Poduromorpha				
Slide No. KC9	Fam. Neanuridae	1 ex.	1 ex.	-	Specimen damaged
Slide No. KC2	Fam. Tullbergiidae	1 ex.	1 ex.	-	Specimen damaged
	Order: Entomobryomorpha				
	Family Isotomidae				
Slide No.KC1	<i>Proisotoma minuta</i> (Tullberg, 1871)	1 ex.	1 ex.	-	Specimen in good condition
	Family Paronellidae				
Slide No.KC4	<i>Cyphoderus</i> sp.	1 ex.	1 ex.	-	Specimen damaged
	Order: Symphypleona				
Slide No.KC6	Fam. Neanuridae	1 ex.	1 ex.	-	Specimen damaged

The specimens are badly damaged in other slides, therefore identification could not been done. For further identification, specimens in good condition may be send.

15-11-2022

(Dr. G.P. Mandal)

Sc – 'E' & O/C, Apterygota section.

Figure 4.15: Collembolan (report) identified by Dr. Mandal from ZSI, Kolkata dated 15-11-2022

List of identification of Examples from Kavita Taneja. Panipat (Haryana)

Vial No	Order	Family	Genus	Species	Example
M-1	Astigmata	Histiostomatidae Berlese 1897	Histiostoma Kramer 1976	<i>Histiostoma feroniarum</i> Dufour, 1839	6 Nos
M-9		Tetranychidae Donnadieu 1875	Eotetranychus Oudemans	<i>Eotetranychus Carapini</i> Oudemans 1905	1 Nos
M-6	Mesostigamata	Prasitidae	Trachygamasus Berlese 1906	<i>Trachygamasus medianus</i> Tichomirov 1977	1 Nos
M-A	-	-	-	-	-
A-3	-	-	-	-	-
A-2	-	-	-	-	-
C-11	-	-	-	-	-
C-9	-	-	-	-	-
M-8	-	-	-	-	-

Figure 4.16: Mites (report) identified by Dr. Shelley Acharya from ZSI, Kolkata

From ,
 Dr. Shelley Acharya
 Scientist- E
 Zoological Survey of India
 New Alipore, M-Block
 Kolkata- 700053

Date : 16.01.2023

Subject : Identification summery

With the requisition of your letter dated 16/09/2022 the identification report of the specimen sent is as follows.

Slide no	Family	Genus	Species	Example
Km 10	Haplozetidae	<i>Trachyoribates</i>	<i>Trachyoribates ovulum</i> (Berlese, 1908)	1
	Scheloribatidae	<i>Scheloribates</i>	<i>Scheloribates curvialatus</i> Hammer, 1961	1
Km7	Protoribatidae	<i>Protoribates</i>	<i>Protoribates magnus</i> Aoki, 1982	1
Km2	Laelapidae	<i>Cosmolaelaps</i>	<i>Cosmolaelaps indicus</i> Bhattacharyya, 1966	1
Km3	Scheloribatidae	<i>Scheloribates</i>	<i>Scheloribates curvialatus</i> Hammer, 1961	
Km10B	Scheloribatidae	<i>Scheloribates</i>	<i>Scheloribates curvialatus</i> Hammer, 1961	1
Km1	Bdellidae	<i>Bdella</i> Latreille, 1795	<i>Bdella</i> sp.	1

	Epilohmanniidae	<i>Epilohmannia</i>	<i>Epilohmannia minuta aegyptica</i> Bayoumi & Mahunka, 1976	1
	Scheloribatidae	<i>Scheloribates</i>	<i>Scheloribates curvialatus</i> Hammer, 1961	1
Km4	No mites specimens were found in the vial			
Km6	Pygmephoridae	<i>Mahunkania</i>	<i>Mahunkania hallensis</i> Rack, 1975	1
Km8	Acaridae	<i>Acarus</i>	<i>Acarus gracillis</i> Hughes, 1957	1
Km16	No mites specimens were found in the vial			
Km15	No mites specimens were found in the vial			
Km14	No mites specimens were found in the vial			
Km13	No mites specimens were found in the vial			
Km(12)	No mites specimens were found in the vial			

	Epilohmanniidae	<i>Epilohmannia</i>	<i>Epilohmannia minuta aegyptica</i> Bayoumi & Mahunka, 1976	1
	Scheloribatidae	<i>Scheloribates</i>	<i>Scheloribates curvialatus</i> Hammer, 1961	1
Km4	No mites specimens were found in the vial			
Km6	Pygmephoridae	<i>Mahunkania</i>	<i>Mahunkania hallensis</i> Rack, 1975	1
Km8	Acaridae	<i>Acarus</i>	<i>Acarus gracillis</i> Hughes,1957	1
Km16	No mites specimens were found in the vial			
Km15	No mites specimens were found in the vial			
Km14	No mites specimens were found in the vial			
Km13	No mites specimens were found in the vial			
Km(12)	No mites specimens were found in the vial			
SIW2X	Acaridae	<i>Rhizoglyphus</i>	<i>Rhizoglyphus echinopus</i> Fumouze and Robin,1868	
SIW2x1	Acaridae	<i>Rhizoglyphus</i>	<i>Rhizoglyphus echinopus</i> Fumouze and robin, 1868	
Km5	Scheloribatidae	<i>Scheloribates</i>	<i>Scheloribates thermophilus</i> Hammer, 1961	1
	Epilohmanniidae	<i>Epilohmannia</i>	<i>Epilohmannia minuta aegyptica</i> Bayoumi & Mahunka, 1976	1
Km11	No mites specimens were found in the vial			
Km9	Pygmephoridae	Mahunkania	<i>Mahunkania secunda</i> Rack, 1975	3

To,
Kavita Taneja,
New Housing Board Colony H. No. 1642,
Sector-11/12, Panipat (Haryana)
132103
Mob No. 8901309040

Figure 4.17: Mites (report) identified by Dr. Shelley Acharya from ZSI, Kolkata dated 16-1-20

Table 4.1: Arthropod fauna at Sugarcane field, Yamunanagar during 2020-21

Month	Collembola	Acarina	Other arthropods (Diptera + Araneae + Thysanura)	Unidentified Specimens	Total
February	2	4	$2 + 2 + 2 = 6$	1	13
March	2	3	$1 + 0 + 2 = 3$	1	9
April	3	4	$2 + 2 + 2 = 6$	2	15
May	9	7	$3 + 0 + 2 = 5$	3	24
June	10	11	$2 + 3 + 3 = 8$	4	33
July	7	6	$2 + 0 + 2 = 4$	3	20
August	7	4	$3 + 2 + 2 = 7$	-	18
September	5	3	$2 + 1 + 3 = 6$	1	15
October	4	3	$2 + 1 + 2 = 5$	-	12
November	5	1	$2 + 1 + 1 = 4$	1	11
Overall	54	46	$21+12+21=54$	16	170

Table 4.2: Arthropod fauna at Sugarcane field, Yamunanagar during 2021-22

Month	Collembola	Acarina	Other arthropods (Diptera + Araneae + Thysanura)	Unidentified specimens	Total
February	2	3	$1 + 0 + 1 = 2$	-	7
March	-	2	$0 + 0 + 0 = 0$	-	2
April	3	5	$0 + 0 + 0 = 0$	2	10
May	6	3	$2 + 0 + 0 = 2$	2	13
June	4	5	$0 + 0 + 1 = 1$	1	11
July	9	6	$0 + 1 + 0 = 1$	2	18
August	1	3	$0 + 0 + 0 = 0$	-	4
September	7	4	$0 + 2 + 0 = 2$	2	15
October	3	6	$0 + 0 + 2 = 2$	1	12
November	3	6	$0 + 1 + 0 = 1$	1	11
Overall	38	43	$3+4+4=11$	11	103

Table: 4.3 Arthropod community and their month wise population at Sugarcane field, Yamunanagar during 2020-21

S.No.	Name of the Class/ Order/ Family/ Genus/ species	February	March	April	May	June	July	August	September	October	November	Total
1.	Collembola/ Poduromorpha /Hypogastruridae /Genus 3	1	-	-	3	1	3	1	1	-	1	11
2.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 2	-	2	-	3	5	2	-	2	2	1	17
3.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 1	1	-	-	1	1	-	1	-	1	2	7
4.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.1	-	-	2	1	2	1	1	-	1	1	9
5.	Collembola/ Entomobryomorpha/ Isotomidae <i>Proisotoma minuta</i>	-	-	1	1	1	1	4	2	-	-	10
6.	Arachnida/ Mesostigamata/ Parasitidae/ <i>Trachygamasus medianus</i>	2	-	1	3	1	-	3	-	-	-	10
7.	Arachnida/Trombidiformes/ Tetranychidae/ <i>Eotetranychus Carapini</i>	2	1	-	1	2	-	-	3	-	-	9
8.	Arachnida/ Sarcoptiformes Scheloribatidae / <i>Scheloribates curvialatus</i>	-	1	-	1	6	2	1	-	-	1	12
9.	Arachnida/ Trombidiformes / Pygmephoridae / <i>Mahunkania hallensis</i>	-	1	-	1	2	3	-	-	-	-	7
10.	Arachnida/ Trombidiformes / Bdellidae / <i>Bdella</i> sp.	-	-	3	1	-	1	-	-	3	-	8

11.	Insecta/ Diptera/ Genus 2	2	1	2	3	2	2	3	2	2	2	21
12.	Euchelicerata /Araneae /Linyphiidae /Genus 1	2	-	2	-	3	-	2	1	1	1	12
13.	Insecta / Thysanura / Specimen 1	2	2	2	2	3	2	2	3	2	1	21
14.	Unidentified Specimen (22)	1	-	-	1	-	-	-	-	-	-	2
15.	Unidentified Specimen (23)	-	1	-	-	-	-	-	-	-	-	1
16.	Unidentified Specimen (25)	-	-	2	-	-	-	-	-	-	-	2
17.	Unidentified Specimen (29)	-	-	-	2	-	-	-	-	-	-	2
18.	Unidentified Specimen (31)	-	-	-	-	3	-	-	-	-	-	3
19.	Unidentified Specimen (32)	-	-	-	-	1	1	-	-	-	-	2
20.	Unidentified Specimen (33)	-	-	-	-	-	2	-	-	-	-	2
21.	Unidentified Specimen (35)	-	-	-	-	-	-	-	1	-	1	2
22.	Total = 21 (Number of taxa observed)	13	9	15	24	33	20	18	15	12	11	170

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.4: Arthropod community and their month wise population at Sugarcane field, Yamunanagar during 2021-22

S.No.	Name of the Class/ Order/ Family/ Genus/ species	February	March	April	May	June	July	August	September	October	November	Total
1.	Collembola/ Poduromorpha /Hypogastruridae /Genus 3	1	-	-	1	2	1	1	-	-	-	6
2.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 2	1	-	-	1	1	1	-	2	1	1	8
3.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 1	-	-	2	1	-	3	-	3	-	2	11
4.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.1	-	-	1	2	-	2	-	1	1	-	8
5.	Collembola/ Entomobryomorpha/ Isotomidae <i>Proisotoma minuta</i>	-	-	-	1	1	2	-	1	1	-	6
6.	Arachnida/ Mesostigamata/ Parasitidae/ <i>Trachygamasus medianus</i>	1	-	-	1	1	-	1	1	2	1	8
7.	Arachnida/ Trombidiformes/ Tetranychidae/ <i>Eotetranychus Carapini</i>	-	1	-	2	-	2	-	-	1	3	9
8.	Arachnida/ Sarcoptiformes/ Scheloribatidae / <i>Scheloribates curvialatus</i>	2	-	2	-	-	1	-	-	1	2	8
9.	Arachnida/ Trombidiformes / Pygmephoridae / <i>Mahunkania hallensis</i>	-	1	-	-	3	1	-	-	1	-	6
10	Arachnida/ Trombidiformes / Bdellidae / <i>Bdella</i> sp	-	-	3	-	1	2	2	3	1	-	12

11	Insecta/ Diptera/ Genus 2	1	-	-	2	-	-	-	-	-	-	3
12	Euchelicerata /Araneae /Linyphiidae /Genus 1	-	-	-	-	-	1	-	2	-	1	4
13	Insecta / Thysanura / Specimen 1	1	-	-	-	1	-	-	-	2	-	4
14	Unidentified Specimen (21)	-	-	1	-	-	-	-	-	-	-	1
15	Unidentified Specimen (24)	-	-	1	-	-	-	-	-	-	-	1
16	Unidentified Specimen (26)	-	-	-	1	-	-	-	-	-	1	2
17	Unidentified Specimen (27)	-	-	-	1	-	-	-	-	-	-	1
18	Unidentified Specimen (28)	-	-	-	-	1	-	-	-	1	-	2
19	Unidentified Specimen (30)	-	-	-	-	-	2	-	-	-	-	2
20	Unidentified Specimen (34)	-	-	-	-	-	-	-	2	-	-	2
21	Total = 20 (Number of taxa observed)	7	2	10	13	11	18	4	15	12	11	103

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.5: Species diversity indices at Sugarcane field, Yamunanagar during 2020-21

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Poduromorpha /Hypogastruridae /Genus 3	11	06.470	2.76	0.9319	3.8942	0.908	0.0681
2.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 2	17	10.000					
3.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 1	7	04.117					
4.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.1	9	05.294					
5.	Collembola/ Entomobryomorpha/ Isotomidae / <i>Proisotoma minuta</i>	10	5.882					
6.	Arachnida/ Mesostigamata/ Parasitidae/ <i>Trachygamasus medianus</i>	10	5.882					
7.	Arachnida/Trombidiformes/ Tetranychidae/ <i>Eotetranychus Carapini</i>	9	05.294					
8.	Arachnida/ Sarcoptiformes Scheloribatidae / <i>Scheloribates curvialatus</i>	12	7.0588					
9.	Arachnida/ Trombidiformes / Pygmephoridae / <i>Mahunkania hallensis</i>	7	04.117					

10.	Arachnida/ Trombidiformes / Bdellidae / <i>Bdella</i> sp.	8	4.705					
11.	Insecta/ Diptera/ Genus 2	21	12.352					
12.	Euchelicerata /Araneae /Linyphiidae /Genus 1	12	7.0588					
13.	Insecta / Thysanura / Specimen 1	21	12.352					
14.	Unidentified Specimen (22)	2	1.176					
15.	Unidentified Specimen (23)	1	0.588					
16.	Unidentified Specimen (25)	2	1.176					
17.	Unidentified Specimen (29)	2	1.176					
18.	Unidentified Specimen (31)	3	1.764					
19.	Unidentified Specimen (32)	2	1.176					
20.	Unidentified Specimen (33)	2	1.176					
21.	Unidentified Specimen (35)	2	1.176					

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.6: Species diversity indices at Sugarcane field, Yamunanagar during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Poduromorpha /Hypogastruridae /Genus 3	6	5.8252	2.77	0.9384	4.091	0.9254	0.0616
2.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 2	8	7.766					
3.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 1	11	10.679					
4.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.1	8	7.766					
5.	Collembola/ Entomobryomorpha/ Isotomidae <i>Proisotoma minuta</i>	6	5.8252					
6.	Arachnida/ Mesostigamata/ Parasitidae/ <i>Trachygamasus medianus</i>	8	7.766					
7.	Arachnida/ Trombidiformes/ Tetranychidae/ <i>Eotetranychus Carapini</i>	9	8.737					
8.	Arachnida/ Sarcoptiformes Scheloribatidae / <i>Scheloribates curvialatus</i>	8	7.766					

9.	Arachnida/ Trombidiformes / Pygmephoridae / <i>Mahunkania hallensis</i>	6	5.8252					
10.	Arachnida/ Trombidiformes / Bdellidae / <i>Bdella</i> sp	12	11.650					
11.	Insecta/ Diptera/ Genus 2	3	2.912					
12.	Euchelicerata /Araneae /Linyphiidae /Genus 1	4	3.883					
13.	Insecta / Thysanura / Specimen 1	4	3.883					
14.	Unidentified Specimen (21)	1	0.970					
15.	Unidentified Specimen (24)	1	0.970					
16.	Unidentified Specimen (26)	2	1.941					
17.	Unidentified Specimen (27)	1	0.970					
18.	Unidentified Specimen (28)	2	1.941					
19.	Unidentified Specimen (30)	2	1.941					
20.	Unidentified Specimen (34)	2	1.941					

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.7 : Arthropod fauna at Sugarcane field, Karnal during 2020-21

Month	Collembola	Acarina	Other arthropods (Diptera + Thysanura)	Unidentified specimens	Total
February	5	4	2 + 1 = 3	2	14
March	4	3	0 + 1 = 1	-	8
April	7	8	1 + 0 = 1	1	17
May	17	12	2 + 0 = 2	3	34
June	16	13	1 + 1 = 2	2	33
July	8	9	1 + 1 = 2	3	22
August	9	7	2 + 0 = 2	-	18
September	4	7	0 + 1 = 1	2	14
October	8	1	1 + 0 = 1	1	11
November	8	-	1 + 1 = 2	-	10
Overall	86	64	11+6= 17	14	181

Table 4.8 : Arthropod fauna at Sugarcane field, Karnal during 2021-22

Month	Collembola	Acarina	Other arthropods (Diptera + Thysanura)	Unidentified specimens	Total
February	1	3	-	-	4
March	-	2	-	-	2
April	5	1	0 + 1 = 1	-	7
May	4	7	2 + 0 = 2	1	14
June	5	5	0 + 2 = 2	-	12
July	2	5	1 + 0 = 1	1	9
August	5	3	-	-	8
September	1	3	-	-	4
October	2	1	1 + 0 = 1	-	4
November	-	3	-	-	3
Overall	25	33	4+3=7	2	67

Table 4.9: Arthropod community and their month wise population at Sugarcane field, Karnal during 2020-21

S.No.	Name of the Class/ Order/ Family/ Genus/ species	February	March	April	May	June	July	August	September	October	November	Total
1.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Cryptopygus</i> sp.1	4	3	2	4	-	1	-	1	5	5	25
2.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.2	-	-	2	11	16	2	3	-	1	-	35
3.	Collembola/ Poduromorpha/ Neanuridae/ Genus 1	1	1	3	2	-	5	6	3	2	3	26
4.	Arachnida/ Sarcoptiformes Scheloribatidae / <i>Schelorbates curvialatus</i>	2	-	5	2	7	-	2	1	-	-	19
5.	Arachnida/ Oribatida/ Haplozetidae / <i>Protorbates magnus</i>	-	1	3	4	1	-	3	1	-	-	13
6.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	1	1	-	4	4	8	-	3	1	-	22
7.	Arachnida /Trombidiformes /Pygmephoridae / <i>Mahunkania secunda</i>	1	1	-	2	1	1	2	2	-	-	10
8.	Insecta/ Diptera/ Genus 4	2	-	1	2	1	1	2	-	1	1	11
9.	Insecta/ Thysanura/ Genus 2	1	-	-	-	-	-	-	1	-	-	2
10.	Insecta/ Thysanura/ Genus 3	-	1	-	-	-	1	-	-	-	1	3
11.	Insecta / Thysanura / Specimen 4	-	-	-	-	1	-	-	-	-	-	1
12.	Unidentified Specimen (36)	2	-	-	-	-	-	-	-	-	-	2

13.	Unidentified Specimen (37)	-	-	1	-	-	-	-	1	-	-	2
14.	Unidentified Specimen (38)	-	-	-	2	-	-	-	-	1	-	3
15.	Unidentified Specimen (39)	-	-	-	1	-	-	-	1	-	-	2
16.	Unidentified Specimen (40)	-	-	-	-	2	-	-	-	-	-	2
17.	Unidentified Specimen (41)	-	-	-	-	-	3	-	-	-	-	3
18.	Total = 17 (Number of taxa observed)	14	8	17	34	33	22	18	14	11	10	181

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.10: Arthropod community and their month wise population at Sugarcane field, Karnal during 2021-22

S.No.	Name of the Class/ Order/ Family/ Genus/ species	February	March	April	May	June	July	August	September	October	November	Total
1.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Cryptopygus sp.1</i>	1	-	4	1	-	1	-	-	1	-	8
2.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus sp.2</i>	-	-	-	1	4	1	-	1	-	-	7
3.	Collembola/ Poduromorpha/ Neanuridae/ Genus1	-	-	1	2	1	-	5	-	1	-	10
4.	Arachnida/ Sarcoptiformes Scheloribatidae <i>Scheloribates curvialatus</i>	-	-	-	6	3	-	1	-	1	-	11
5.	Arachnida/ Sarcoptiformes/ Epilohmanniidae <i>Epilohmannia minuta aegyptica</i>	3	2	-	1	1	1	1	-	-	3	12
6.	Arachnida /Trombidiformes /Pygmephoridae <i>Mahunkania secunda</i>	-	-	1	-	1	4	1	3	-	-	10
7.	Insecta/ Diptera/ Genus 4	-	-	-	2	-	1	-	-	1	-	4
8.	Insecta/ Thysanura/ Genus 2	-	-	1	-	-	-	-	-	-	-	1
9.	Insecta/ Thysanura/ Genus 3	-	-	-	-	1	-	-	-	-	-	1
10.	Insecta / Thysanura / Specimen 4	-	-	-	-	1	-	-	-	-	-	1
11.	Unidentified Specimen (36)	-	-	-	1	-	-	-	-	-	-	1
12.	Unidentified Specimen (42)	-	-	-	-	-	1	-	-	-	-	1
13.	Total = 12 (Number of taxa observed)	4	2	7	14	12	9	8	4	4	3	67

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.11: Species diversity indices at Sugarcane field, Karnal during 2020-21

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Cryptopygus</i> sp.1	25	13.812	2.36	0.8893	3.0778	0.8342	0.1107
2.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.2	35	19.337					
3.	Collembola/ Poduromorpha/ Neanuridae/ Genus1	26	14.364					
4.	Arachnida/ Sarcoptiformes Scheloribatidae / <i>Scheloribates curvialatus</i>	19	10.497					
5.	Arachnida/ Oribatida/ Haplozetidae / <i>Protoribates magnus</i>	13	7.182					
6.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	22	12.154					
7.	Arachnida /Trombidiformes /Pygmephoridae / <i>Mahunkania secunda</i>	10	5.524					
8.	Insecta/ Diptera/ Genus 4	11	6.077					
9.	Insecta/ Thysanura/ Genus 2	2	1.104					
10.	Insecta/ Thysanura/ Genus 3	3	1.657					

11.	Insecta / Thysanura / Specimen 4	1	0.552					
12.	Unidentified Specimen (36)	2	1.104					
13.	Unidentified Specimen (37)	2	1.104					
14.	Unidentified Specimen (38)	3	1.657					
15.	Unidentified Specimen (39)	2	1.104					
16.	Unidentified Specimen (40)	2	1.104					
17.	Unidentified Specimen (41)	3	1.657					

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.12: Species diversity indices at Sugarcane field, Karnal during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Cryptopygus</i> sp.1	8	11.94	2.14	0.8815	2.6161	0.8629	0.1185
2.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.2	7	10.447					
3.	Collembola/ Poduromorpha/ Neanuridae/ Genus1	10	14.925					
4.	Arachnida/ Sarcoptiformes Scheloribatidae / <i>Scheloribates curvialatus</i>	11	16.417					
5.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	12	17.910					
6.	Arachnida /Trombidiformes /Pygmephoridae / <i>Mahunkania secunda</i>	10	14.925					
7.	Insecta/ Diptera/ Genus 4	4	5.970					
8.	Insecta/ Thysanura/ Genus 2	1	1.492					
	Insecta/ Thysanura/ Genus 3	1	1.492					
9.	Insecta / Thysanura / Specimen 4	1	1.492					
10.	Unidentified Specimen (36)	1	1.492					
11.	Unidentified Specimen (42)	1	1.492					

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.13: Arthropod fauna at Rice field, Karnal during 2020-21

Month	Collembola	Acarina	Other arthropods (Thysanura + Diptera + Araneae)	Total
June	4	5	$1 + 3 + 4 = 8$	17
July	6	3	$1 + 1 + 0 = 2$	11
August	8	7	$0 + 0 + 0 = 0$	15
September	3	4	$0 + 0 + 1 = 1$	8
October	-	4	$0 + 1 + 0 = 1$	5
Overall	21	23	$2 + 5 + 5 = 12$	56

Table 4.14: Arthropod fauna at Rice field, Karnal during 2021-22

Month	Collembola	Acarina	Other arthropods (Thysanura + Diptera + Araneae)	Total
June	3	1	$1 + 1 + 1 = 3$	7
July	4	-	$1 + 0 + 1 = 2$	6
August	1	1	$0 + 0 + 0 = 0$	2
September	-	1	$0 + 1 + 0 = 1$	2
October	2	2	$0 + 0 + 1 = 1$	5
Overall	10	5	$2 + 2 + 3 = 7$	21

Table 4.15: Arthropod community and their month wise population Rice field, Karnal during 2020-21

S.No.	Name of the Class/ Order/ Family/ Genus/ species	June	July	August	September	October	Total
1.	Collembola/ Entomobryomorpha / Paronullidae/ <i>Cyphoderus sp.</i>	1	4	5	1	-	11
2.	Collembola/ Symphyleona/ Sminthuridae / Genus 1	3	2	3	2	-	10
3.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	3	1	3	4	1	12
4.	Arachnida /Trombidiformes /Pygmephoridae / <i>Mahunkania secunda</i>	2	2	4	-	3	11
5.	Insecta/ Diptera/ Specimen 3	3	1	-	-	1	5
6.	Insecta/ Thysanura/ Specimen 5	1	1	-	-	-	2
7.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	4	-	-	1	-	5
8.	Total = 7 (Number of taxa observed)	17	11	15	8	5	56

Table 4.16: Arthropod community and their month wise population Rice field, Karnal during 2021-22

S.No.	Name of the Class/ Order/ Family/ Genus/ species	June	July	August	September	October	Total
1.	Collembola/ Entomobryomorpha / Paronullidae/ <i>Cyphoderus sp.</i>	1	3	-	-	1	5
2.	Collembola/ Symphypleona/ Sminthuridae / Genus 1	2	1	1	-	1	5
3.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	-	-	1	-	1	2
4.	Arachnida /Trombidiformes /Pygmephoridae / <i>Mahunkania secunda</i>	1	-	-	1	1	3
5.	Insecta/ Diptera/ Specimen 3	1	1	-	-	-	2
6.	Insecta/ Thysanura/ Specimen 5	1	-	-	1	-	2
7.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	1	1	-	-	1	2
8.	Total = 7 (Number of taxa observed)	7	5	2	2	5	21

Table 4.17: Species diversity indices at Rice field, Karnal during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1	Collembola/ Entomobryomorpha / Paronullidae/ <i>Cyphoderus sp.</i>	11	19.64	1.38	0.76580	0.7708	0.9938	0.2342
2	Collembola/ Symphypleona/ Sminthuridae / Genus 1	10	17.85					
3	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	12	21.42					
4	Arachnida /Trombidiformes /Pygmephoridae / <i>Mahunkania secunda</i>	11	19.64					
5	Insecta/ Diptera/ Specimen 3	5	08.92					
6	Insecta/ Thysanura/ Specimen 5	2	03.57					
7	Euchelicerata/ Araneae / Linyphiidae / Genus 1	5	08.92					

Table 4.18: Species diversity indices at Rice field, Karnal during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Entomobryomorpha / Paronullidae/ <i>Cyphoderus sp.</i>	5	23.809	1.83	0.8456	1.4906	0.9392	0.1544
2.	Collembola/ Symphypleona/ Sminthuridae / Genus 1	5	23.809					
3.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	2	9.523					
4.	Arachnida /Trombidiformes /Pygmephoridae / <i>Mahunkania secunda</i>	3	14.285					
5.	Insecta/ Diptera/ Specimen 3	2	9.523					
6.	Insecta/ Thysanura/ Specimen 5	2	9.523					
7.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	2	9.523					

Table 4.19: Arthropod fauna at Rice field, Kaithal during 2020-21

Month	Collembola	Acarina	Other arthropods (Diptera + Araneae)	Total
June	12	4	$3 + 1 = 4$	20
July	7	6	$0 + 0 = 0$	13
August	10	6	$1 + 0 = 1$	17
September	6	4	$0 + 0 = 0$	10
October	3	4	$1 + 0 = 1$	8
Overall	38	24	$5 + 1 = 6$	68

Table 4.20: Arthropod fauna at Rice field, Kaithal during 2021-22

Month	Collembola	Acarina	Other arthropods (Diptera + Araneae)	Total
June	3	5	$1 + 0 = 1$	9
July	4	5	$0 + 0 = 0$	9
August	3	5	$0 + 0 = 0$	8
September	1	3	$1 + 0 = 1$	5
October	4	2	$1 + 1 = 2$	8
Overall	15	20	$3 + 1 = 4$	39

Table 4.21: Arthropod community and their month wise population Rice field, Kaithal during 2020-21

S.No.	Name of the Class/ Order/ Family/ Genus/ species	June	July	August	September	October	Total
1.	Collembola/ Entomobryomorpha / Paronullidae/ <i>Cyphoderus sp.</i>	6	2	2	-	3	13
2.	Collembola/ Poduromorpha/ Neanuridae/ Genus1	2	3	5	2	-	12
3.	Collembola/ Symphypleona/ Sminthuridae / Genus 1	4	2	3	4	-	13
4.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	2	1	2	4	2	11
5.	Arachnida/ Sarcoptiformes Scheloribatidae/ <i>Scheloribates thermophilus</i>	2	5	4	-	2	13
6.	Insecta/ Diptera/ Specimen 2	1	-	-	-	1	2
7.	Insecta/ Diptera/ Specimen 3	2	-	1	-	-	3
8.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	1	-	-	-	-	1
9.	Total = 8 (Number of taxa observed)	20	13	17	10	8	68

Table 4.22: Arthropod community and their month wise population Rice field, Kaithal during 2021 - 22

S.No.	Name of the Class/ Order/ Family/ Genus/ species	June	July	August	September	October	Total
1.	Collembola/ Entomobryomorpha / Paronullidae/ <i>Cyphoderus sp.</i>	1	1	2	-	2	6
2.	Collembola/ Poduromorpha/ Neanuridae/ Genus1	1	2	-	1	1	5
3.	Collembola/ Symphypleona/ Sminthuridae / Genus 1	1	1	1	-	1	4
4.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	1	-	3	1	1	6
5.	Arachnida/ Sarcoptiformes Scheloribatidae/ <i>Scheloribates thermophilus</i>	4	5	2	2	1	14
6.	Insecta/ Diptera/ Specimen 2	1	-	-	-	1	2
7.	Insecta/ Diptera/ Specimen 3	-	-	-	1	-	1
8.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	-	-	-	-	1	1
9.	Total = 8 (Number of taxa observed)	9	9	8	5	8	39

Table 4.23: Species diversity indices at Rice field, Kaithal during 2020-21

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Entomobryomorpha / Paronullidae/ <i>Cyphoderus sp.</i>	13	19.117	1.85	0.8447	1.659	0.8912	0.1553
2.	Collembola/ Poduromorpha/ Neanuridae/ Genus1	12	17.647					
3.	Collembola/ Symphypleona/ Sminthuridae / Genus 1	13	19.117					
4.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	11	16.176					
5.	Arachnida/ Sarcoptiformes Scheloribatidae/ <i>Scheloribates thermophilus</i>	13	19.117					
6.	Insecta/ Diptera/ Specimen 2	2	2.941					
7.	Insecta/ Diptera/ Specimen 3	3	4.411					
8.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	1	1.470					

Table 4.24: Species diversity indices at Rice field, Kaithal during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Entomobryomorpha / Paronullidae/ <i>Cyphoderus sp.</i>	6	15.384	1.78	0.8184	1.9107	0.8564	0.1816
2.	Collembola/ Poduromorpha/ Neanuridae/ Genus1	5	12.820					
3.	Collembola/ Symphypleona/ Sminthuridae / Genus 1	4	10.256					
4.	Arachnida/ Sarcoptiformes/ Epilohmanniidae / <i>Epilohmannia minuta aegyptica</i>	6	15.384					
5.	Arachnida/ Sarcoptiformes Scheloribatidae/ <i>Scheloribates thermophilus</i>	14	35.897					
6.	Insecta/ Diptera/ Specimen 2	2	5.128					
7.	Insecta/ Diptera/ Specimen 3	1	2.564					
8.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	1	2.564					

Table 4.25: Arthropod fauna at Wheat field, Sirsa during 2020-21

Month	Collembola	Acarina	Other arthropods (Araneae)	Unidentified specimens	Total
November	5	6	2	1	14
December	5	7	2	-	14
January	6	9	2	2	19
February	8	9	1	-	18
March	9	15	1	1	26
April	8	9	1	1	19
Overall	41	55	9	5	110

Table 4.26: Arthropod fauna at Wheat field, Sirsa during 2021-22

Month	Collembola	Acarina	Other arthropods (Araneae)	Unidentified specimens	Total
November	5	4	0	-	9
December	3	5	0	1	9
January	-	6	1	2	9
February	7	3	2	-	12
March	8	5	0	2	15
April	7	7	2	1	17
Overall	30	30	5	6	71

Table4. 27: Arthropod community and their month wise population Wheat field, Sirsa during 2020-21

S.No.	Name of the Class/ Order/ Family/ Genus/ species	November	December	January	February	March	April	Total
1.	Collembola/ Poduromorpha / Tullbergiidae/ Genus 1	2	-	2	3	4	2	13
2.	Collembola/ Entomobryomorpha/ Isotomidae Proisotoma <i>minuta</i>	1	4	2	3	-	3	13
3.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.2	2	1	2	2	5	3	15
4.	Arachnida/ Sarcoptiformes/ Acaridae/ <i>Rhizoglyphus echinopus</i>	1	5	3	3	6	3	21
5.	Arachnida/ Astigmata/ Histiostomatidae/ <i>Histiostoma feroniarum</i>	2	-	3	5	7	5	22
6.	Arachnida/ Sarcoptiformes/ Acaridae/ <i>Acarus gracillis</i>	3	2	3	1	2	1	12
7.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	2	2	2	1	1	1	9
8.	Unidentified Specimen (05)	-	-	2	-	-	-	2
9.	Unidentified Specimen (08)	1	-	-	-	-	1	2
10.	Unidentified Specimen (11)	-	-	-	-	1	-	1
11.	Total = 10 (Number of taxa observed)	14	14	19	18	26	19	110

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.28: Arthropod community and their month wise population Wheat field, Sirsa during 2021-22

S.No.	Name of the Class/ Order/ Family/ Genus/ species	November	December	January	February	March	April	Total
1.	Collembola/ Poduromorpha / Tullbergiidae/ Genus 1	-	1	-	3	3	1	8
2.	Collembola/ Entomobryomorpha/ Isotomidae <i>Proisotoma minuta</i>	1	2	-	2	2	4	11
3.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.2	4	-	-	2	3	2	11
4.	Arachnida/ Sarcoptiformes/ Acaridae/ <i>Rhizoglyphus echinopus</i>	-	2	2	3	2	-	9
5.	Arachnida/ Astigmata/ Histiostomatidae/ <i>Histiostoma feroniarum</i>	-	3	2	-	1	4	10
6.	Arachnida/ Sarcoptiformes/ Acaridae/ <i>Acarus gracillis</i>	4	-	2	-	2	3	11
7.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	-	-	1	2	-	2	5
8.	Unidentified Specimen (06)	-	-	1	-	-	-	1
9.	Unidentified Specimen (07)	-	1	-	-	-	-	1
10.	Unidentified Specimen (09)	-	-	1	-	-	1	2
11.	Unidentified Specimen (10)	-	-	-	-	2	-	2
12.	Total = 11 (Number of taxa observed)	9	9	9	12	15	17	71

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.29: Species diversity indices at Wheat field, Sirsa during 2020-21

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Poduromorpha / Tullbergiidae/ Genus 1	13	11.818	2.05	0.8668	1.9147	0.8901	0.1332
2.	Collembola/ Entomobryomorpha/ Isotomidae <i>Proisotoma minuta</i>	13	11.818					
3.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.2	15	13.636					
4.	Arachnida/ Sarcoptiformes/ Acaridae/ <i>Rhizoglyphus echinopus</i>	21	19.090					
5.	Arachnida/ Astigmata/ Histiotomatidae/ <i>Histiostoma feroniarum</i>	22	20.000					
6.	Arachnida/ Sarcoptiformes/ Acaridae/ <i>Acarus gracillis</i>	12	10.909					
7.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	9	8.181					
8.	Unidentified Specimen (05)	2	1.818					
9.	Unidentified Specimen (08)	2	1.818					
10.	Unidentified Specimen (11)	1	0.909					

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.30: Species diversity indices at Wheat field, Sirsa during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Poduromorpha / Tullbergiidae/ Genus 1	8	11.267	2.16	0.8865	2.3459	0.9002	0.1135
2.	Collembola/ Entomobryomorpha/ Isotomidae <i>Proisotoma minuta</i>	11	15.492					
3.	Collembola/ Entomobryomorpha/ Isotomidae/ <i>Isotomurus</i> sp.2	11	15.492					
4.	Arachnida/ Sarcoptiformes/ Acaridae/ <i>Rhizoglyphus echinopus</i>	9	12.676					
5.	Arachnida/ Astigmata/ Histiostomatidae/ <i>Histiostoma feroniarum</i>	10	14.084					
6.	Arachnida/ Sarcoptiformes/ Acaridae/ <i>Acarus gracillis</i>	11	15.492					
7.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	5	7.042					
8.	Unidentified Specimen (06)	1	1.408					
9.	Unidentified Specimen (07)	1	1.408					
10.	Unidentified Specimen (09)	2	2.816					
11.	Unidentified Specimen (10)	2	2.816					

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.31: Arthropod fauna at Wheat field, Hisar during 2020-21

Month	Collembola	Acarina	Other arthropods (Araneae)	Unidentified specimens	Total
November	5	3	2	2	12
December	3	7	1	1	12
January	11	9	1	3	24
February	3	9	3	1	16
March	4	10	2	-	16
April	5	6	2	1	14
Overall	31	44	11	8	94

Table 4.32: Arthropod fauna at Wheat field, Hisar during 2021-22

Month	Collembola	Acarina	Other arthropods (Araneae)	Unidentified specimens	Total
November	5	3	1	2	11
December	7	4	1	1	13
January	9	8	0	-	17
February	7	8	0	3	18
March	9	7	1	2	19
April	8	7	1	1	17
Overall	45	37	4	9	95

Table 4.33: Arthropod community and their month wise population Wheat field, Hisar during 2020-21

S.No.	Name of the Class/ Order/ Family/ Genus/ species	November	December	January	February	March	April	Total
1.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 3	1	-	2	1	-	3	7
2.	Collembola/ Poduromorpha / Tullbergiidae/Genus 1	-	3	2	1	3	-	9
3.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 4	3	-	4	-	1	1	9
4.	Collembola/ Poduromorpha /Hypogastruridae /Genus 2	2	-	3	1	-	1	7
5.	Arachnida/ Oribatida/ Haplozetidae/ <i>Trachyoribates ovulum</i>	1	2	3	3	2	2	13
6.	Arachnida/ Oribatida/ Protoribatidae/ <i>Protoribates magnus</i>	-	4	4	-	5	2	15
7.	Arachnida/ Sarcopiformes Scheloribatidae/ <i>Schelorbates thermophilus</i>	2	1	2	6	3	2	16
8.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	2	1	1	3	2	2	11
9.	Unidentified Specimen (12)	1	-	-	-	-	1	2
10.	Unidentified Specimen (15)	1	-	-	1	-	-	2
11.	Unidentified Specimen (16)	-	1	-	-	-	-	1
12.	Unidentified Specimen (18)	-	-	3	-	-	-	3
13.	Total = 12 (Number of taxa observed)	13	12	22	16	16	14	93

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.34: Arthropod community and their month wise population Wheat field, Hisar during 2021-22

S.No.	Name of the Class/ Order/ Family/ Genus/ species	November	December	January	February	March	April	Total
1.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 3	1	-	4	3	3	2	13
2.	Collembola/ Poduromorpha / Tullbergiidae/Genus 1	1	3	3	-	4	2	13
3.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 4	2	2	1	2	2	1	10
4.	Collembola/ Poduromorpha /Hypogastruridae /Genus 2	1	2	1	2	-	3	9
5.	Arachnida/ Oribatida/ Haplozetidae/ <i>Trachyoribates ovulum</i>	3	2	2	3	-	-	10
6.	Arachnida/ Oribatida/ Protoribatidae/ <i>Protoribates magnus</i>	-	-	5	2	2	4	13
7.	Arachnida/ Sarcoptiformes Scheloribatidae/ <i>Schelorbates thermophilus</i>	-	2	1	3	5	3	14
8.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	1	1	-	-	1	1	4
9.	Unidentified Specimen (13)	1	-	-	-	1	-	2
10.	Unidentified Specimen (14)	1	-	-	-	-	-	1
11.	Unidentified Specimen (17)	-	1	-	-	1	-	2
12.	Unidentified Specimen (19)	-	-	-	2	-	1	3
13.	Unidentified Specimen (20)	-	-	-	1	-	-	1
14.	Total = 13 (Number of taxa observed)	11	13	17	18	19	17	95

Note: number in parenthesis i.e. () in the extreme left column's last rows specifies the codes given to unidentified specimens.

Table 4.35: Species diversity indices at Wheat field, Hisar during 2020-21

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 3	7	7.526	2.26	0.8943	2.4155	0.911	0.1057
2.	Collembola/ Poduromorpha / Tullbergiidae/ Genus 1	9	9.677					
3.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 4	9	9.677					
4.	Collembola/ Poduromorpha /Hypogastruridae /Genus 2	7	7.526					
5.	Arachnida/ Oribatida/ Haplozetidae/ Trachyoribates ovulum	13	13.978					
6.	Arachnida/ Oribatida/ Protoribatidae/ Protoribates magnus	15	16.129					
7.	Arachnida/ Sarcoptiformes Scheloribatidae/ Scheloribates thermophilus	16	17.204					
8.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	11	11.827					
9.	Unidentified Specimen (12)	2	2.150					
10.	Unidentified Specimen (15)	2	2.150					
11.	Unidentified Specimen (16)	1	1.075					
12.	Unidentified Specimen (18)	3	3.225					

Table 4.36: Species diversity indices at Wheat field, Hisar during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 3	13	13.684	2.30	0.8976	2.6351	0.8955	0.1024
2.	Collembola/ Poduromorpha / Tullbergiidae/Genus 1	13	13.684					
3.	Collembola/Entomobryomorpha/ Isotomidae/ Genus 4	10	10.526					
4.	Collembola/ Poduromorpha /Hypogastruridae /Genus 2	9	9.473					
5.	Arachnida/ Oribatida/ Haplozetidae/ <i>Trachyoribates ovulum</i>	10	10.526					
6.	Arachnida/ Oribatida/ Protoribatidae/ <i>Protoribates magnus</i>	13	13.684					
7.	Arachnida/ Sarcoptiformes Scheloribatidae/ <i>Schelorbates thermophilus</i>	14	14.736					
8.	Euchelicerata/ Araneae / Linyphiidae / Genus 1	4	4.210					
9.	Unidentified Specimen (13)	2	2.105					
10.	Unidentified Specimen (14)	1	1.052					
11.	Unidentified Specimen (17)	2	2.105					
12.	Unidentified Specimen (19)	3	3.157					
13.	Unidentified Specimen (20)	1	1.052					

Table 4.37: Arthropod fauna at Jowar field, Rohtak during 2020-21

Month	Collembola	Acarina	Other arthropods (Diptera)	Total
April	9	8	3	20
May	17	14	3	34
June	8	9	1	18
July	6	7	2	15
Overall	40	38	9	87

Table 4.38: Arthropod fauna at Jowar field, Rohtak during 2021-22

Month	Collembola	Acarina	Other arthropods (Diptera)	Total
April	3	3	-	6
May	2	3	-	5
June	2	1	1	4
July	-	1	-	1
Overall	7	8	1	16

Table 4.39: Arthropod community and their month wise population Jowar field, Rohtak during 2020-21

S.No.	Name of the species/Genus/ Family/Order	April	May	June	July	Total
1.	<i>Cosmolaelaps indicus</i> (Bhattacharyya, 1966)	3	4	5	3	15
2.	<i>Bdella</i> (Latreille, 1795)	2	6	2	2	12
3.	<i>Rhizoglyphus echinopus</i> (Fumouze & Robin,1868)	3	4	2	2	11
4.	Hypogastruridae Sp. 1	3	4	-	2	9
5.	Hypogastruridae Sp. 2	1	8	1	1	11
6.	Hypogastruridae Sp. 3	2	1	3	-	6
7.	Isotomidae Sp. 1	1	1	2	1	5
8.	Isotomidae Sp. 3	2	3	2	2	9
9.	Diptera Sp. 1	1	-	1	2	4
10.	Diptera Sp. 2	2	3	-	-	5
11.	Total =10 (Number of taxa observed)	20	34	18	15	87

Table 4.40: Arthropod community and their month wise population Jowar field, Rohtak during 2021-22

S.No.	Name of the species/Genus/ Family/Order	April	May	June	July	Total
1.	<i>Cosmolaelaps indicus</i> (Bhattacharyya, 1966)	-	1	1	-	2
2.	<i>Bdella</i> (Latreille, 1795)	3	1	-	-	4
3.	<i>Rhizoglyphus echinopus</i> (Fumouze & Robin,1868)	-	1	-	1	2
4.	Hypogastruridae Sp. 1	1	-	1	-	2
5.	Hypogastruridae Sp. 2	-	1	-	-	1
6.	Isotomidae Sp. 1	1	1	-	-	2
7.	Isotomidae Sp. 3	1	-	1	-	2
8.	Diptera Sp. 1	-	-	1	-	1
9.	Total = 8 (Number of taxa observed)	6	5	4	1	16

Table 4.41: Species diversity indices at Jowar field, Rohtak during 2020-21

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	<i>Cosmolaelaps indicus</i> (Bhattacharyya, 1966)	15	17.241	2.22	0.8959	2.0153	0.9654	0.1041
2.	<i>Bdella</i> (Latreille, 1795)	12	13.793					
3.	<i>Rhizoglyphus echinopus</i> (Fumouze & Robin,1868)	11	12.643					
4.	Hypogastruridae Sp. 1	9	10.344					
5.	Hypogastruridae Sp. 2	11	12.643					
6.	Hypogastruridae Sp. 3	6	6.896					
7.	Isotomidae Sp. 1	5	5.747					
8.	Isotomidae Sp. 3	9	10.344					
9.	Diptera Sp. 1	4	4.597					
10.	Diptera Sp. 2	5	5.747					

Table 4.42: Species diversity indices at Jowar field, Rohtak during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	<i>Cosmolaelaps indicus</i> (Bhattacharyya, 1966)	2	12.5	1.99	0.9137	2.5247	0.9583	0.0863
2.	<i>Bdella</i> (Latreille, 1795)	4	25					
3.	<i>Rhizoglyphus echinopus</i> (Fumouze & Robin, 1868)	2	12.5					
4.	Hypogastruridae Sp. 1	2	12.5					
5.	Hypogastruridae Sp. 2	1	6.25					
6.	Isotomidae Sp. 1	2	12.5					
7.	Isotomidae Sp. 3	2	12.5					
8.	Diptera Sp. 1	1	6.25					

Table 4.43: Arthropod fauna at Forest land, Panipat during 2020-21

Month	Collembola	Acarina	Unidentified specimens	Total
November	2	-	-	2
December	-	-	-	0
January	1	-	-	1
February	3	-	1	4
March	-	-	-	0
April	-	-	-	0
May	3	-	2	5
June	2	-	-	2
July	1	-	1	2
August	1	-	-	1
September	-	-	-	0
October	-	-	-	0
Overall	13	-	4	17

Table 4.44: Arthropod fauna at Forest land, Panipat during 2021-22

Month	Collembola	Acarina	Unidentified specimens	Total
November	2	-	-	2
December	1	-	-	1
January	-	-	-	0
February	2	-	3	5
March	3	-	-	3
April	2	-	-	2
May	1	-	1	2
June	1	-	-	1
July	-	-	-	0
August	2	-	-	2
September	1	-	-	1
October	-	-	-	0
Overall	15	-	4	19

Table 4.45: Arthropod community and their month wise population Forest land, Panipat during 2020-21

Name of the Class/ Order/ Family/ Genus/ species	November	December	January	February	March	April	May	June	July	August	September	October	Total
Collembola/ Entomobryomorpha/ Isotomidae/ Genus 1	1	-	-	2	-	-	1	2	-	1	-	-	7
Collembola/ Poduromorpha/ Hypogastruridae/ Genus 1	1	-	1	1	-	-	2	-	1	-	-	-	6
Unidentified Specimen (01)	-	-	-	1	-	-	1	-	1	-	-	-	3
Unidentified Specimen (02)	-	-	-	-	-	-	1	-	-	-	-	-	1
Total = 4 (Number of taxa observed)	2	0	1	4	0	0	5	2	2	1	0	0	17

Table 4.46: Arthropod community and their month wise population Forest land, Panipat during 2021-22

Name of the Class/ Order/ Family/ Genus/ species	Novembe r	Decembe r	Januar y	Februar y	Marc h	Apri l	Ma y	Jun e	Jul y	Augus t	Septembe r	Octobe r	Tota l
Collembola/ Poduromorpha/ Neanuridae/ Genus 1	2	-	-	1	1	-	1	1	-	1	-	-	7
Collembola/ Entomobryomorph a/ Isotomidae/ Genus 1	-	1	-	1	2	2	-	-	-	1	1	-	8
Unidentified Specimen (03)	-	-	-	2	-	-	-	-	-	-	-	-	2
Unidentified Specimen (04)	-	-	-	1	-	-	1	-	-	-	-	-	2
Total = 4 (Number of taxa observed)	2	1	0	5	3	2	2	1	0	2	1	0	19

Table 4.47: Species diversity indices at Forest land, Panipat during 2020-21

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 1	7	41.176	1.21	0.7292	1.0589	0.8697	0.2708
2	Collembola/ Poduromorpha/ Hypogastruridae/ Genus 1	6	35.294					
3	Unidentified Specimen (01)	3	17.647					
4	Unidentified Specimen (02)	1	5.882					

Table 4.48: Species diversity indices at Forest land, Panipat during 2021-22

S. No.	Taxa / Specimens	Species Abundance	Relative frequency	Shannon Diversity Index (H)	Dominance Index	Richness Index	Evenness Index	Simpson's Index (D)
1.	Collembola/ Poduromorpha/ Neanuridae/ Genus 1	7	36.842	1.21	0.7167	1.0189	0.87	0.2833
2.	Collembola/ Entomobryomorpha/ Isotomidae/ Genus 1	8	42.105					
3.	Unidentified Specimen (03)	2	10.526					
4.	Unidentified Specimen (04)	2	10.526					

Table 4.49 : Overall collembolans reported from different study fields

Taxonomic Position		2020-21										Total	2021-22										Total
		Sugarcane		Rice		Wheat		Jowar		Panipat			Sugarcane		Rice		Wheat		Jowar		Panipat		
CLASS	Genus/Species	Yamu na Nagar	Ka r nal	Ka r nal	Ka i thal	Sirs a	Hisa r	Rohta k	Fore st land	Texti le Land	1	Yamuna nagar	Ka r nal	Ka r nal	Ka i thal	Si r sa	Hi s ar	Roh tak	Fore st land	Texti le land	2	1 +	2
Order-Poduroomorpha																							
Family 1: Hypogastruri dae	Genus 1	-	-	-	-	-	-	9	6	-	15	-	-	-	-	-	-	2	-	-	2	17	
	Genus 2	-	-	-	-	-	7	11	-	-	18	-	-	-	-	-	9	1	-	-	10	28	
	Genus 3	11	-	-	-	-	-	6	-	-	17	6	-	-	-	-	-	-	-	-	6	23	
Family 2: Tullbergiidae	Genus 1	-	-	-	-	13	9	-	-	-	22	-	-	-	-	8	13	-	-	-	21	43	
Family 3: Neanuridae	Genus 1	-	26	-	12	-	-	-	-	-	38	-	10	-	5	-	-	-	-	-	15	53	
Order- Entomobryomorpha																							
Family 1: Isotomidae	<i>Isotomurus</i> sp.1	9	-	-	-	-	-	-	-	-	9	8	-	-	-	-	-	-	-	-	8	17	
	<i>Isotomurus</i> sp.2	-	35	-	-	15	-	-	-	-	50	-	7	-	-	11	-	-	-	-	18	68	

	<i>Cryptopygus</i> sp.1	-	25	-	-	-	-	-	-	-	25	-	8	-	-	-	-	-	-	8	33	
	<i>Proisotoma minuta</i> (Tullberg, 1871)	10	-	-	-	13	-	-	-	-	23	6	-	-	-	11	-	-	-	-	17	40
	Genus 1	7	-	-	-	-	-	5	7	-	19	11	-	-	-	-	-	2	8	-	21	40
	Genus 2	17	-	-	-	-	-	-	-	-	17	8	-	-	-	-	-	-	-	-	8	25
	Genus 3	-	-	-	-	-	7	9	-	-	16	-	-	-	-	-	13	2	-	-	15	31
	Genus 4	-	-	-	-	-	9	-	-	-	9	-	-	-	-	-	10	-	-	-	10	19
Family 2: Paronullidae	<i>Cyphoderus</i> sp.	-	-	11	13	-	-	-	-	-	24	-	-	5	6	-	-	-	-	-	11	35
Order – Symphypleona																						
Family 1: Sminthuridae	Genus 1	-	-	10	13	-	-	-	-	-	23	-	-	5	14	-	-	-	-	-	19	42
Total Collembolans		54	86	21	38	41	32	40	13	-	325	39	25	10	25	30	45	7	8	-	189	514

Table 4.50: Overall mites reported from different study sites

Taxonomic Position		2020-21										2021-22										
		Sugarcane		Rice		Wheat		Jowar	Panipat		Total 1	Sugarcane		Rice		Wheat		Jowar	Panipat		Total 2	Total 1+2
CLASS ARACHNIDA	Genus/Species	Yamunanagar	Karnal	Karnal	Kaithal	Sirsa	Hisar	Rohatak	Forestland	Textileland		Yamunanagar	Karnal	Karnal	Kaithal	Sirsa	Hisar	Rohatak	Forestland	Textileland		
Order- Astigmata																						
Family 1:	<i>Histiostoma feroniarum</i>	-	-	-	-	22	-	-	-	-	22	-	-	-	-	10	-	-	-	-	10	32
Order – Trombidiformes																						
Family 1:	<i>Eotetranychus Carapini</i>	9	-	-	-	-	-	-	-	-	9	9	-	-	-	-	-	-	-	-	9	18
Family 2:	<i>Bdella sp.</i>	8	-	-	-	-	-	12	-	-	20	12	-	-	-	-	-	4	-	-	16	36
Family 3:	<i>Mahunkania hallensis</i>	7	-	11	-	-	-	-	-	-	18	6	-	3	-	-	-	-	-	-	9	27
	<i>Mahunkania secunda</i>	-	10	-	-	-	-	-	-	-	10	-	10	-	-	-	-	-	-	-	10	20
Order – Mesostigmata																						
Family 1:	<i>Trachygamasus medianus</i>	10	-	-	-	-	-	-	-	-	10	8	-	-	-	-	-	-	-	-	8	18

Family 2: Laelapidae	<i>Cosmolaelaps indicus</i>	-	-	-	-	-	-	15	-	-	15	-	-	-	-	-	-	2	-	-	2	17
Order – Oribatida																						
Family 1: Haplozetidae	<i>Trachyoribates ovulum</i>	-	-	-	-	-	13	-	-	-	13	-	-	-	-	-	10	-	-	-	10	23
Order – Sarcoptiformes																						
Family 1: Scheloribatidae	<i>Schelorbitates curvialatus</i>	12	19	-	-	-	-	-	-	-	31	8	11	-	-	-	-	-	-	-	19	50
	<i>Schelorbitates thermophilus</i>	-	-	-	13	-	16	-	-	-	29	-	-	-	14	-	14	-	-	-	28	57
Family 2: Protoribatidae	<i>Protoribates magnus</i>	-	13	-	-	-	15	-	-	-	28	-	-	-	-	-	13	-	-	-	13	41
Family 3: Epilohmanniidae	<i>Epilohmannia minuta aegyptica</i>	-	22	12	11	-	-	-	-	-	45	-	12	2	6	-	-	-	-	-	20	65
Family 4: Acaridae	<i>Acarus gracillis</i>	-	-	-	-	12	-	-	-	-	12	-	-	-	-	11	-	-	-	-	11	23
	<i>Rhizoglyphus echinopus</i>	-	-	-	-	21	-	11	-	-	32	-	-	-	-	9	-	2	-	-	11	43
Total mites		46	64	23	24	55	44	38	-	-	294	43	33	5	20	30	37	8	-	-	176	470

Table 4.51: Other arthropods reported from different study sites

Other Identified Arthropods		2020-21										2021-22										Total 1+2
		Sugarcane		Rice		Wheat		Jowar	Panipat		Total 1	Sugarcane		Rice		Wheat		Jowar	Panipat		Total 2	
CLASS INSECTA	Genus/Species	Yamunanagar	Karnal	Karnal	Kaithal	Sirsa	Hisar	Rohtak	Forest land	Textile land		Yamunanagar	Karnal	Karnal	Kaithal	Sirsa	Hisar	Rohtak	Forest land	Textile land		
Order – Diptera																						
	Specimen 1	-	-	-	-	-	-	4	-	-	4	-	-	-	-	-	-	1	-	-	1	5
	Specimen 2	21	-	-	2	-	-	5	-	-	28	3	-	-	1	-	-	-	-	-	4	32
	Specimen 3	-	-	5	3	-	-	-	-	-	8	-	-	2	2	-	-	-	-	-	4	12
	Specimen 4	-	11	-	-	-	-	-	-	-	11	-	4	-	-	-	-	-	-	-	4	15
Order – Thysanura																						
	Specimen 1	21	-	-	-	-	-	-	-	-	21	4	-	-	-	-	-	-	-	-	4	25
	Specimen 2	-	2	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	1	3

	Specimen 3	-	3	-	-	-	-	-	-	-	3	-	1	-	-	-	-	-	-	-	1	4	
	Specimen 4	-	1	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	1	2	
	Specimen 5	-	-	2	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	2	4	
CLASS EUHELICERATA																							
Order – Araneae																							
Family1: Linyphiidae	Genus 1	12	-	5	1	9	11	-	-	-	3 8	4	-	2	1	5	4	-	-	-	16	54	
Total		54	17	12	6	9	11	9	-	-	1 1 8	11	7	6	4	5	4	1	-	-	38	15 6	

Table 4.52 : Unidentified specimens reported from different study fields

Unidentified Specimens (On the basis of morphology)	2020-21									2021-22								
	Sugarcane		Rice		Wheat		Jowar	Panipat		Sugarcane		Rice		Wheat		Jowar	Panipat	
	Yamun anagar	Karn al	Kar nal	Kait hal	Sirsa	Hisar	Rohtak	Forest land	Textile land	Yamuna nagar	Kar nal	Kar nal	Kait hal	Sirsa	Hisar	Rohtak	Forest land	Textile land
Unidentified Specimen (01)	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (02)	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (03)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Unidentified Specimen (04)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Unidentified Specimen (05)	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (06)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Unidentified Specimen (07)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Unidentified Specimen (08)	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-

Unidentified Specimen (09)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Unidentified Specimen (10)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Unidentified Specimen (11)	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (12)	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (13)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Unidentified Specimen (14)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Unidentified Specimen (15)	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (16)	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (17)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
Unidentified Specimen (18)	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (19)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-

Unidentified Specimen (20)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Unidentified Specimen (21)	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Unidentified Specimen (22)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (23)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (24)	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Unidentified Specimen (25)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (26)	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Unidentified Specimen (27)	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Unidentified Specimen (28)	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Unidentified Specimen (29)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (30)	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-

Unidentified Specimen (31)	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (32)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (33)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (34)	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Unidentified Specimen (35)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (36)	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Unidentified Specimen (37)	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (38)	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (39)	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (40)	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Specimen (41)	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Unidentified Specimen (42)	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
-----------------------------------	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Note: Reason behind so many unidentified specimens was either their damage during identification by specialists or very few in number or once photographed then lost during screening.

4.3 Effects of edaphic variables on the soil arthropods of several districts in Haryana

Soil supports a large variety of flora, fungi, and fauna, of which soil arthropods contribute a very significant ratio. Biodiversity varies widely with the composition of the soil. Therefore, it is crucial to consider how soil edaphic variables affect the variety of soil microarthropods. The great species richness or the diverse ecosystems that exist beneath the soil may be the cause of the existing lack of information regarding the distribution and diversity patterns of soil arthropods (Brussaard et al., 1997). It is now widely accepted that edaphic factors can only substantially influence the population of soil arthropods.

This study's objective was to shed light on how soil edaphic variables affected the variety and spread of soil arthropod populations. We selected nine different types of fields in Haryana. We formulate the hypothesis that the changes in edaphic factors may impact the soil arthropod population. A linear regression analysis of the population dynamics of soil arthropods is carried out with respect to the edaphic factors and the chemical composition of the soil. Additionally, we looked at the relationship between the population of soil microarthropods, edaphic variables, and the chemical makeup of soil. We used EXCEL 2007 to carry out the statistical analysis of the samples collected from different study fields in different districts of Haryana.

The results are summarised field-wise during the two years (2020 - 2021 and 2021 - 2022) of study for correlation as well as linear regression as follows:

For Sugarcane fields in Yamunanagar, soil moisture, OC, available N, Fe, and Cu always remain statistically negatively correlated, while soil temperature, OM, and available Mn always remain statistically positively correlated. In other edaphic factors like soil pH, EC, available S, P, K, and Zn, both types of correlations are observed year-wise (Table 4.53, Figure 4.18). For Sugarcane fields in Karnal, soil temperature, OM, EC, available S, P, K, Cu, and Mn always remain statistically positively correlated, while SOM, pH, and available N always remain statistically negatively correlated. In other edaphic factors like soil moisture, available Zn, and Fe, both types

of correlations are observed year-wise (Table 4.54, Figure 4.19). For Rice fields, Karnal, soil pH, EC, available N, S, P, Fe, and Cu always remain statistically negatively correlated, while soil temperature, available K, Zn, and Mn always remain statistically positively correlated. In other edaphic factors like soil moisture, OC, OM, and available Cu, both types of correlations are observed year-wise (Table 4.55, Figure 4.20). For Rice fields, Kaithal, soil moisture, temperature, available K, and Zn always remain statistically positively correlated, while soil pH, EC, available N, S, P, Fe, Cu, and Zn always remain statistically negatively correlated. In other edaphic factors like SOC and SOM, both types of correlations are observed year-wise (Table 4.56, Figure 4.21).

For Wheat fields, Sirsa, soil moisture, temperature, available P, and Fe always remain statistically positively correlated, while SOM, pH, available S, Zn, and Fe always remain statistically negatively correlated. In other edaphic factors like SOC, pH, EC, available N, K, and Mn, both types of correlations are observed year-wise (Table 4.57, Figure 4.22). For Wheat field, Hisar, soil pH, available N, and K always remain statistically positively correlated, while soil moisture, EC, and available Fe, Cu, and Mn always remain statistically negatively correlated. In other edaphic factors like soil temperature, OC, OM, available S, and P, both types of correlations are observed year-wise. In addition, the available Zn shows a neutral correlation in the previous year while a negative correlation in the next year (Table 4.58, Figure 4.23). For Jowar field, Rohtak, soil moisture, OM, available S, K, Cu, and Mn always remain statistically positively correlated, while soil temperature, pH, available N, Zn, and Fe always remain statistically negatively correlated. In other edaphic factors like SOC, EC, and available P, both types of correlations are observed year-wise (Table 4.59, Figure 4.24). For forest land in Panipat, soil EC always remains statistically positively correlated, while SOC, OM, pH, and available P always remain statistically negatively correlated. In other edaphic factors like soil moisture, temperature, available N, S, K, Zn, Fe, Cu, and Mn, both types of correlations are observed year-wise (Table 4.60, Figure 4.25).

Table 4.53: Correlation between edaphic factors and soil arthropods observed at Sugarcane field, Yamunanagar

S. No.	Edaphic Factors ↓	2020-2021			2021-2022		
		Collembola	Acarina	Total Arthropods	Collembola	Acarina	Total Arthropods
1	Soil Moisture	-0.518	-0.484	-0.565*	-0.573*	-0.545*	-0.725*
2	Soil Temperature	0.843*	0.841*	0.883*	0.605*	0.289	0.597*
3	SOC	-0.001	-0.124	-0.176	-0.044	-0.164	-0.174
4	SOM	0.705*	0.756*	0.836*	0.561*	-0.330	0.264
5	Soil pH	-0.350	-0.508	-0.412	-0.350	0.403	0.117
6	Soil EC	0.292	0.169	0.159	-0.145	0.078	-0.038
7	Available N	-0.135	-0.231	-0.269	-0.236	0.120	-0.011
8	Available S	0.004	0.503	0.283	-0.055	-0.513	-0.380
9	Available P	0.276	0.427	0.370	-0.201	-0.663*	-0.428
10	Available K	0.379	0.637*	0.511	-0.158	-0.734*	-0.629*
11	Available Zn	0.115	0.345	0.165	0.073	-0.610*	-0.444
12	Available Fe	-0.559*	-0.605*	-0.635*	-0.475	0.218	-0.238
13	Available Cu	-0.522	-0.246	-0.407	-0.235	-0.258	-0.333
14	Available Mn	-0.048	0.283	0.158	-0.514	0.373	0.118

* - Significant at 0.05

Table 4.54: Correlation between edaphic factors and soil arthropods observed at Sugarcane field, Karnal

S. No.	Edaphic Factors ↓	2020-2021			2021-2022		
		Collembola	Acarina	Total Arthropods	Collembola	Acarina	Total Arthropods
1	Soil Moisture	-0.259	-0.473	-0.219	0.269	-0.279	0.028
2	Soil Temp.	0.765*	0.877*	0.896*	0.594*	0.466	0.764*
3	SOC	0.037	-0.304	-0.067	-0.672	0.044	-0.233
4	SOM	0.675*	0.866*	0.877*	0.617*	0.525	0.823*
5	Soil pH	-0.360	-0.479	-0.594*	0.058	-0.554*	-0.503
6	Soil EC	0.280	0.060	0.312	0.121	0.390	0.416
7	Available N	-0.264	-0.561*	-0.412	-0.236	-0.234	-0.389
8	Available S	0.268	0.210	0.352	0.329	0.172	0.271
9	Available P	0.376	0.267	0.313	0.064	0.210	0.038
10	Available K	0.386	0.423	0.435	0.204	0.274	0.167
11	Available Zn	0.359	0.418	0.539*	0.219	-0.371	-0.329
12	Available Fe	-0.175	-0.167	-0.179	0.587*	-0.218	0.145
13	Available Cu	0.285	-0.036	0.161	0.356	-0.146	0.173
14	Available Mn	0.177	0.277	0.177	0.487	0.002	0.326

* - Significant at 0.05

Table 4.55: Correlation between edaphic factors and soil arthropods observed at Rice field, Karnal

S. No.	Edaphic Factors ↓	2020-2021			2021-2022		
		Collembola	Acarina	Total Arthropods	Collembola	Acarina	Total Arthropods
1	Soil Moisture	0.827*	0.503	0.139	-0.715*	-0.061	-0.929*
2	Soil Temperature	-0.355	0.073	0.710*	0.806*	-0.399	0.764*
3	SOC	-0.534*	-0.177	-0.209	0.021	0.679*	0.704*
4	SOM	-0.534*	-0.177	-0.209	0.210	0.070	0.816*
5	Soil pH	-0.850*	-0.344	-0.800*	-0.204	0.730*	-0.038
6	Soil EC	0.274	0.275	-0.315	-0.632*	-0.258	-0.950*
7	Available N	0.720*	0.211	-0.587*	-0.649*	0.659*	-0.494
8	Available S	0.184	-0.077	-0.215	-0.174	-0.433	-0.828*
9	Available P	-0.294	-0.171	-0.761*	-0.525	0.191	-0.735*
10	Available K	-0.180	-0.011	0.782*	0.641*	-0.618*	0.609*
11	Available Zn	0.160	-0.059	0.743*	0.857*	-0.332	0.789*
12	Available Fe	0.936*	-0.133	-0.643*	-0.287	0.781*	-0.229
13	Available Cu	-0.998*	-0.436	-0.728*	2.298	0.846*	0.312
14	Available Mn	0.744*	0.294	0.825*	0.310	-0.852*	0.023

* - Significant at 0.05

Table 4.56: Correlation between edaphic factors and soil arthropods observed at Rice field, Kaithal

S. No.	Edaphic Factors ↓	2020-2021			2021-2022		
		Collembola	Acarina	Total Arthropods	Collembola	Acarina	Total Arthropods
1	Soil Moisture	0.779*	-0.416	0.766*	0.0317	0.746*	0.515
2	Soil Temperature	0.754*	-0.224	0.774*	0.124	0.753*	0.537*
3	SOC	0.344	0.481	0.481	0.17	-0.741*	-0.187
4	SOM	-0.479	-0.626*	-0.390	0.339	-0.770*	0.056
5	Soil pH	-0.435	-0.442	-0.480	-0.372	-0.430	-0.537*
6	Soil EC	-0.637*	-0.783*	-0.713*	0.274	-0.871*	-0.081
7	Available N	-0.352	0.002	-0.324	-0.116	-0.608*	-0.415
8	Available S	-0.450	0.559*	-0.515	-0.167	-0.150	-0.457
9	Available P	-0.759*	-0.233	-0.835*	-0.220	-0.726*	-0.657*
10	Available K	0.658*	-0.238	0.615*	-0.300	0.673*	0.180
11	Available Zn	0.780*	0.170	0.816*	0.204	0.843*	0.598*
12	Available Fe	-0.895*	-0.555*	-0.897*	-0.310	-0.969*	-0.688*
13	Available Cu	-0.687*	-0.792*	-0.644*	-0.588*	2.178E	-0.452
14	Available Mn	0.053	0.606*	-0.015	-0.414	0.085	-0.459

* - Significant at 0.05

Table 4.57: Correlation between edaphic factors and soil arthropods observed at Wheat field, Sirsa

S. No.	Edaphic Factors ↓	2020-2021			2021-2022		
		Collembola	Acarina	Total Arthropods	Collembola	Acarina	Total Arthropods
1	Soil Moisture	0.970*	0.760*	0.786*	0.924*	-0.135	0.713*
2	Soil Temperature	0.714*	0.771*	0.848*	0.614*	0.508	0.906*
3	SOC	0.163	0.137	0.155	0.205	-0.426	-0.338
4	SOM	-0.797*	-0.728*	-0.661*	-0.084	-0.514	-0.603*
5	Soil pH	-0.663*	-0.613*	-0.564*	-0.191	-0.512	-0.686*
6	Soil EC	0.038	0.468	0.316	-0.596*	-0.147	-0.313
7	Available N	0.144	0.118	0.138	0.261	-0.453	-0.318
8	Available S	-0.312	-0.515	-0.453	-0.607*	-0.548*	-0.864*
9	Available P	0.362	0.273	0.150	0.544*	-0.469	0.410
10	Available K	-0.027	-0.491	-0.395	0.862*	-0.446	0.631*
11	Available Zn	-0.754*	-0.876*	-0.856*	-0.598*	-0.494	-0.825*
12	Available Fe	0.875*	0.481	0.509	0.239	-0.310	0.085
13	Available Cu	-0.294	-0.406	-0.526	-0.871*	-0.473	-0.402
14	Available Mn	0.109	0.108	0.214	-0.725	-0.206	-0.931*

* - Significant at 0.05

Table 4.58: Correlation between edaphic factors and soil arthropods observed at Wheat field, Hisar

S. No.	Edaphic Factors ↓	2020-2021			2021-2022		
		Collembola	Acarina	Total Arthropods	Collembola	Acarina	Total Arthropods
1	Soil Moisture	-0.671*	0.210	-0.385	-0.572*	0.025	-0.131
2	Soil Temperature	-0.310	0.005	-0.313	0.221	0.250	0.471
3	SOC	0.298	0.663*	0.686*	-0.151	0.103	-0.087
4	SOM	0.622	-0.402	0.249	-0.373	-0.377	-0.636*
5	Soil pH	0.215	0.05	0.347	-0.223	0.180	0.050
6	Soil EC	-0.363	0.432	-0.190	0.067	-0.381	-0.168
7	Available N	0.369	0.779*	0.785*	0.301	0.663*	0.470
8	Available S	0.265	-0.234	0.252	-0.475	0.060	-0.188
9	Available P	-0.751*	0.454	-0.308	-0.103	0.083	0.292
10	Available K	0.190	0.416	0.464	0.110	0.523	0.241
11	Available Zn	0.002	-0.102	0	-0.489	-0.282	-0.531
12	Available Fe	-0.573*	-0.264	-0.452	-0.676*	-0.133	-0.232
13	Available Cu	-0.777*	-0.626*	-0.939*	-0.273	-0.165	-0.004
14	Available Mn	0.120	-0.635*	-0.032	-0.183	-0.057	-0.291

* - Significant at 0.05

Table 4.59: Correlation between edaphic factors and soil arthropods observed at Jowar field, Rohtak

S. No.	Edaphic Factors ↓	2020-2021			2021-2022		
		Collembola	Acarina	Total Arthropods	Collembola	Acarina	Total Arthropods
1	Soil Moisture	0.950*	0.984*	0.951*	-0.136	0.861*	0.661*
2	Soil Temperature	-0.164	0.042	-0.180	-0.944*	-0.688*	-0.490
3	SOC	-0.330	-0.514	-0.327	0.987*	0.742*	0.794*
4	SOM	0.391	0.289	0.379	0.914*	0.868*	0.824*
5	Soil pH	-0.374	-0.166	-0.383	-0.755*	-0.894*	-0.597*
6	Soil EC	0.109	0.320	0.097	-0.926*	-0.765*	-0.588*
7	Available N	-0.908*	-0.832*	-0.918*	0.148	-0.754*	-0.348
8	Available S	0.101	-0.104	0.105	0.952*	0.697*	0.530
9	Available P	0.243	0.201	0.265	-0.171	0.090	-0.512
10	Available K	0.930*	0.841*	0.929*	-0.401	0.746*	0.654*
11	Available Zn	-0.737*	-0.598*	-0.751*	-0.5	-0.942*	-0.942*
12	Available Fe	-0.816*	-0.677*	-0.818*	0.028	-0.898*	-0.661*
13	Available Cu	0.591*	0.407	0.603*	0	0.862*	0.496
14	Available Mn	0.459	0.639*	0.449	-0.970*	-7.021*	0.084

* - Significant at 0.05

Table 4.60: Correlation between edaphic factors and soil arthropods observed at Forest land, Panipat

S. No.	Edaphic Factors ↓	2020-2021			2021-2022		
		Collembola	Acarina	Total Arthropods	Collembola	Acarina	Total Arthropods
1	Soil Moisture	-0.118	-	-0.183	0.291	-	0.197
2	Soil Temperature	0.028	-	0.207	-0.307	-	-0.185
3	SOC	0.536*	-	0.600*	-0.345	-	0.265
4	SOM	0.554*	-	0.608*	-0.244	-	0.419
5	Soil pH	0.560*	-	0.232	0.5	-	0.424
6	Soil EC	-0.566*	-	-0.475	-1.897*	-	-0.025
7	Available N	0.433	-	0.330	-0.519	-	-0.126
8	Available S	0.186	-	0.681	-0.391	-	-0.066
9	Available P	0.186	-	0.681*	0.003	-	0.096
10	Available K	0.432	-	0.673*	-0.397	-	-0.025
11	Available Zn	-0.482	-	0.068	-0.381	-	-0.333
12	Available Fe	0.177	-	0.133	-0.390	-	-0.056
13	Available Cu	0.441	-	0.485	-0.167	-	-0.033
14	Available Mn	0.563	-	0.816	-0.253	-	-0.125

* - Significant at 0.05

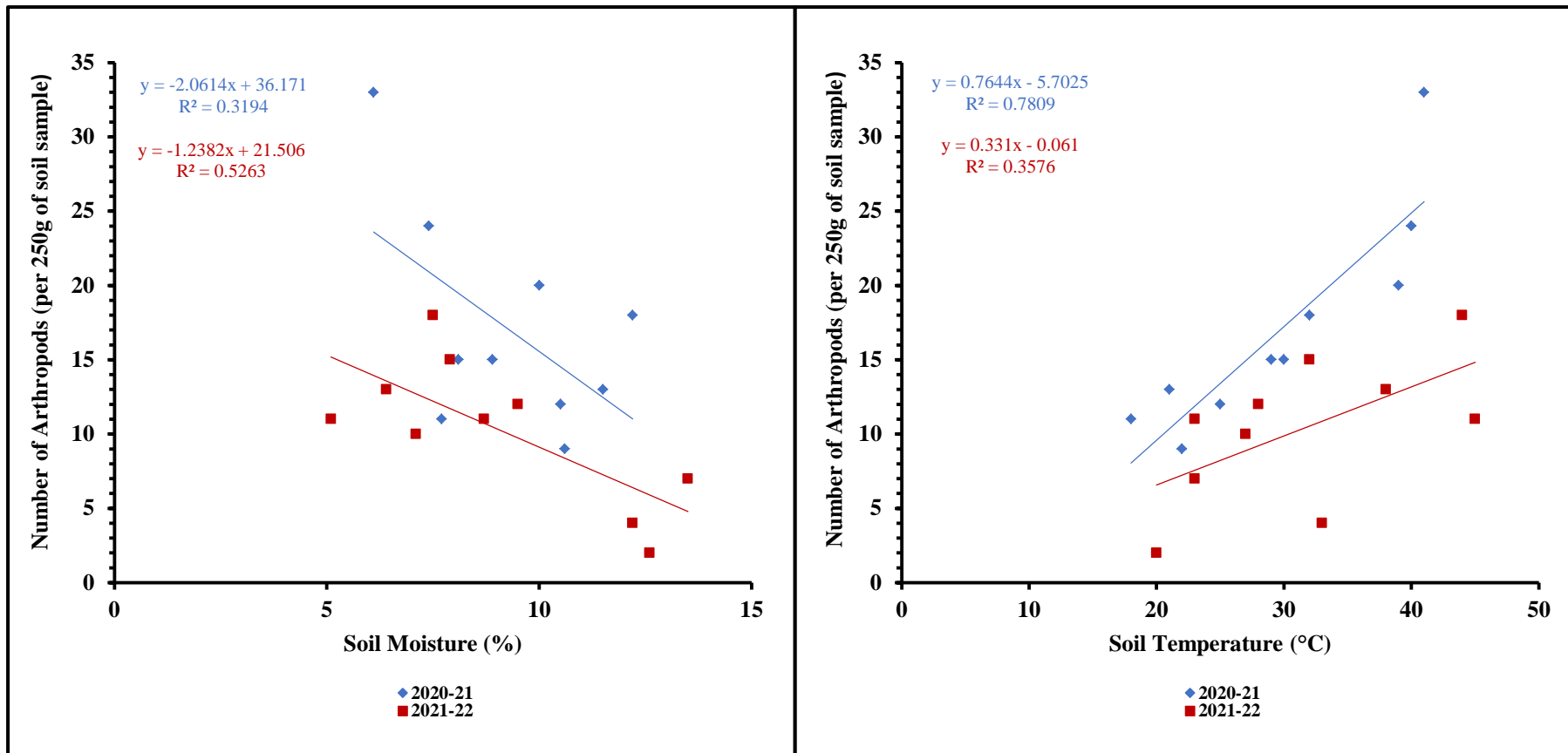


Figure 4.18: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Yamunanagar

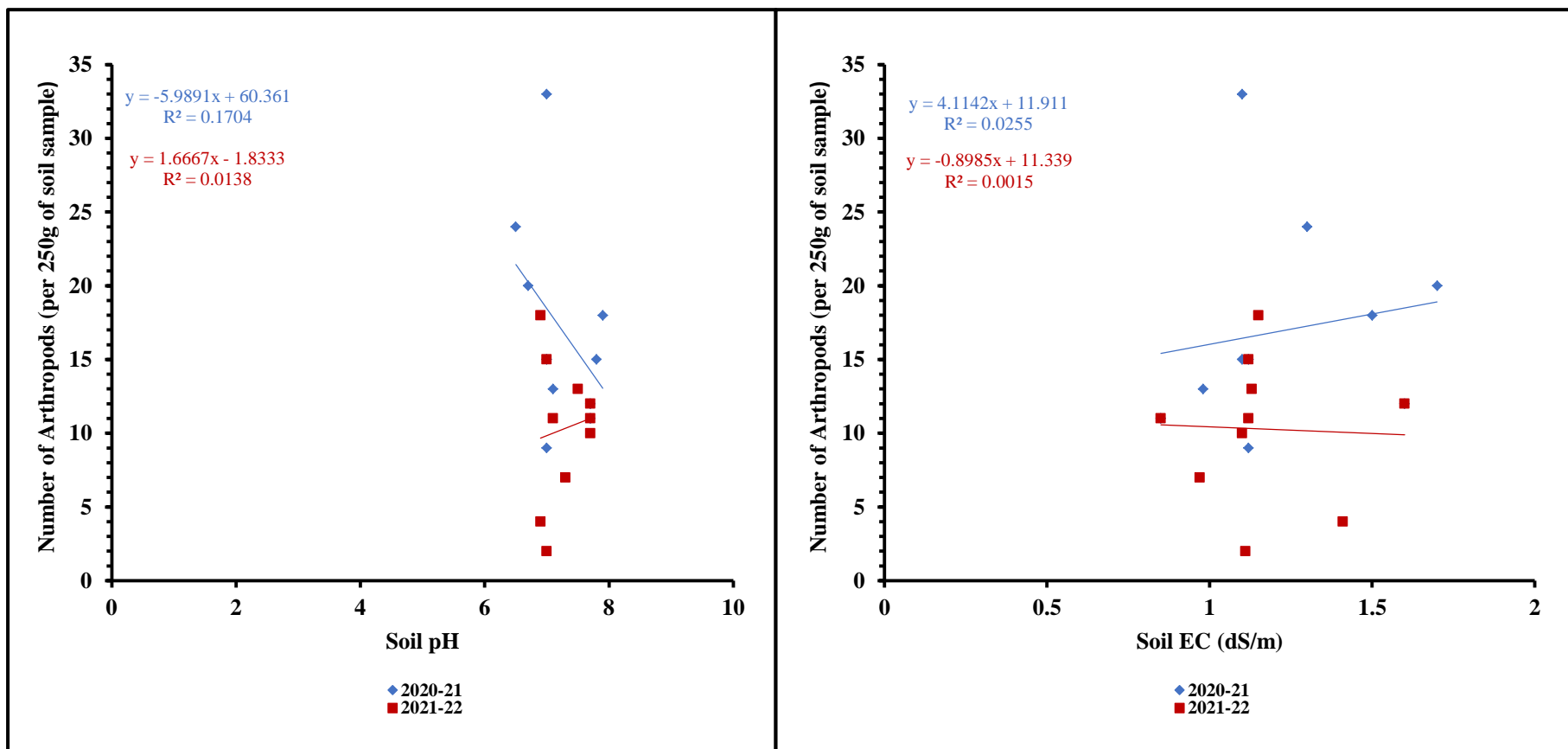


Figure 4.18: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Yamunanagar

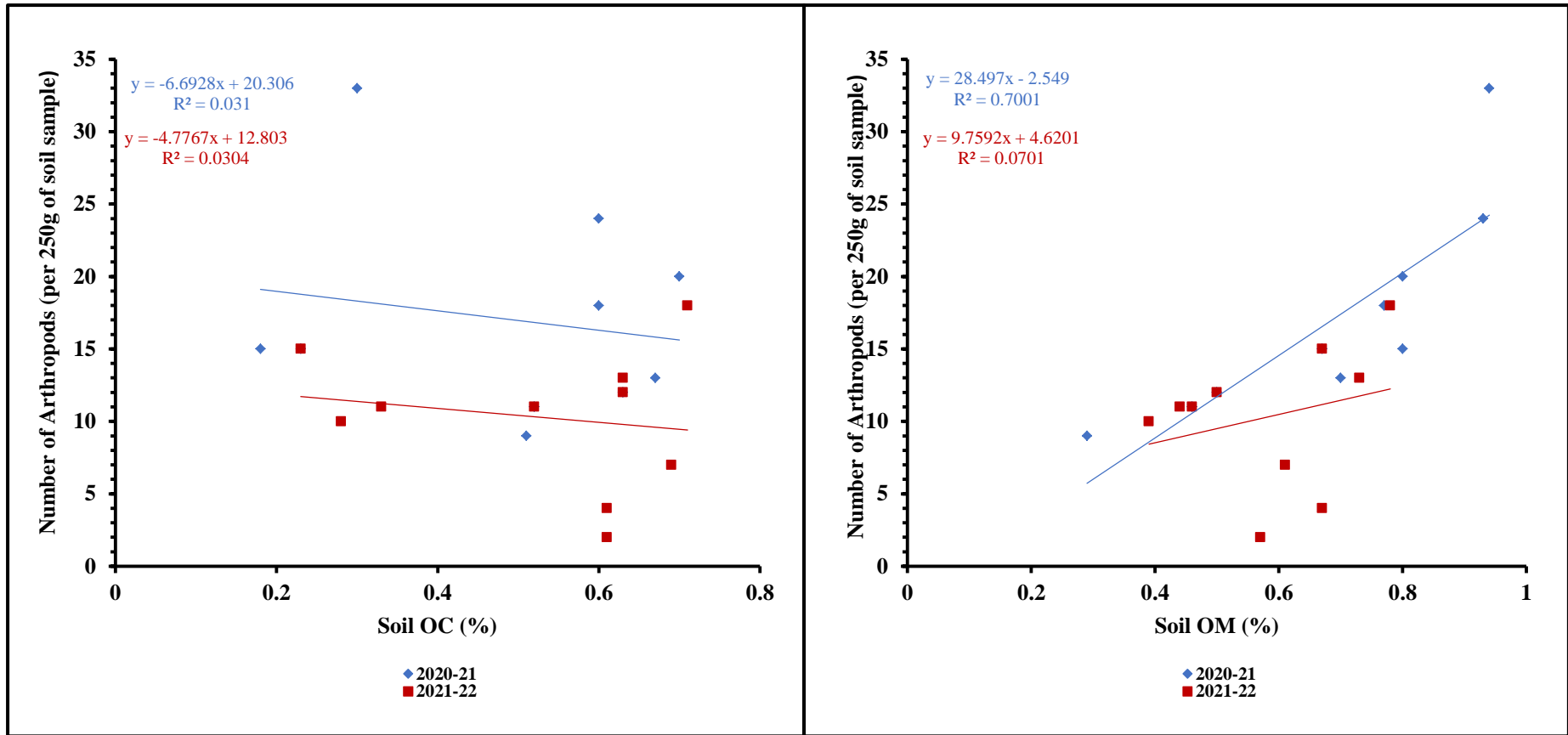


Figure 4.18: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Yamunanagar

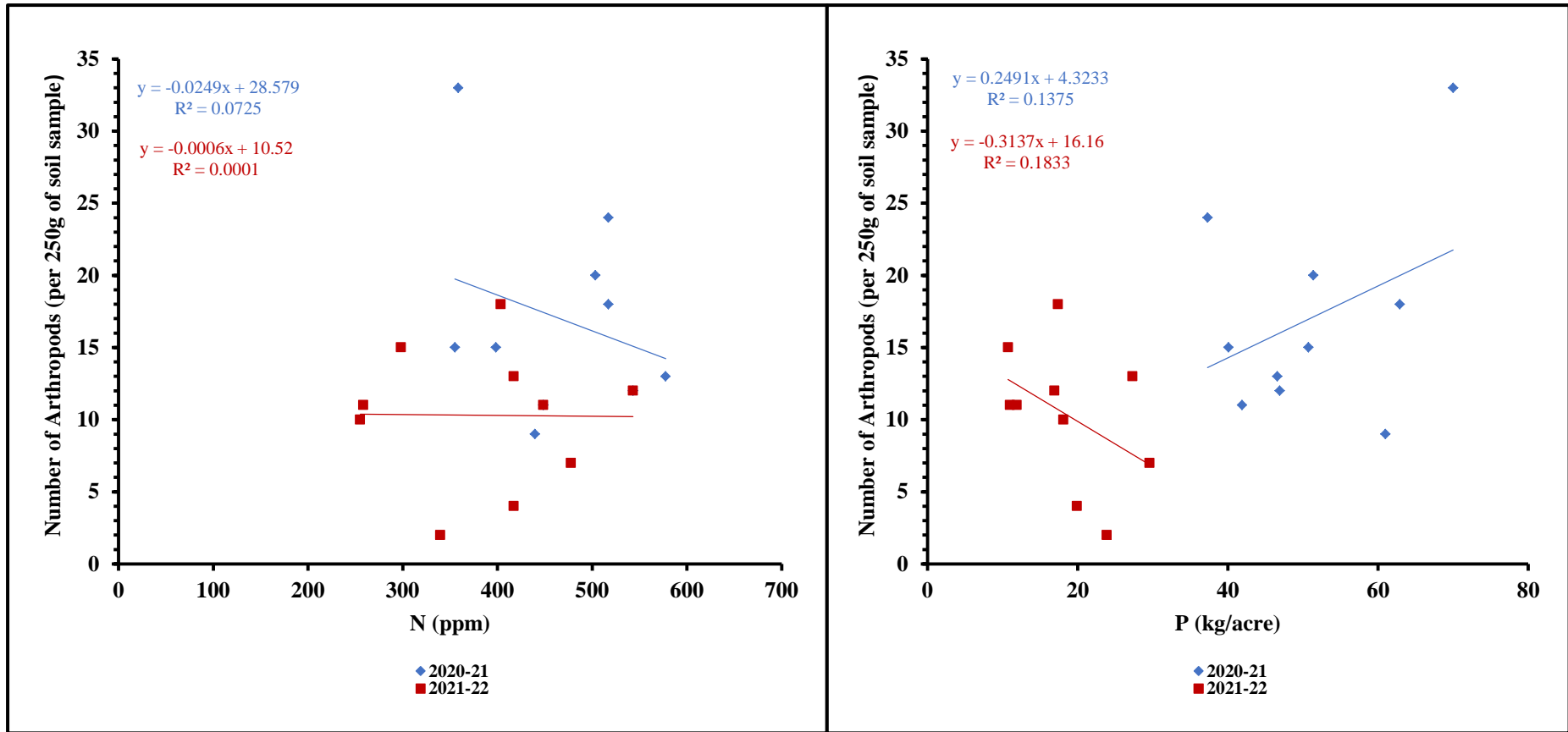


Figure 4.18: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Yamunanagar

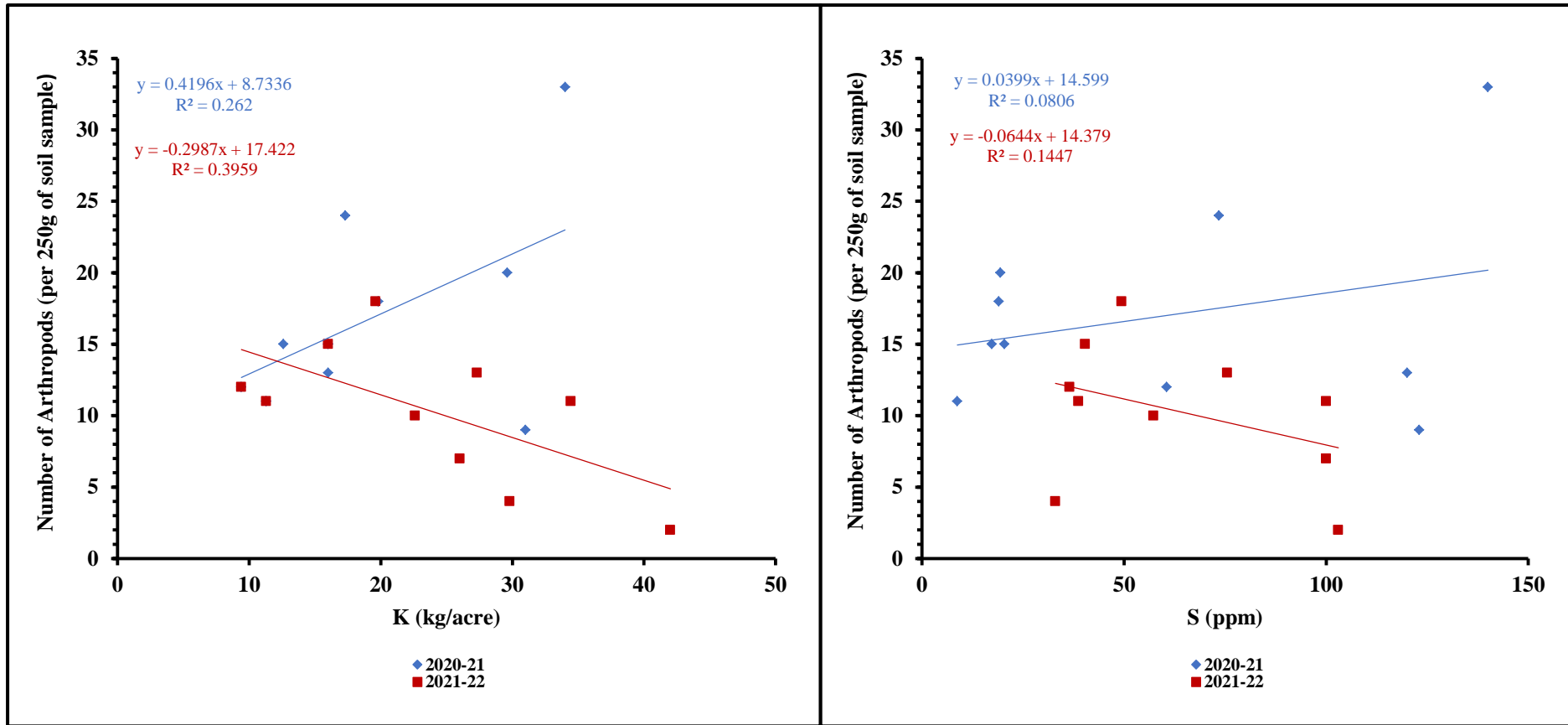


Figure 4.18: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Yamunanagar

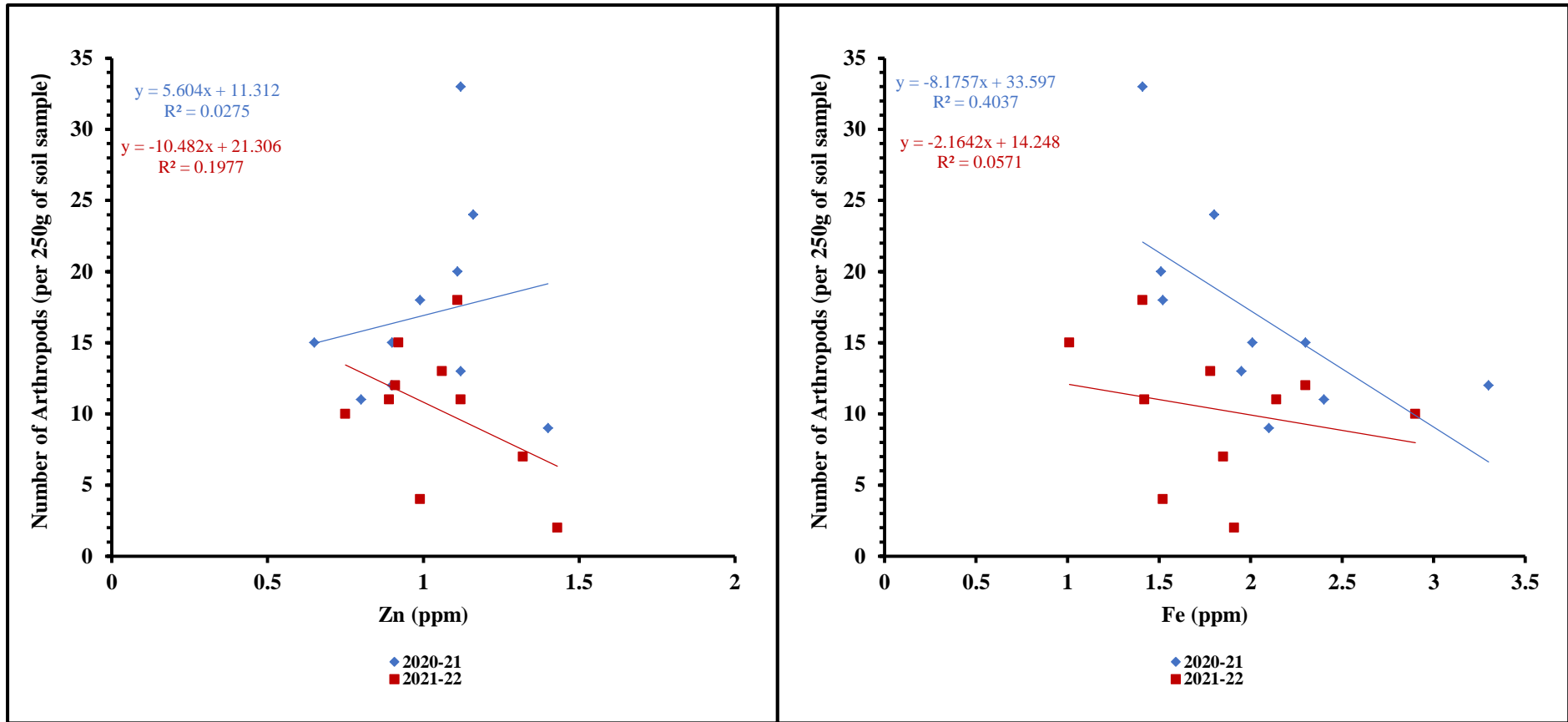
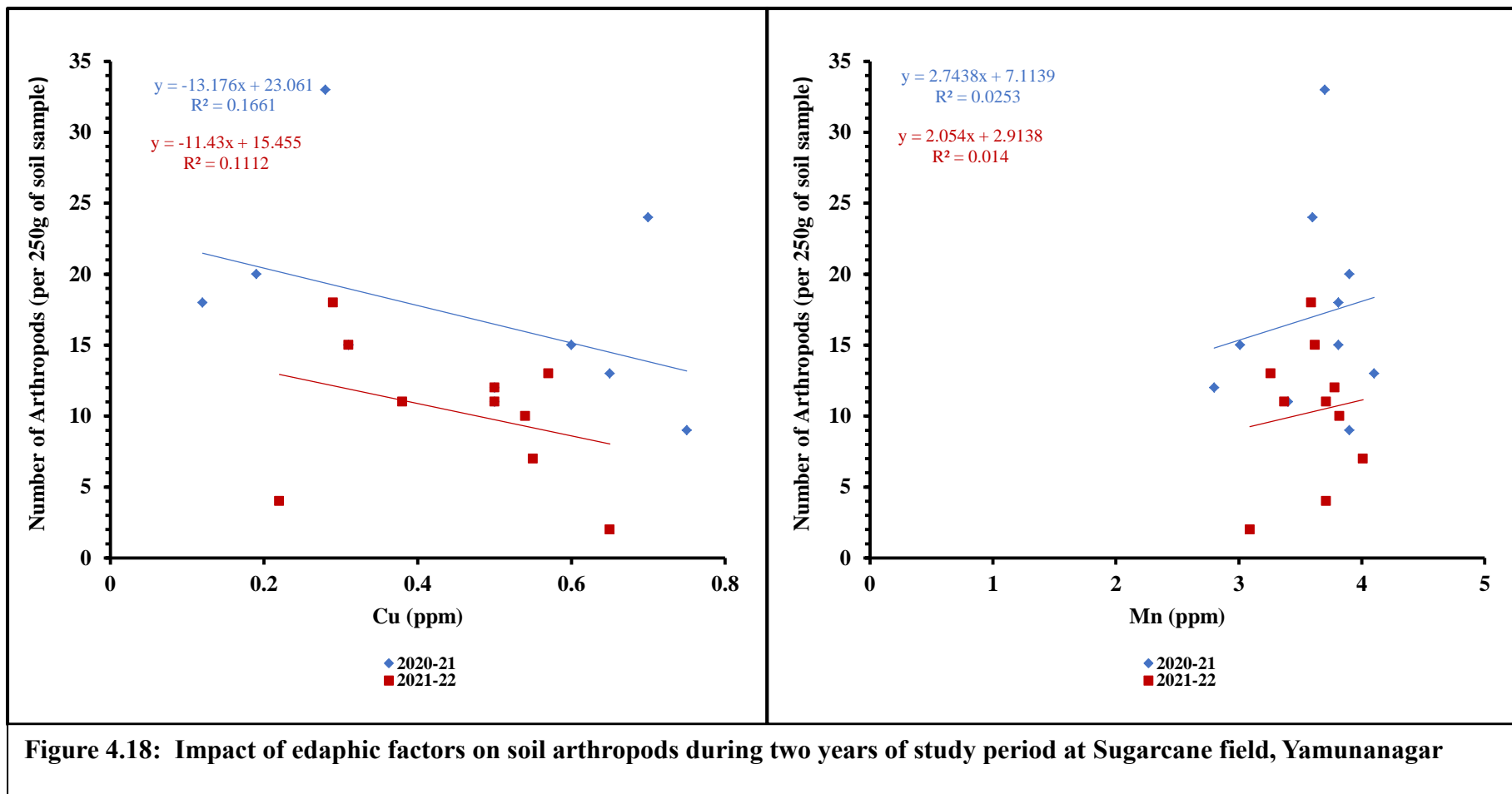


Figure 4.18: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Yamunanagar



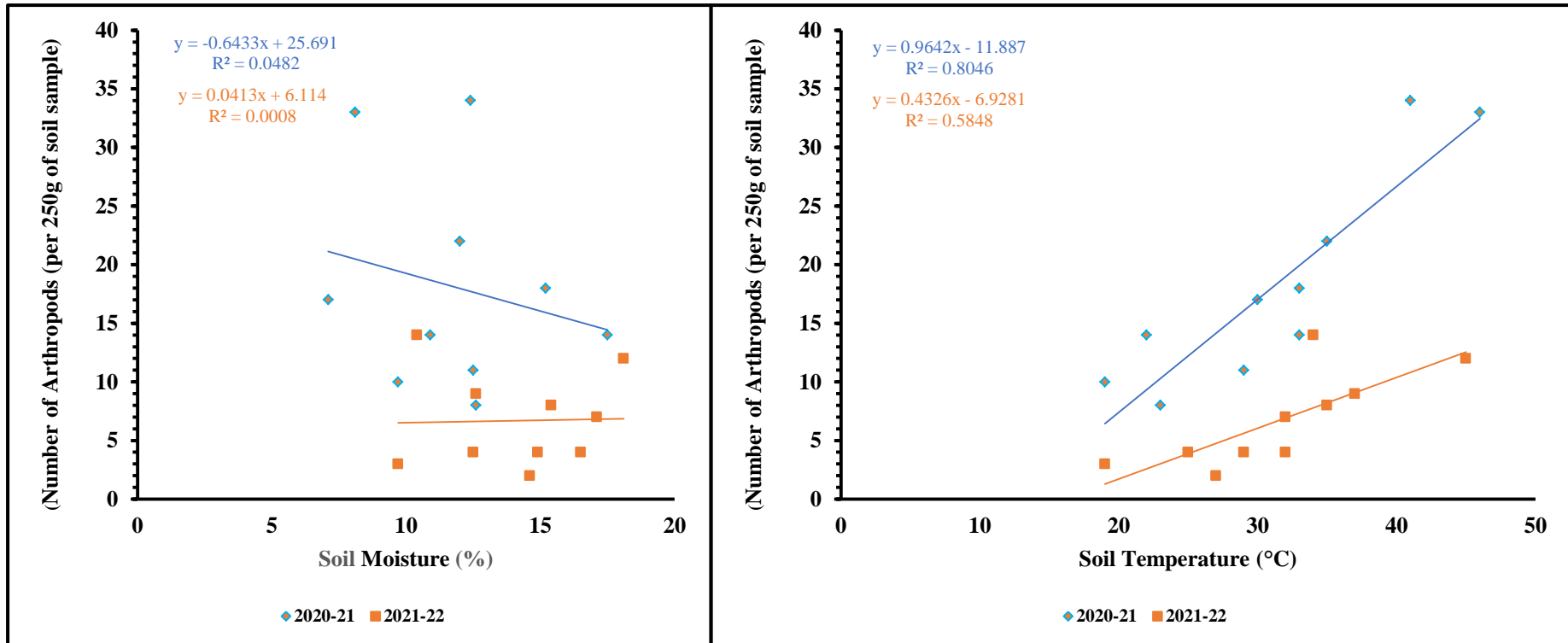


Figure 4.19: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Karnal

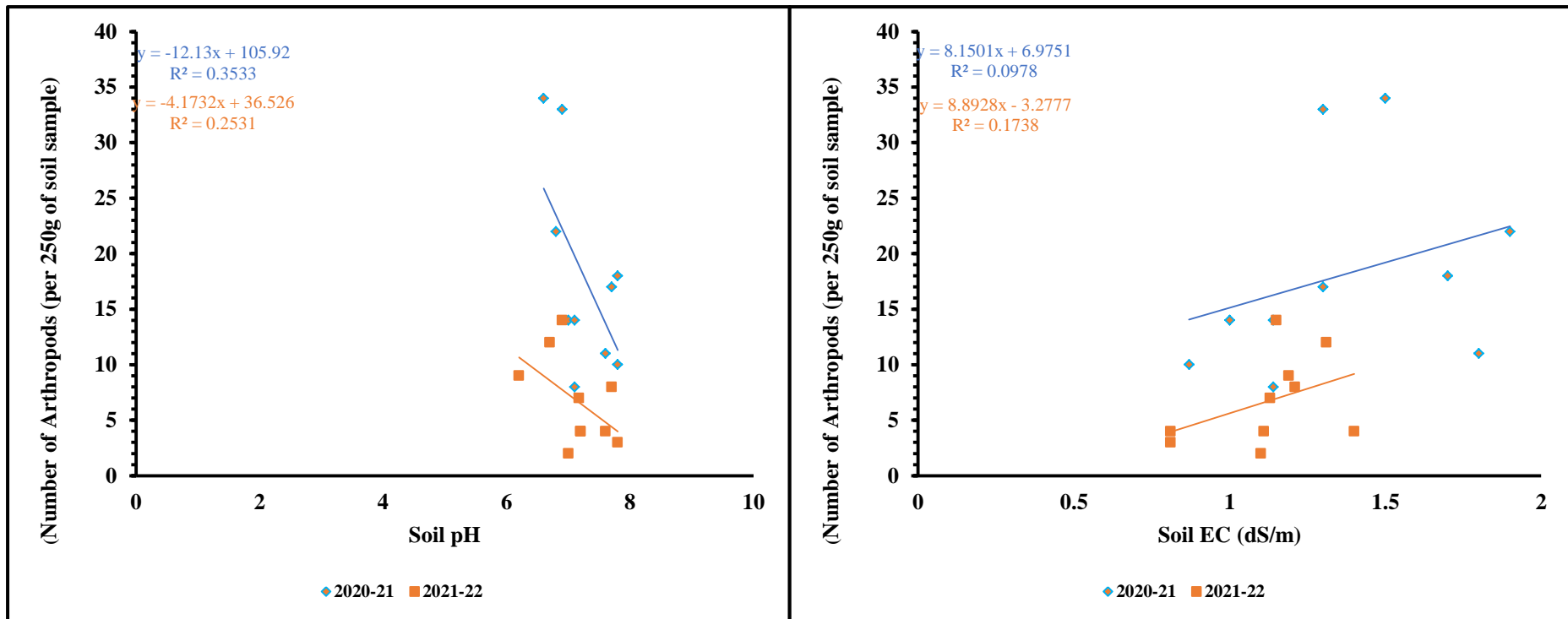


Figure 4.19: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Karnal

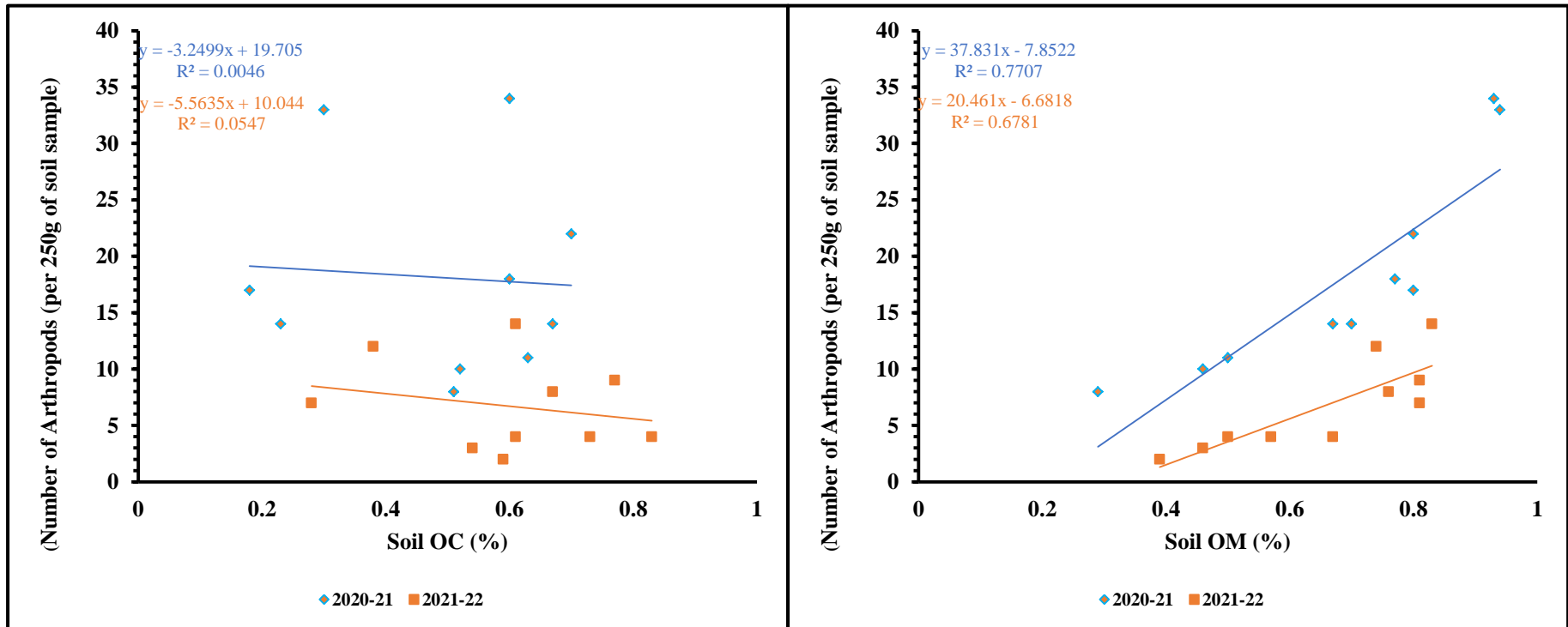


Figure 4.19: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Karnal

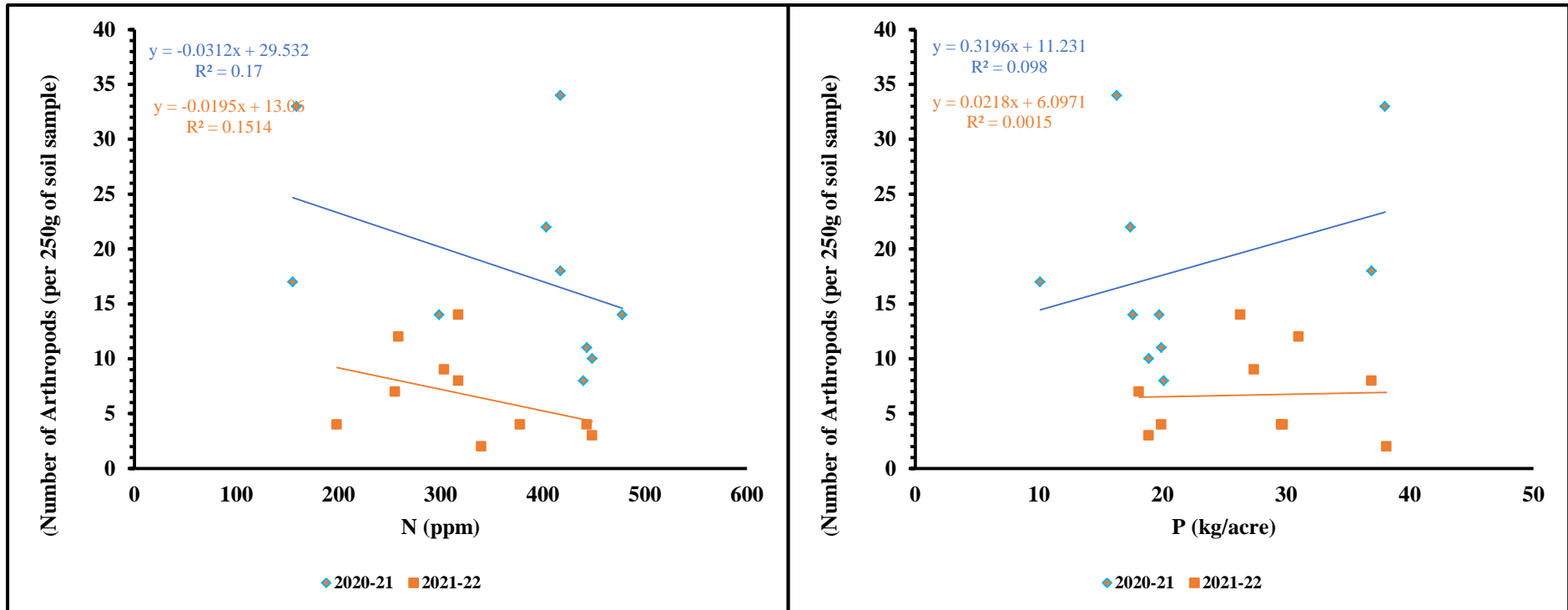


Figure 4.19: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Karnal

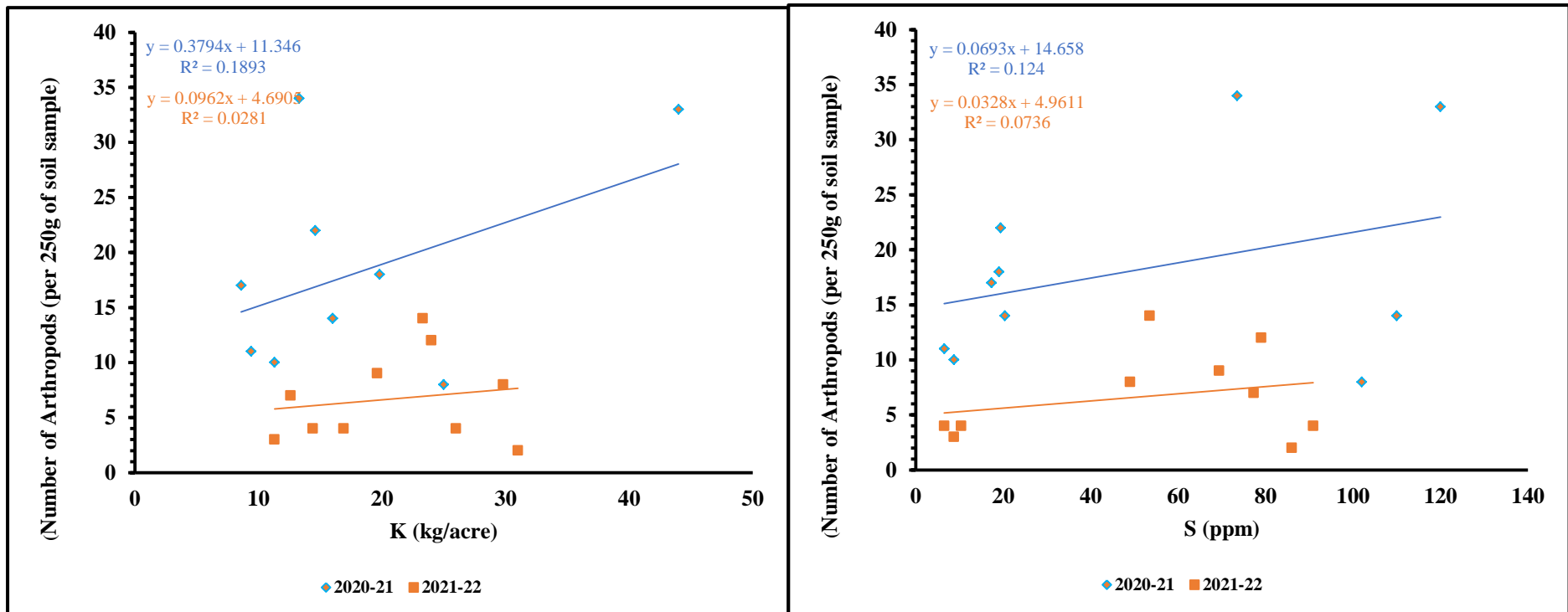


Figure 4.19: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Karnal

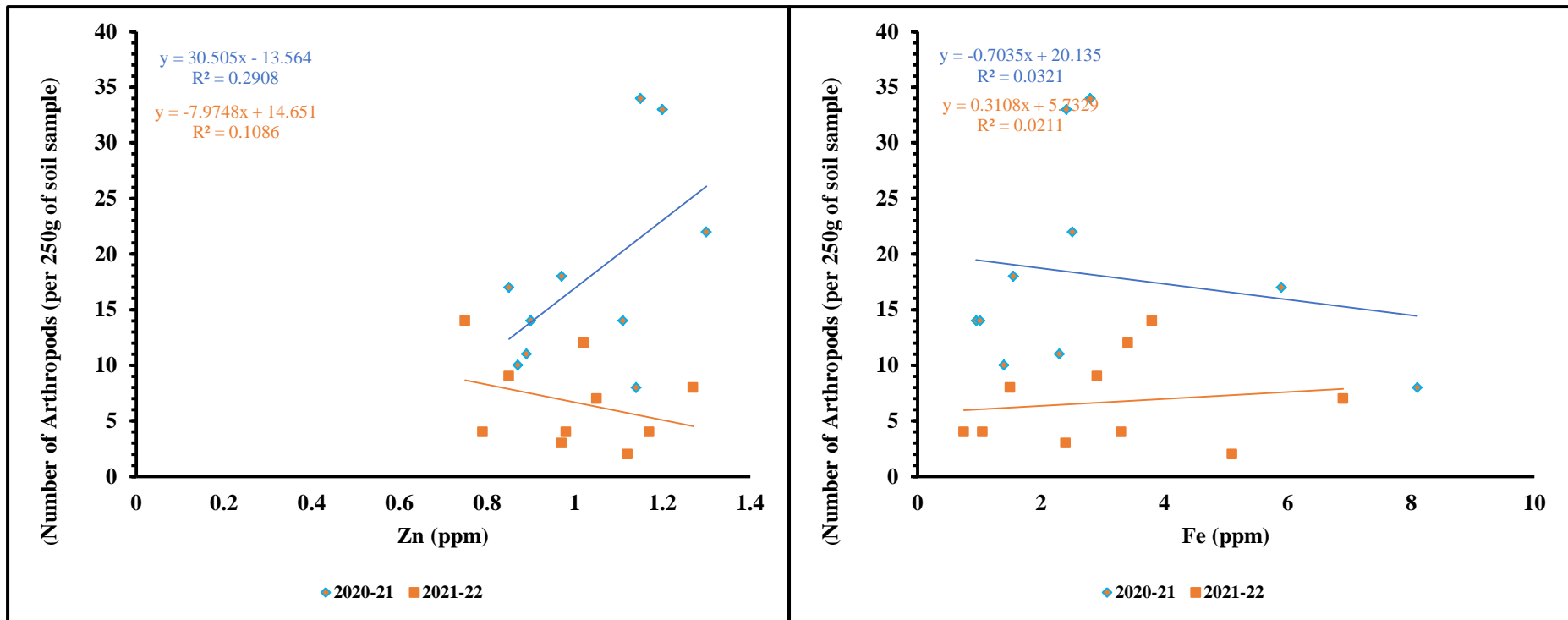


Figure 4.19: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Karnal

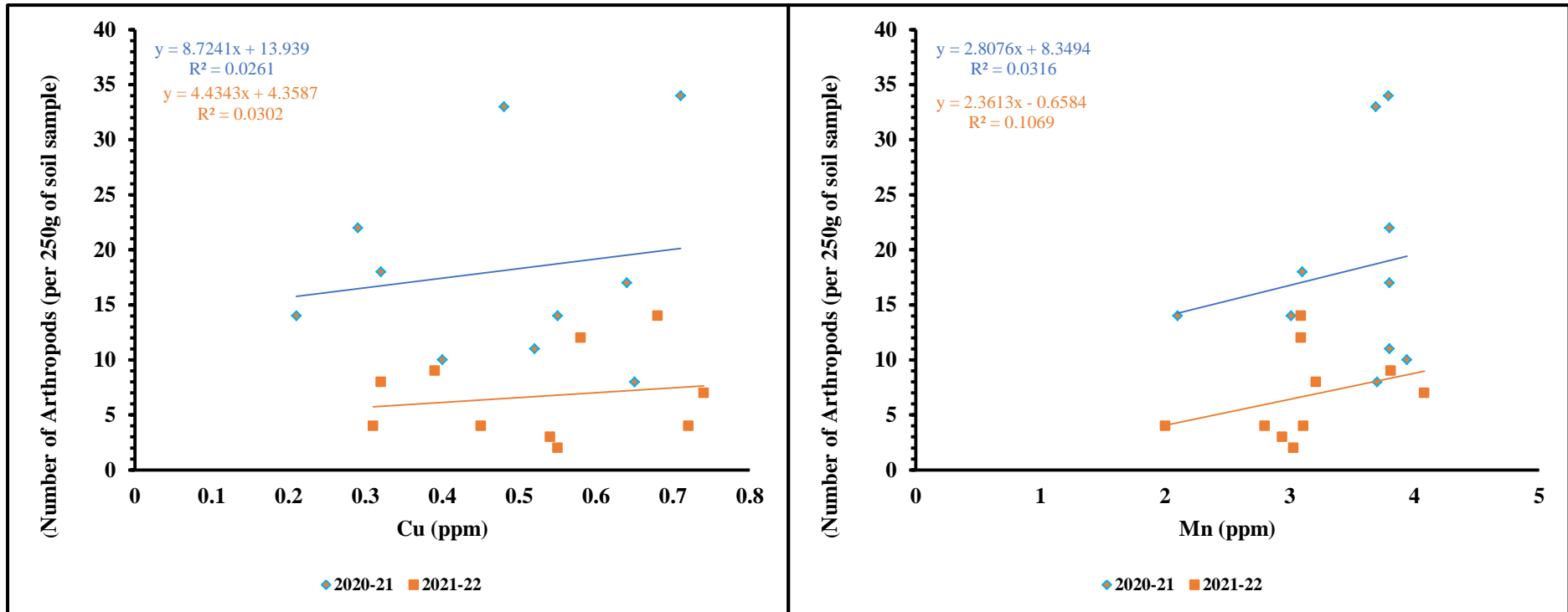


Figure 4.19: Impact of edaphic factors on soil arthropods during two years of study period at Sugarcane field, Karnal

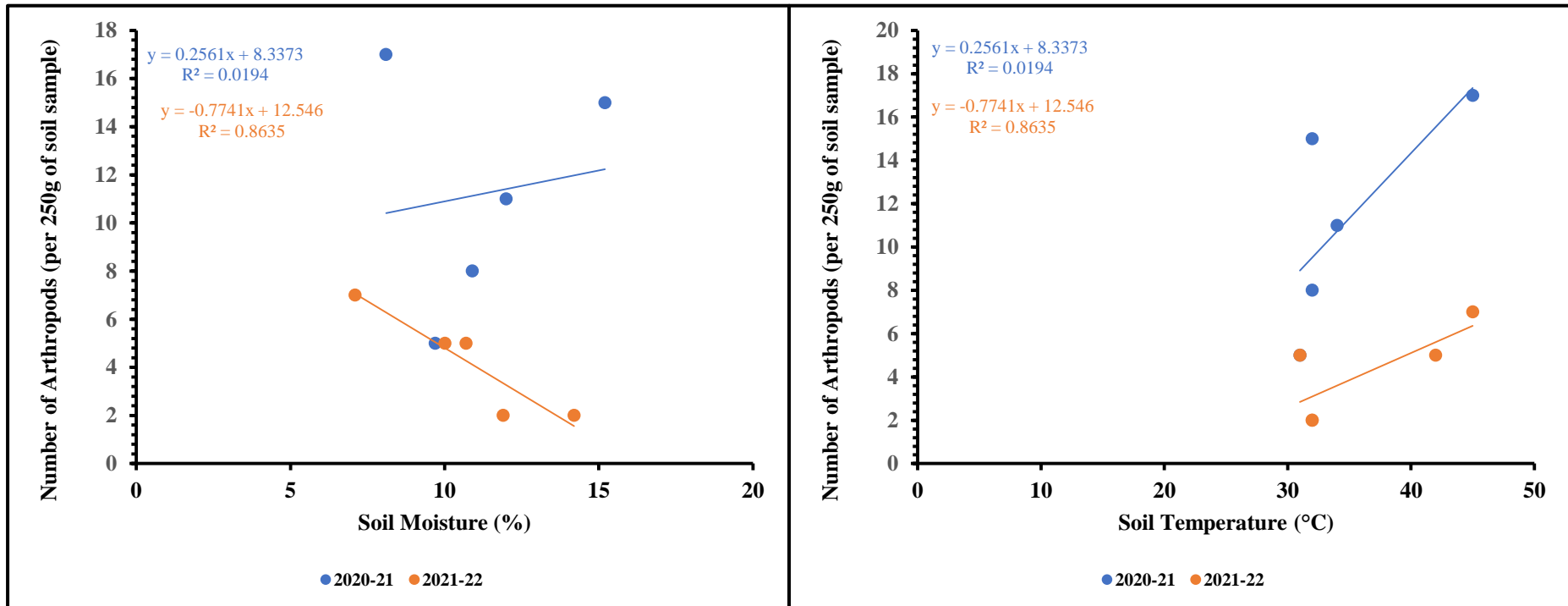


Figure 4.20: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Karnal

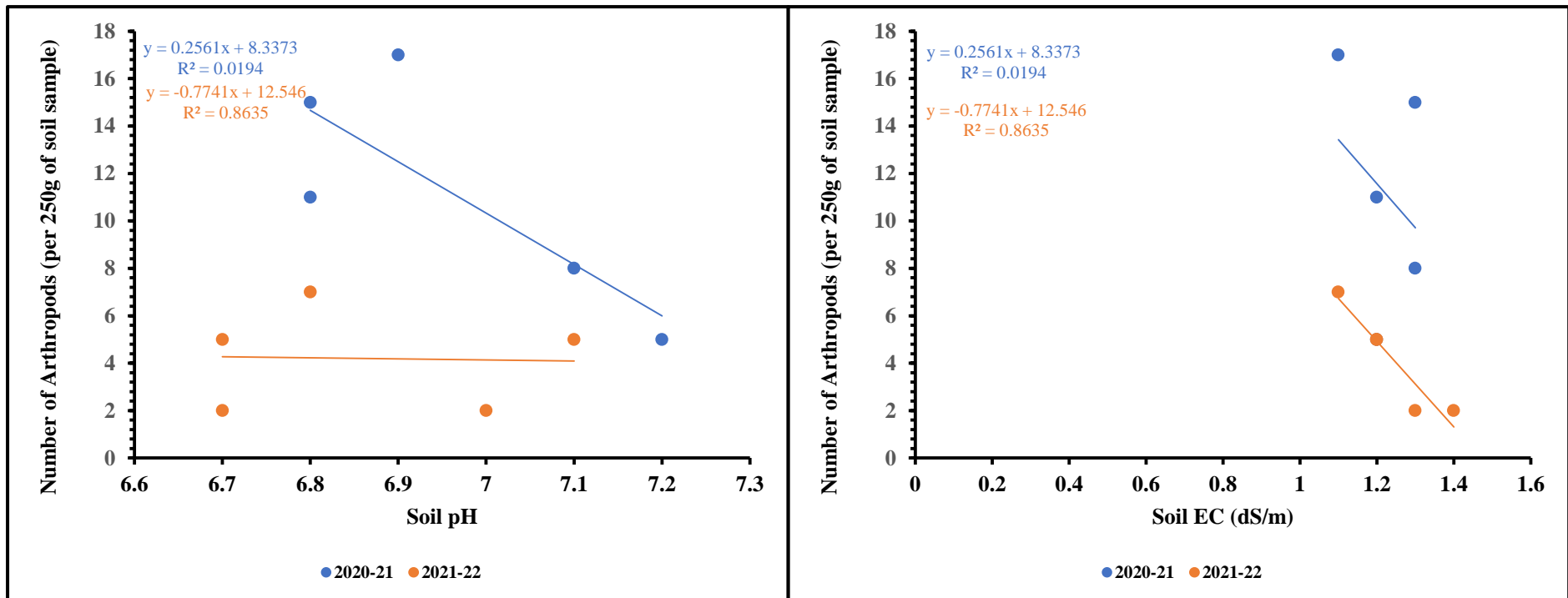
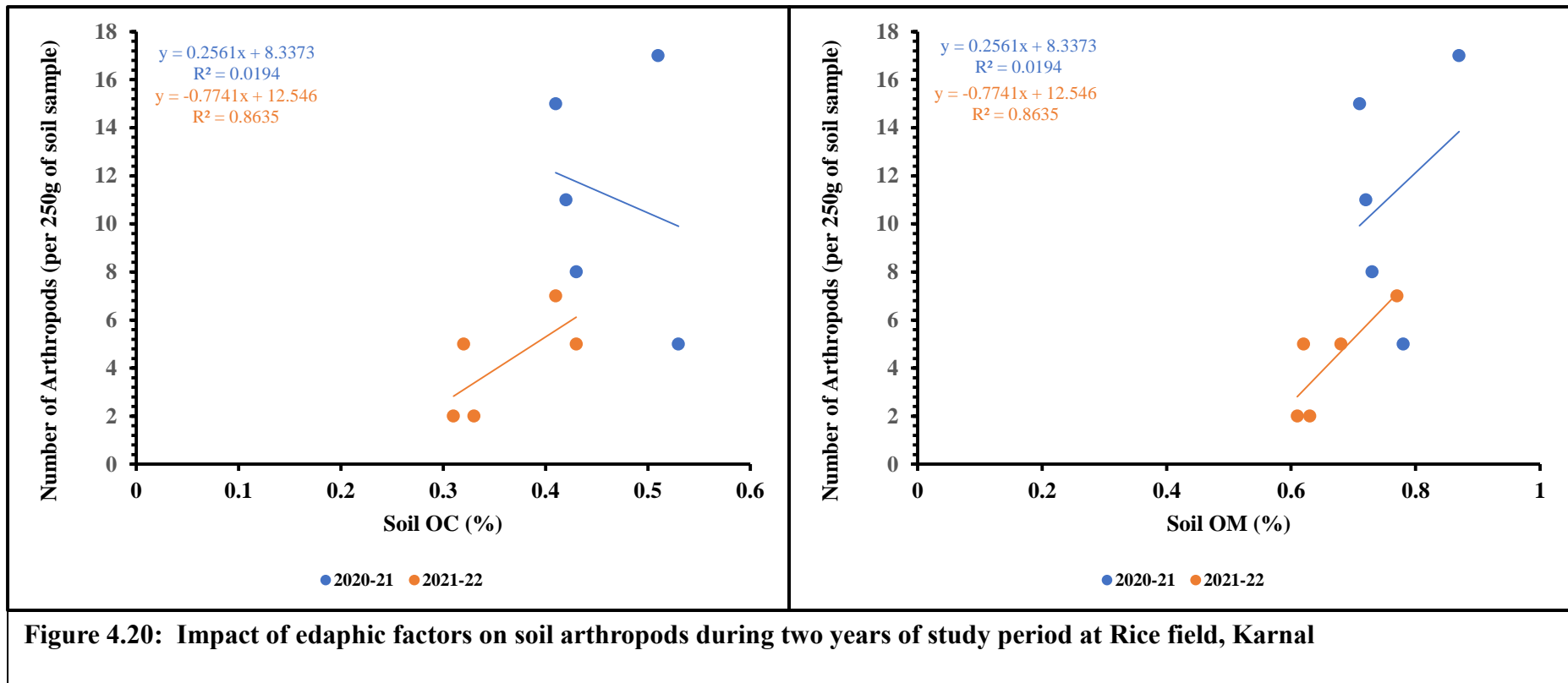


Figure 4.20: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Karnal



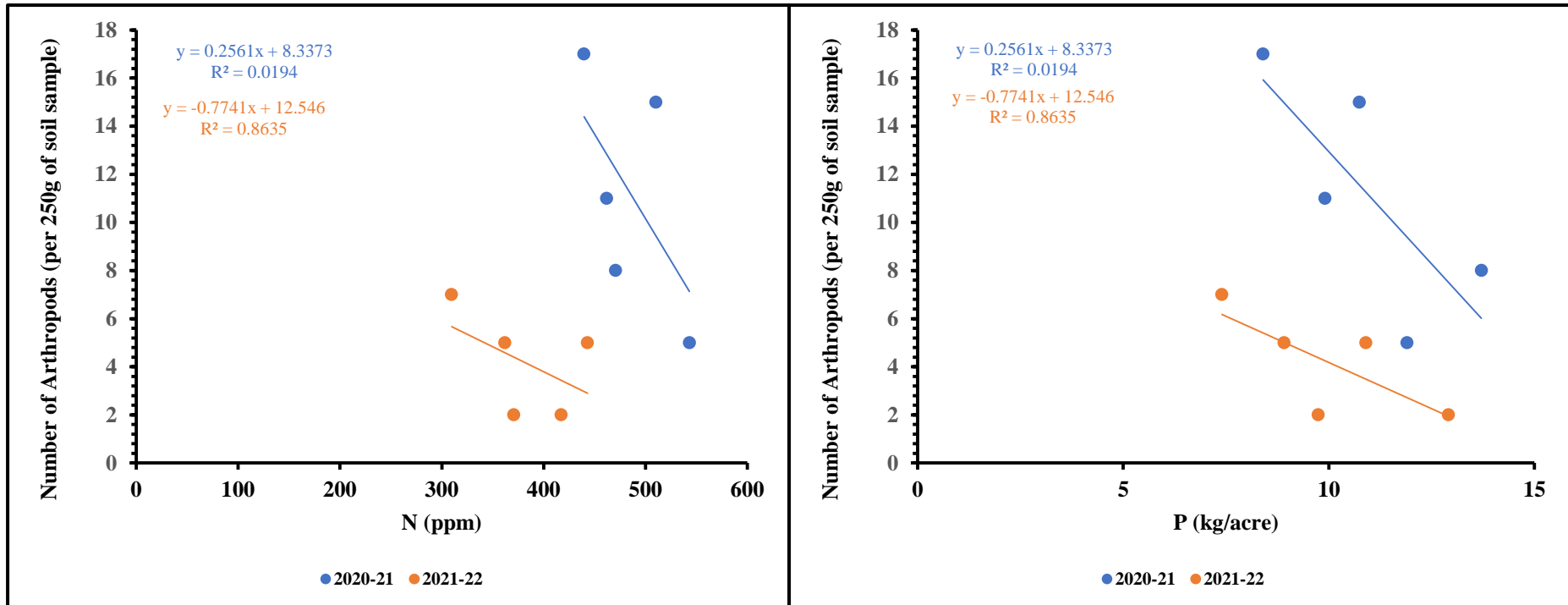


Figure 4.20: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Karnal

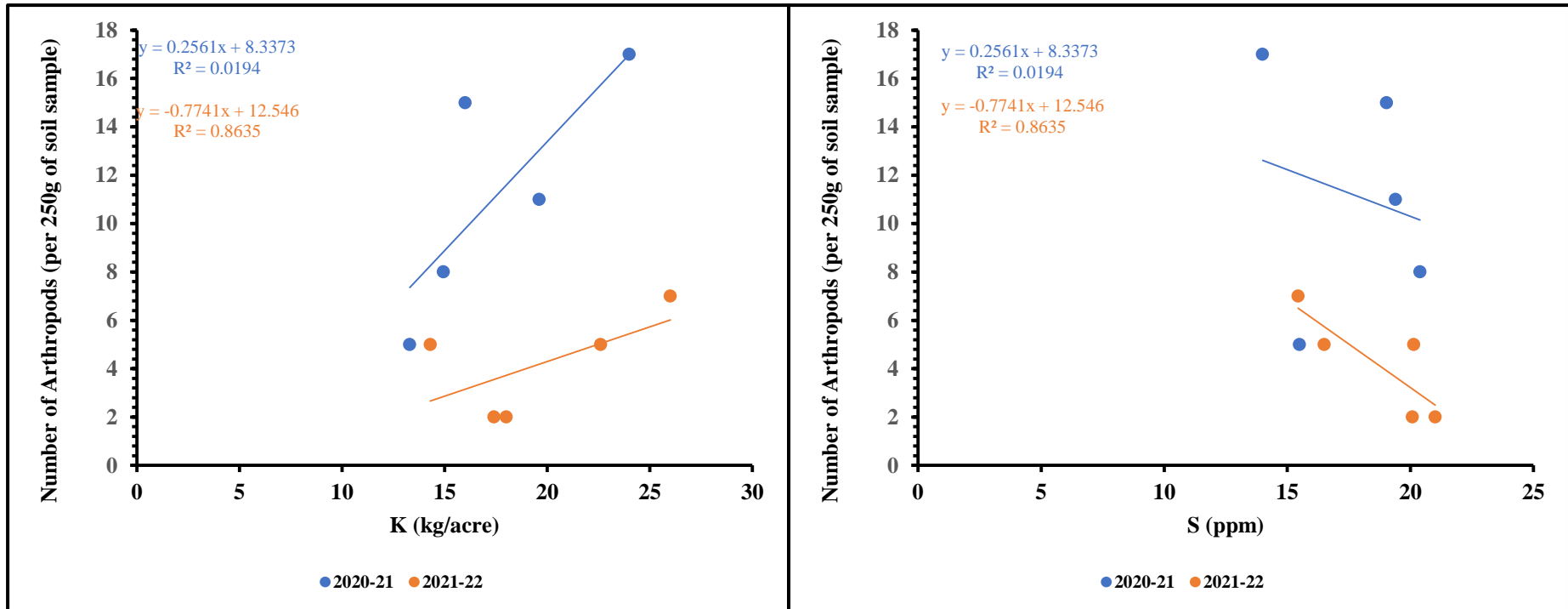


Figure 4.20: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Karnal

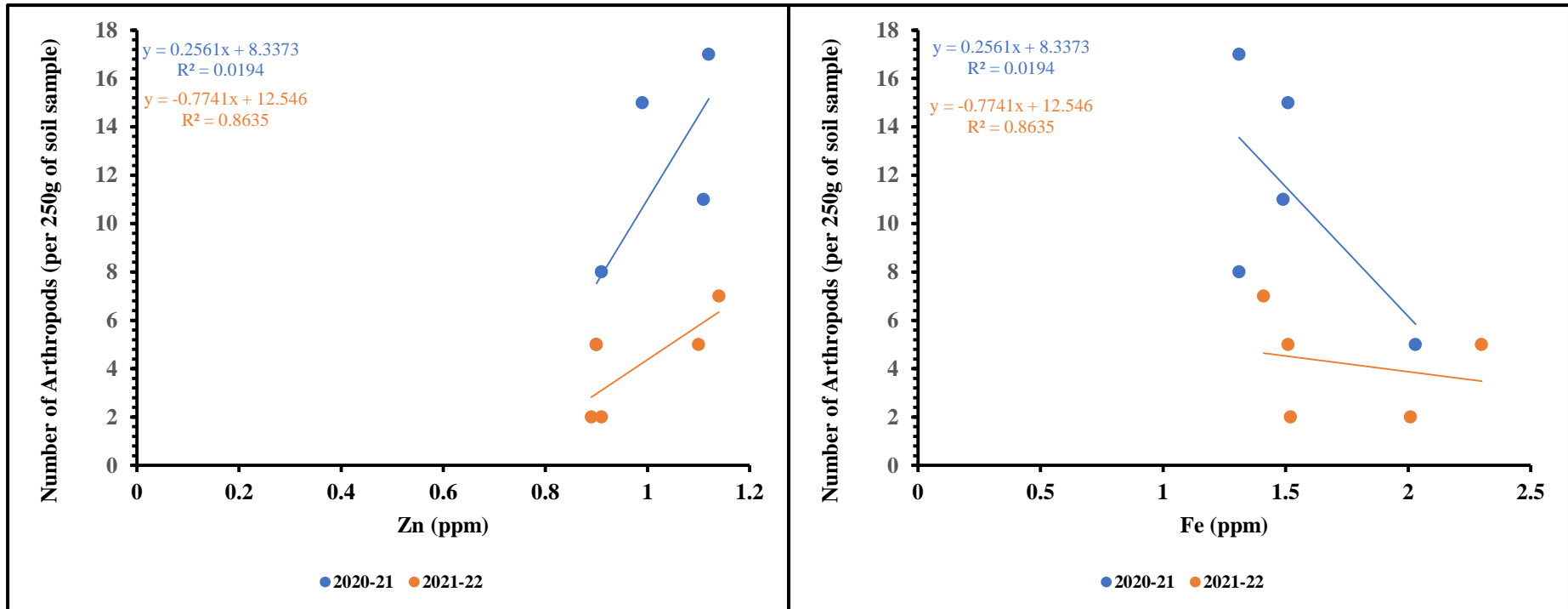


Figure 4.20: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Karnal

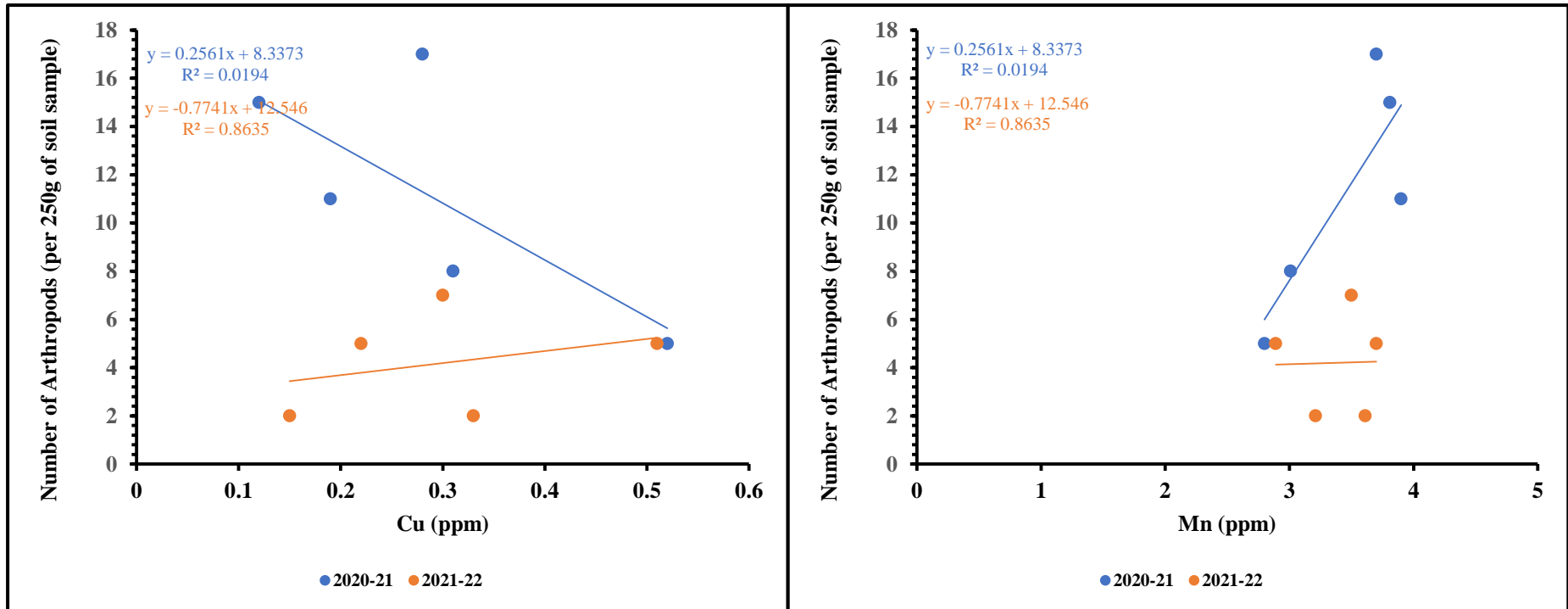


Figure 4.20: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Karnal

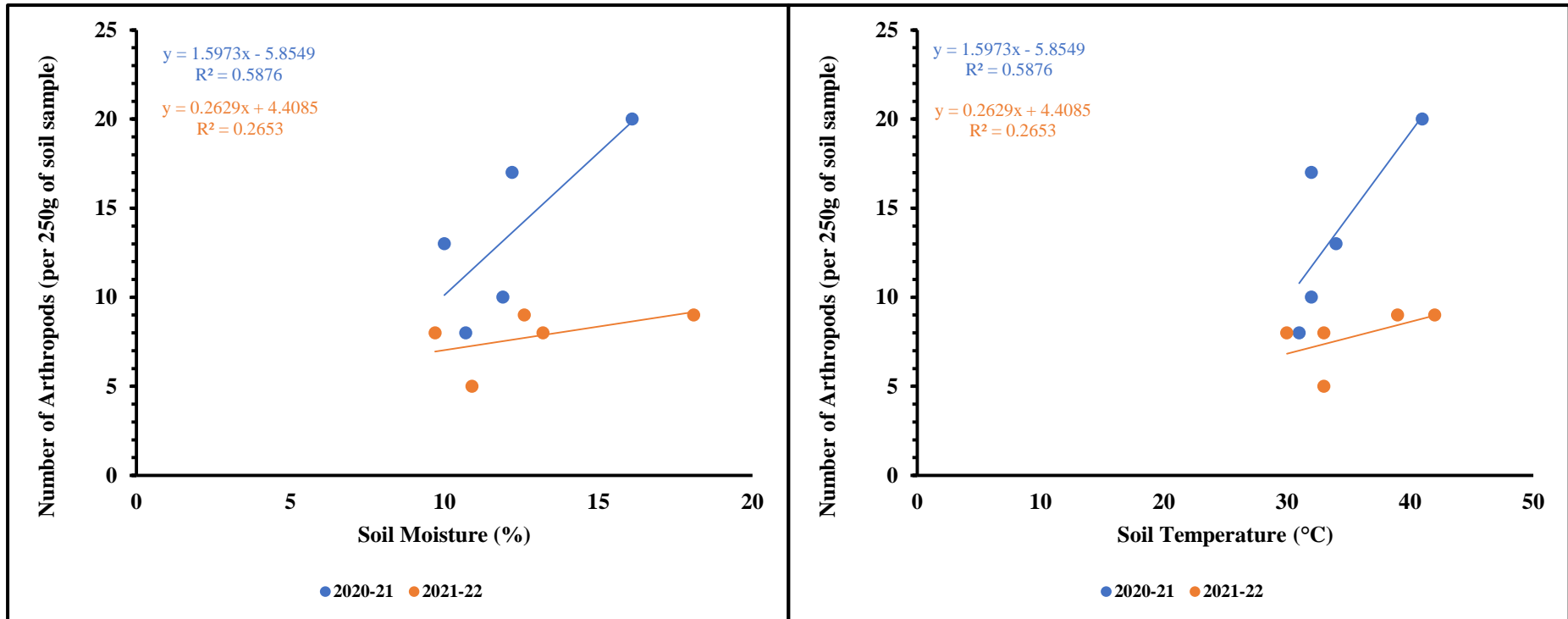


Figure 4.21: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Kaithal

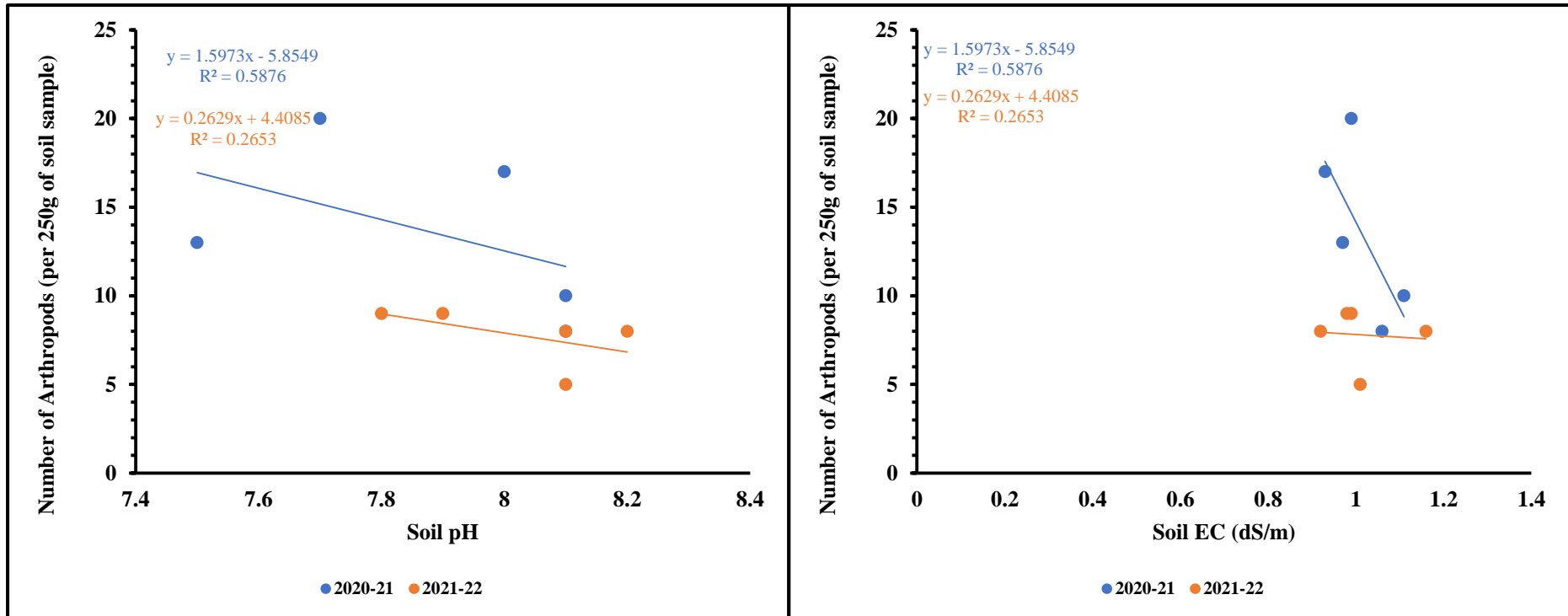


Figure 4.21: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Kaithal

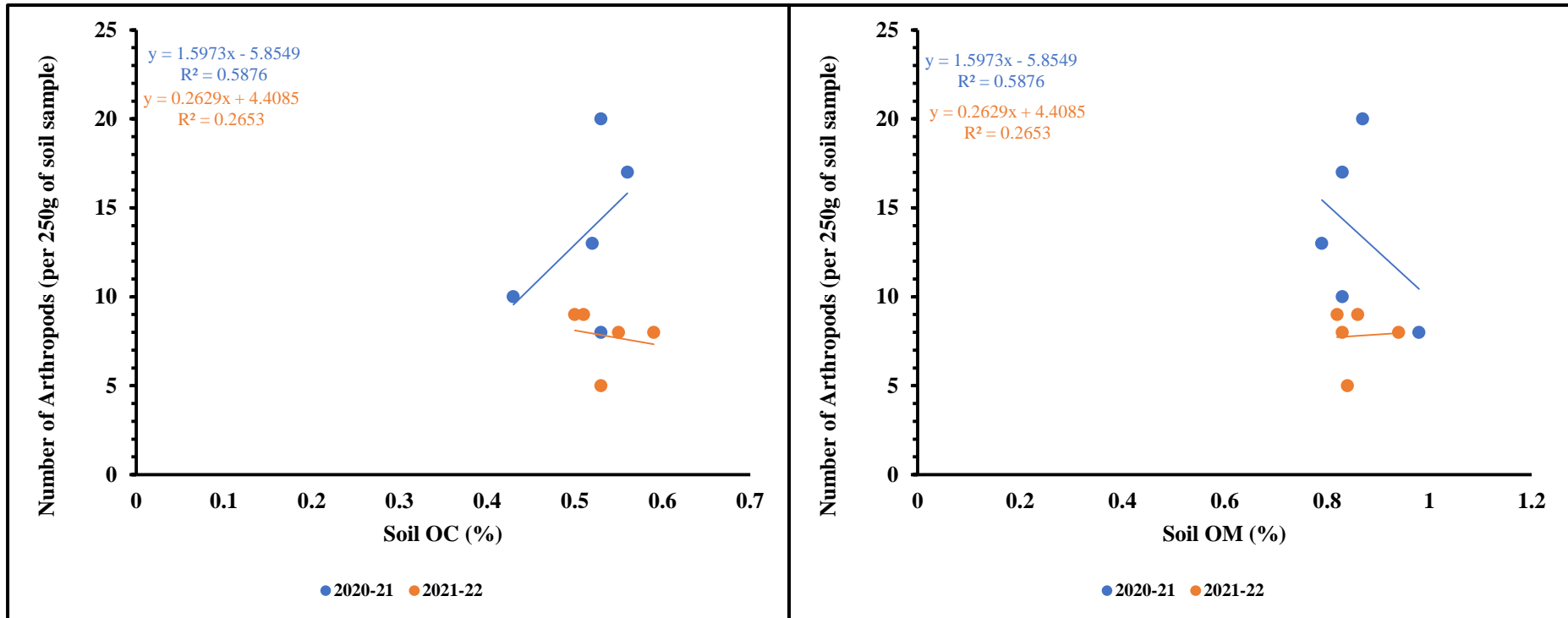


Figure 4.21: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Kaithal

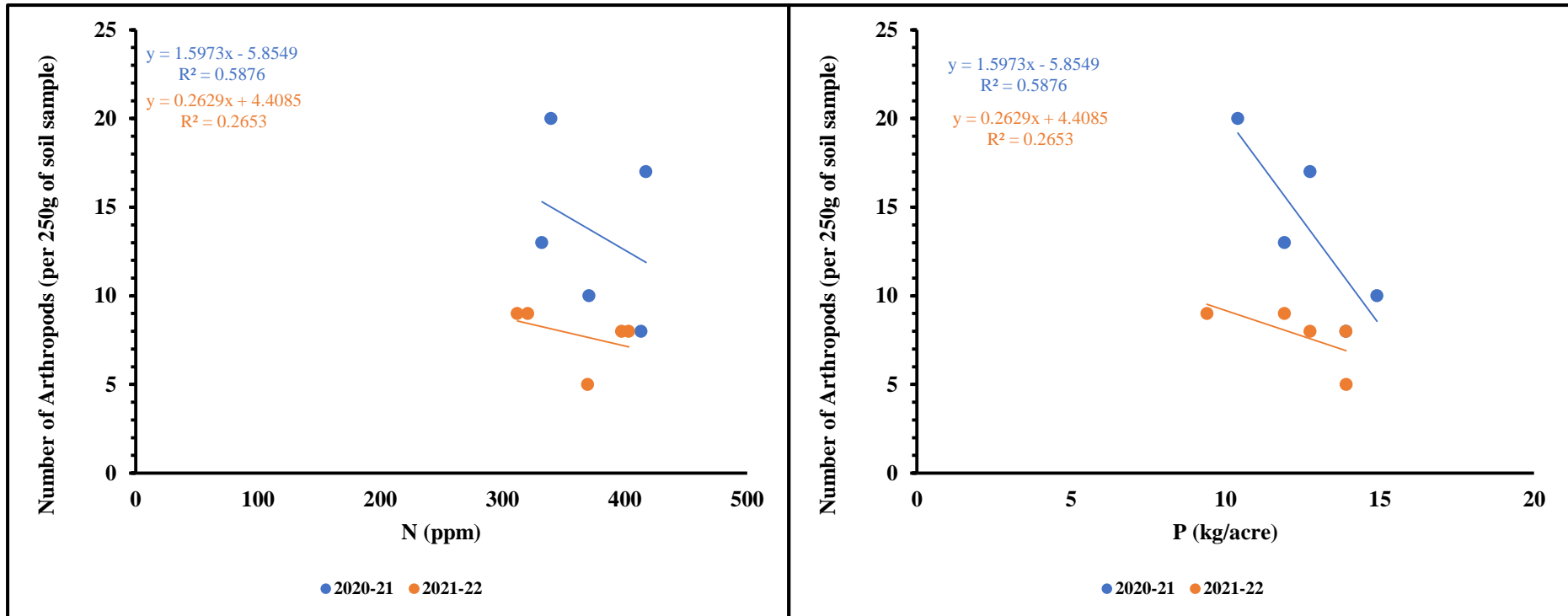


Figure 4.21: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Kaithal

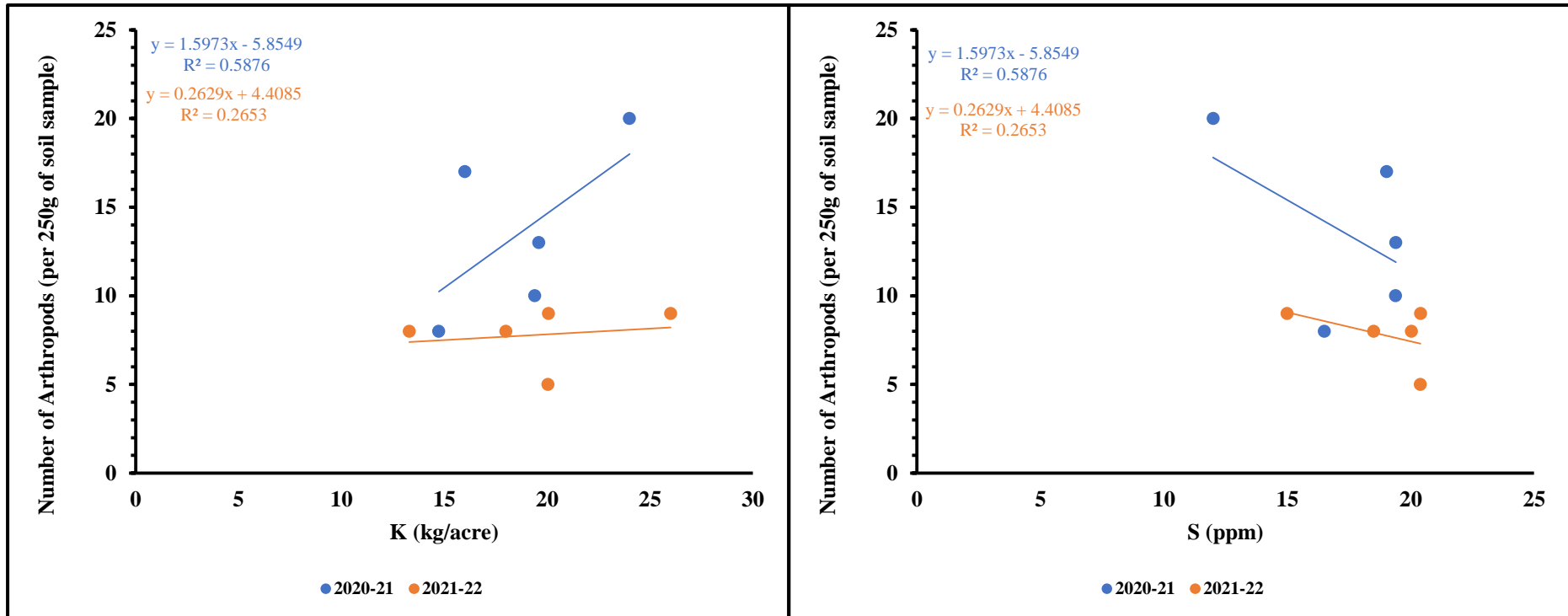


Figure 4.21: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Kaithal

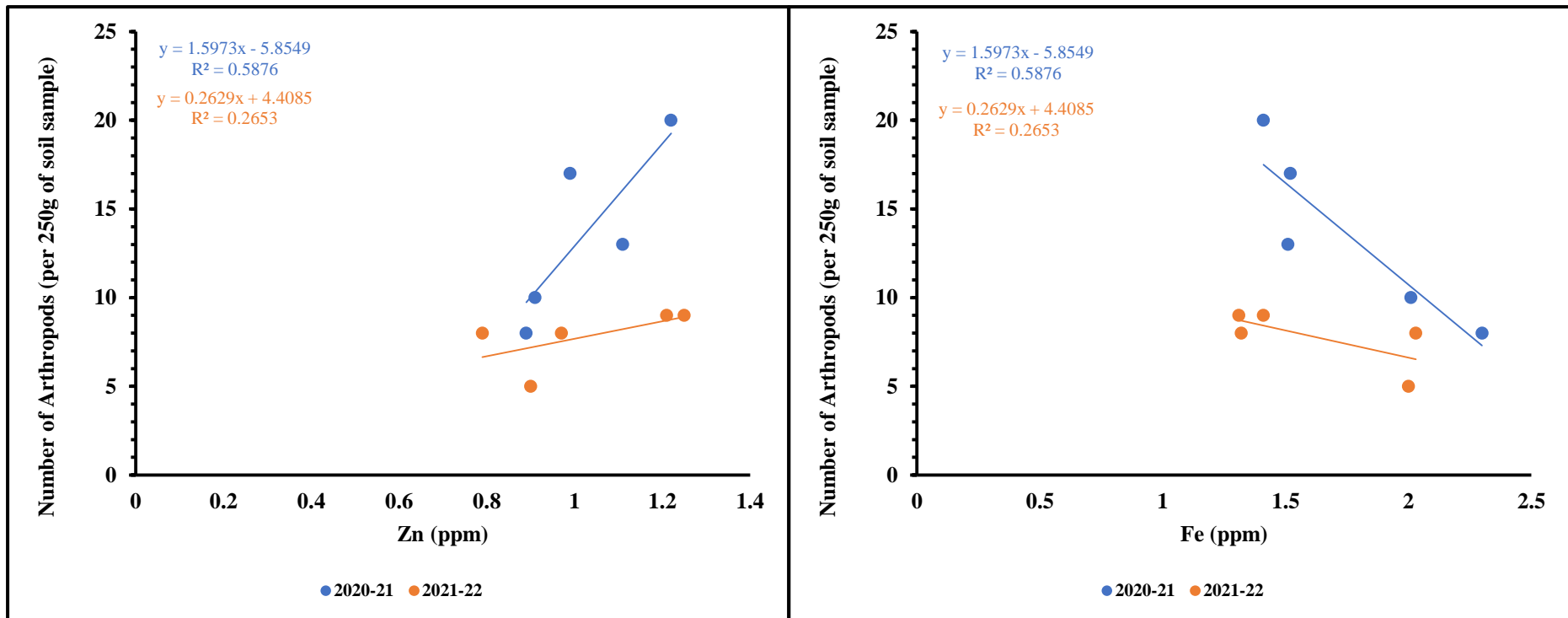


Figure 4.21: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Kaithal

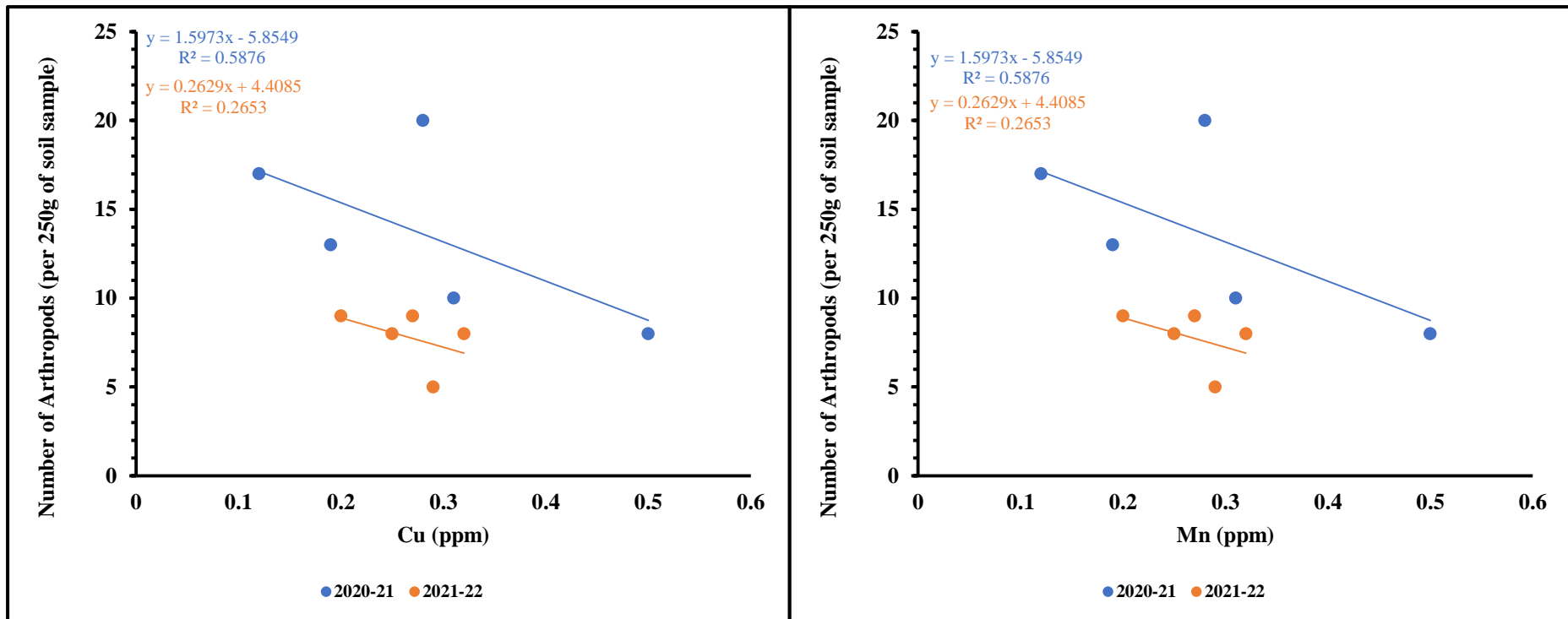


Figure 4.21: Impact of edaphic factors on soil arthropods during two years of study period at Rice field, Kaithal

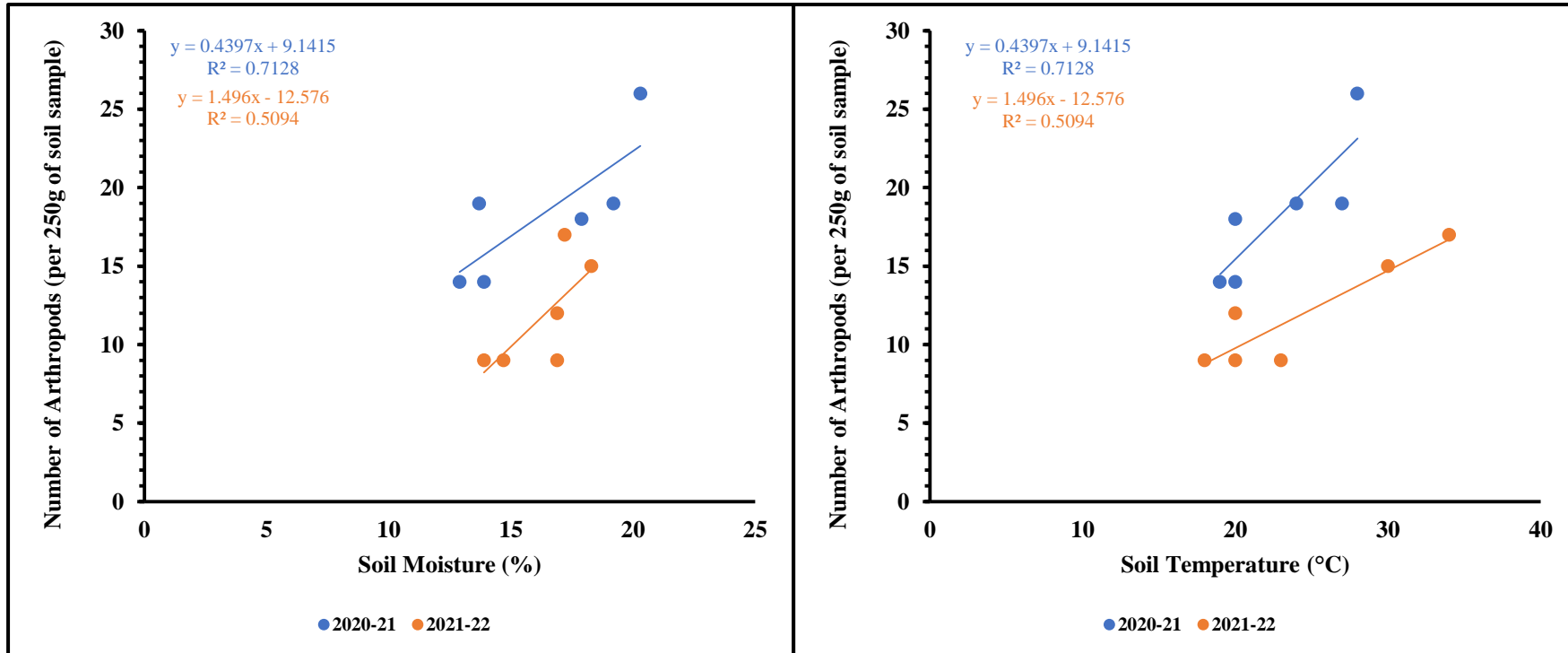


Figure 4.22: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Sirsa

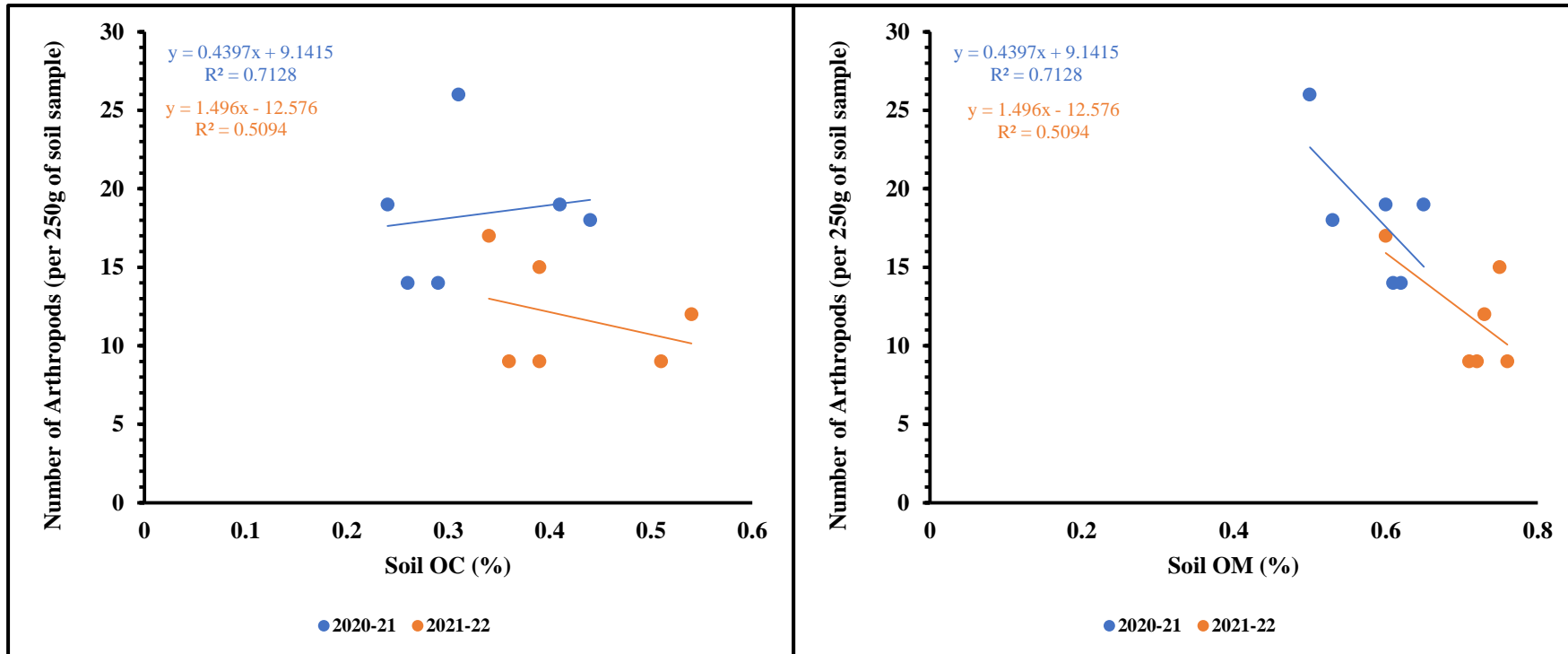


Figure 4.22: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Sirsa

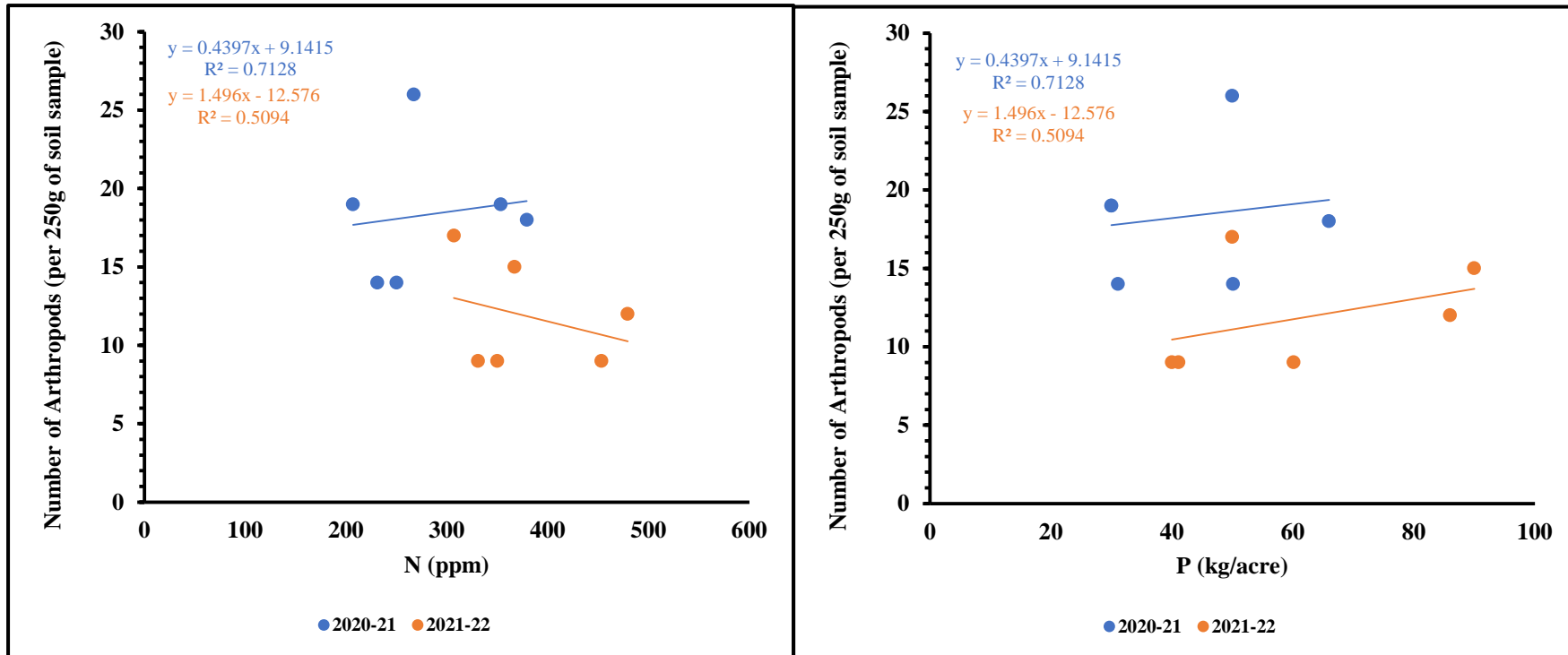


Figure 4.22: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Sirsa

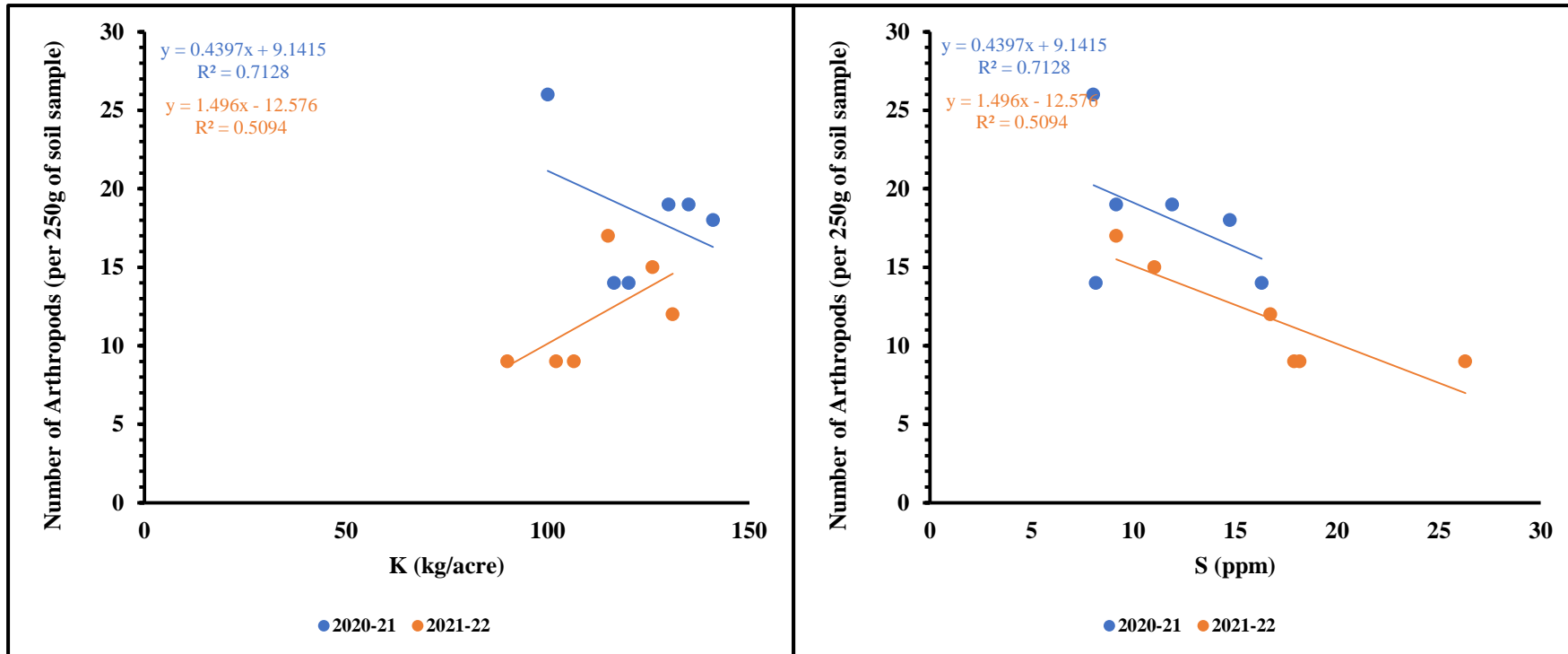


Figure 4.22: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Sirsa

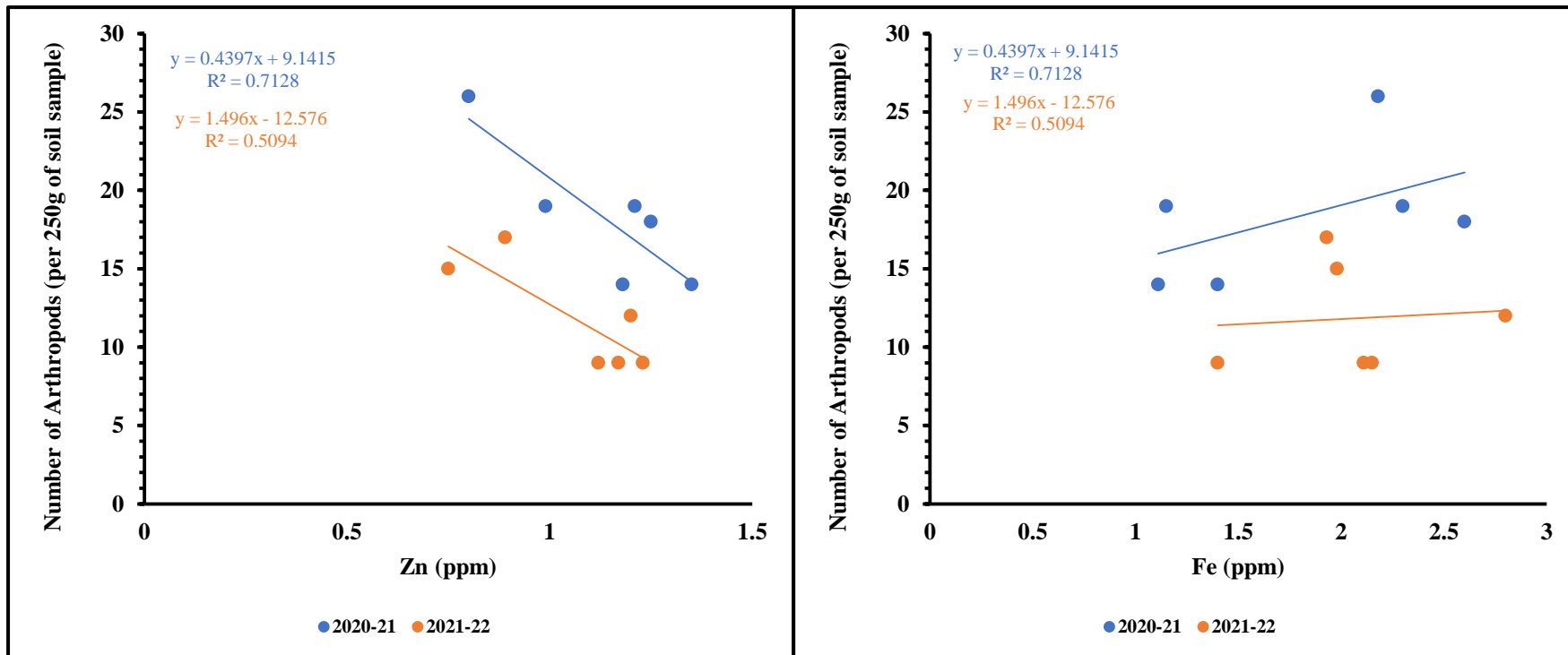


Figure 4.22: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Sirsa

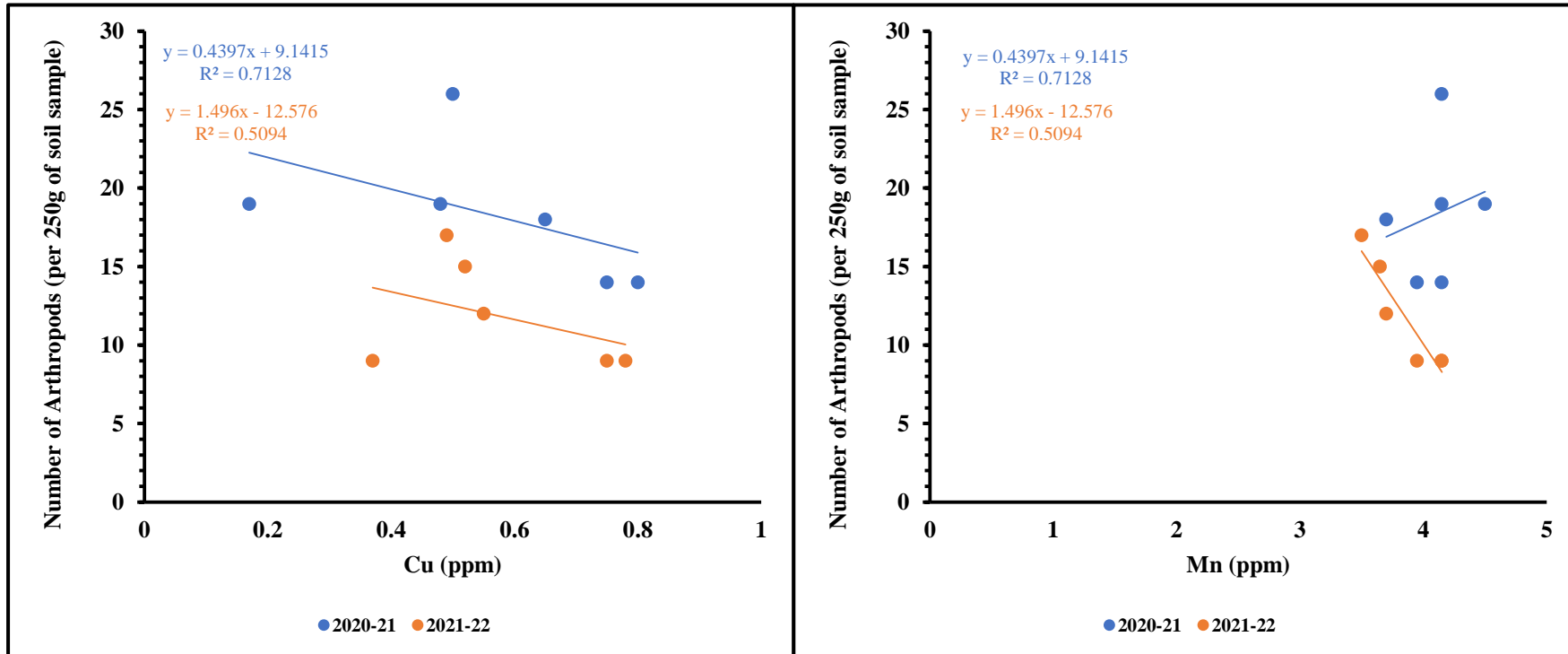


Figure 4.22: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Sirsa

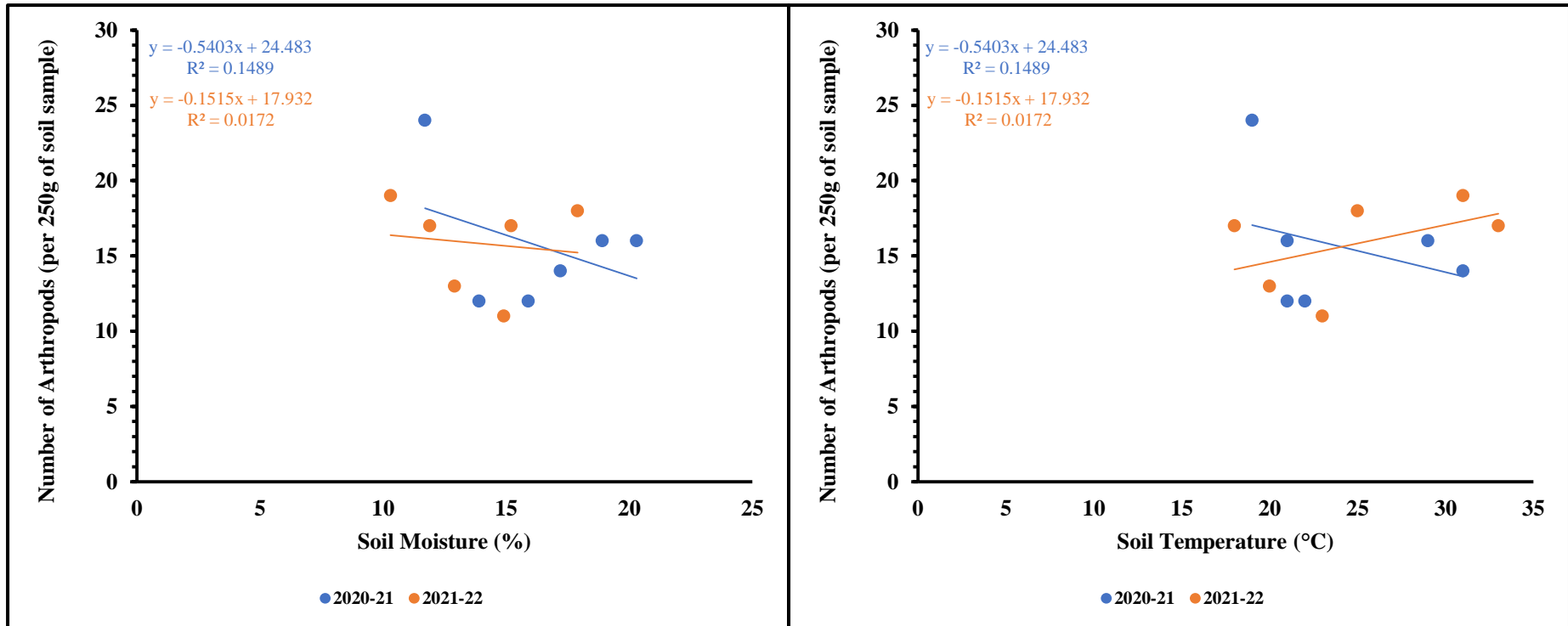


Figure 4.23: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Hisar

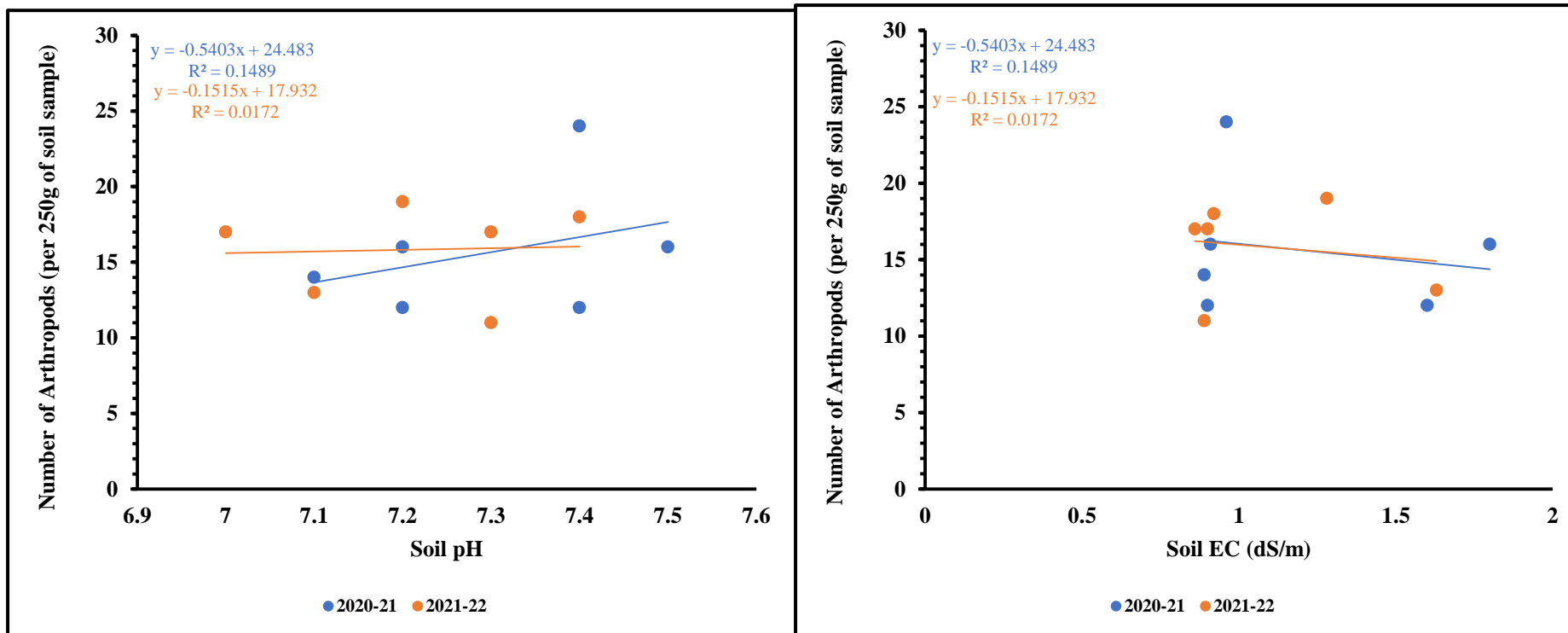


Figure 4.23: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Hisar

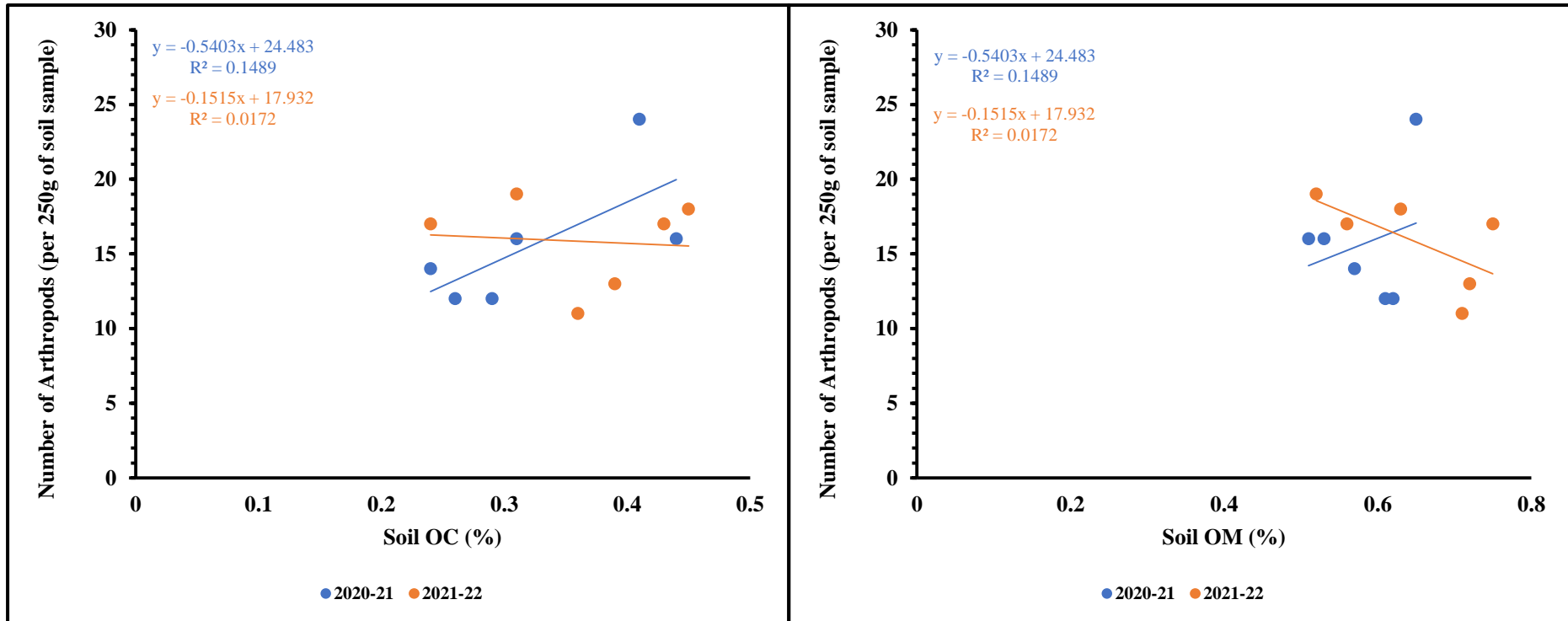


Figure 4.23: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Hisar

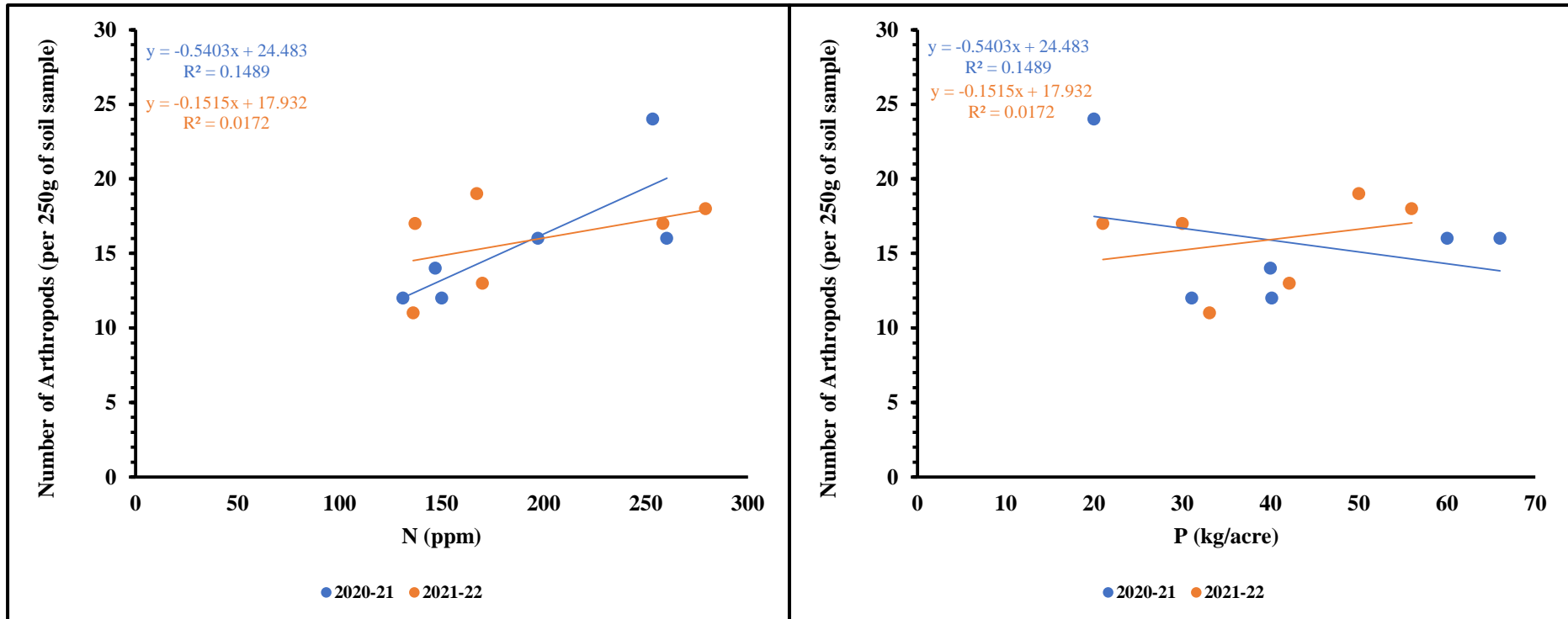


Figure 4.23: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Hisar

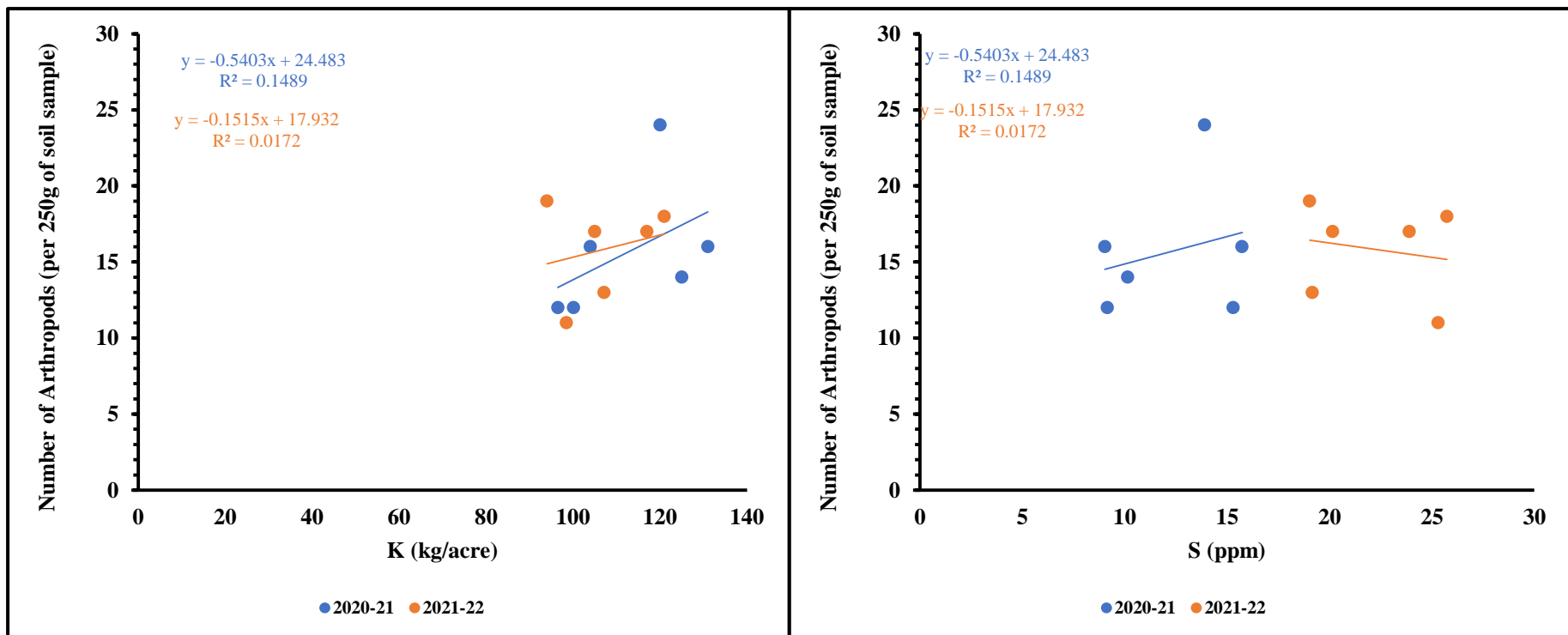


Figure 4.23: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Hisar

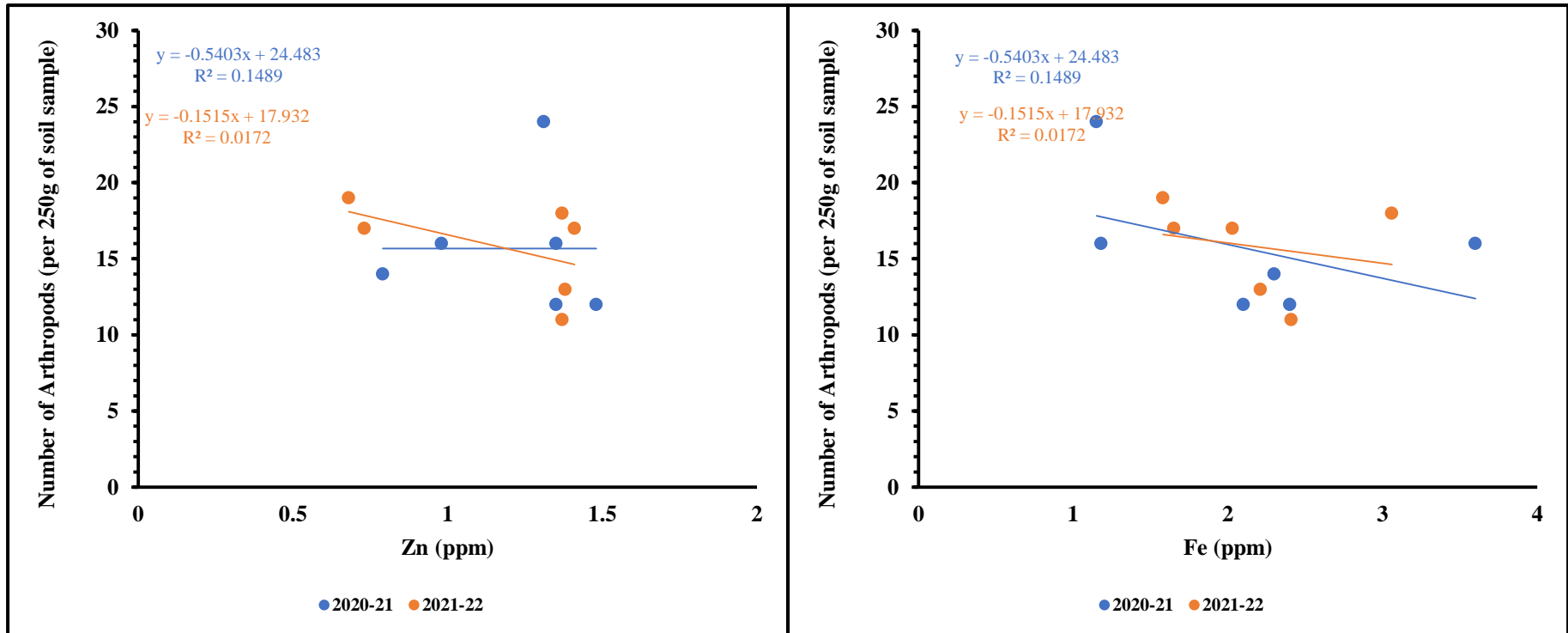


Figure 4.23: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Hisar

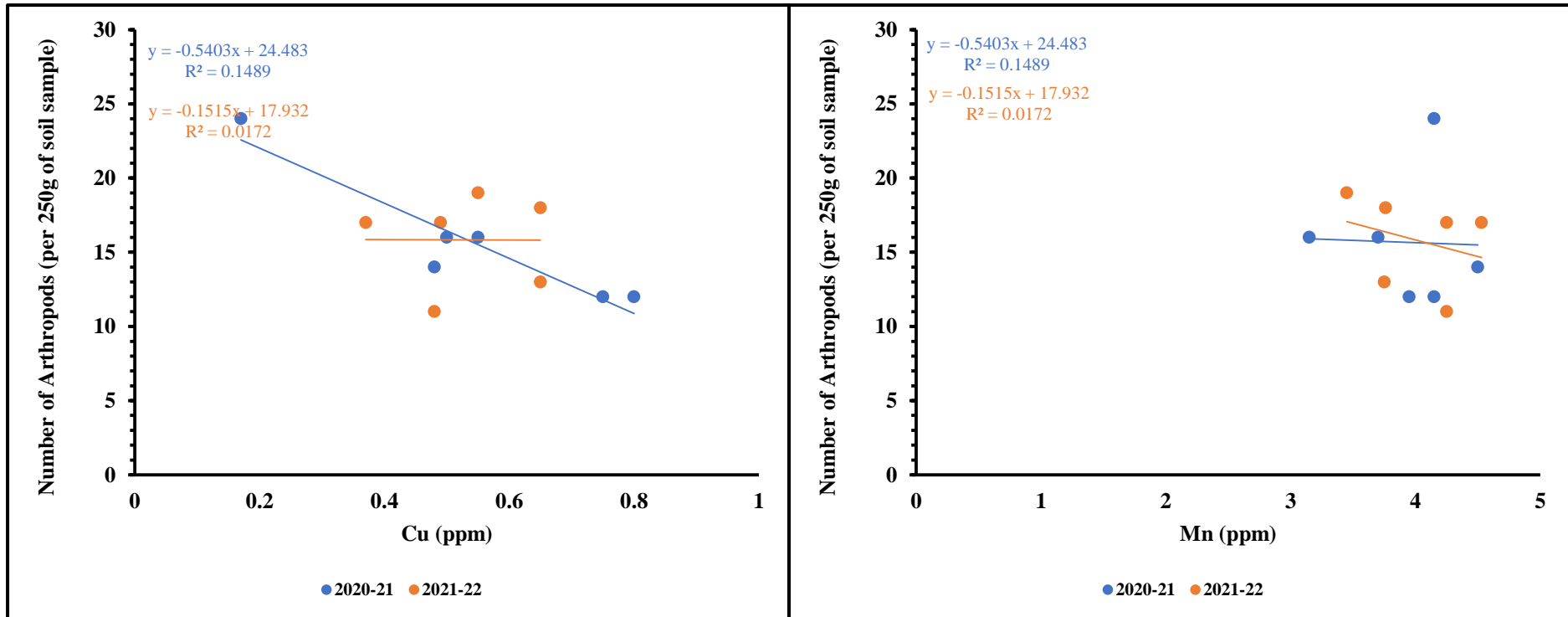


Figure 4.23: Impact of edaphic factors on soil arthropods during two years of study period at Wheat field, Hisar

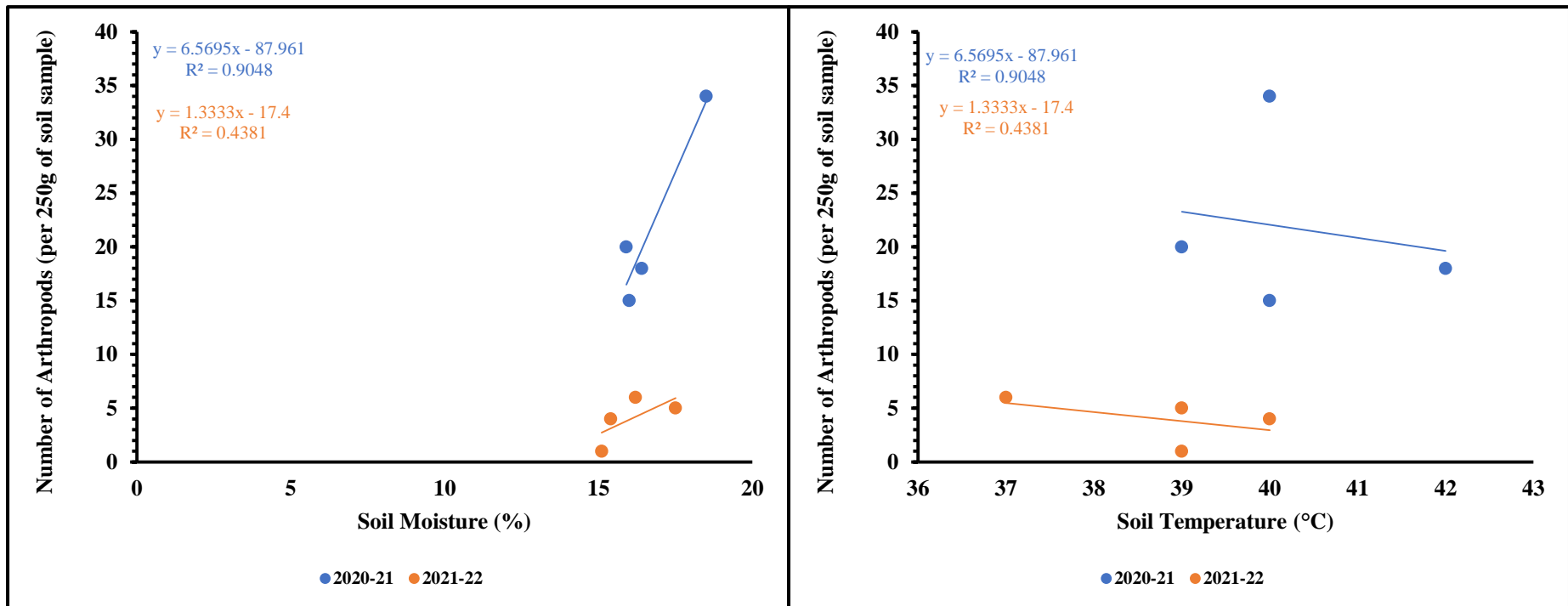


Figure 4.24: Impact of edaphic factors on soil arthropods during two years of study period at Jowar field, Rohtak

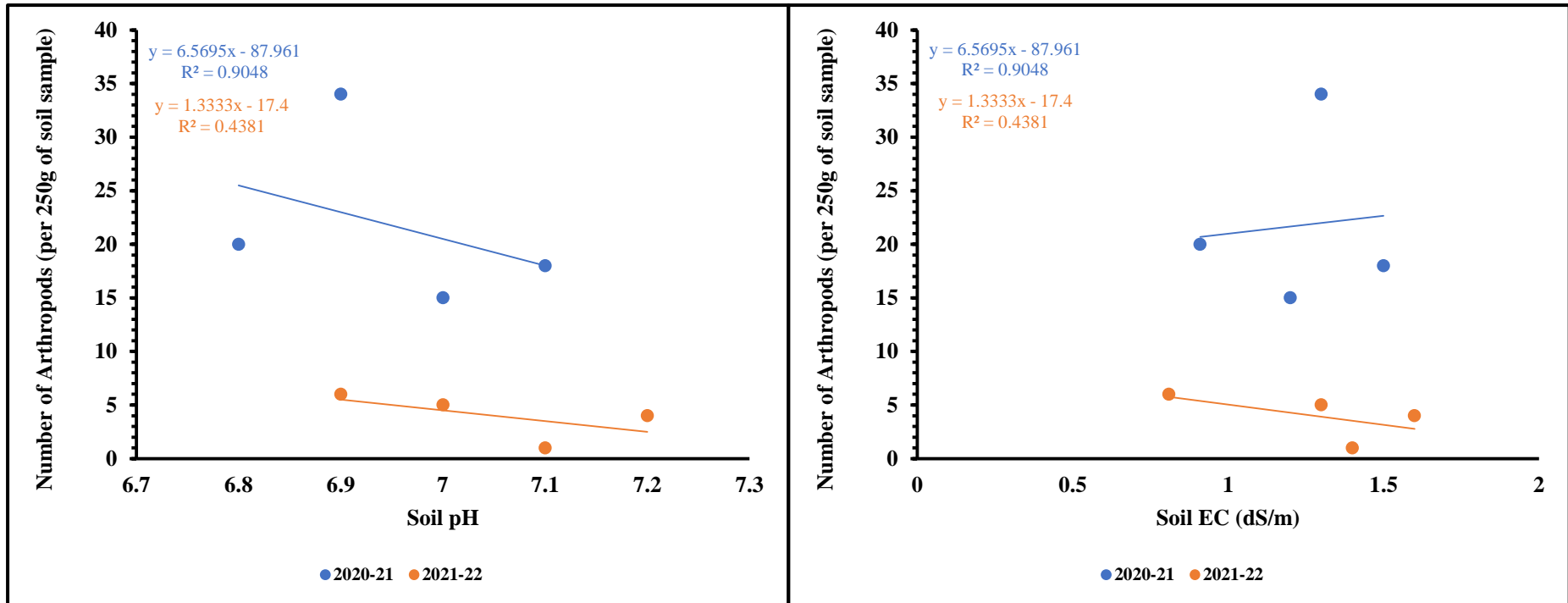


Figure 4.24: Impact of edaphic factors on soil arthropods during two years of study period at Jowar field, Rohtak

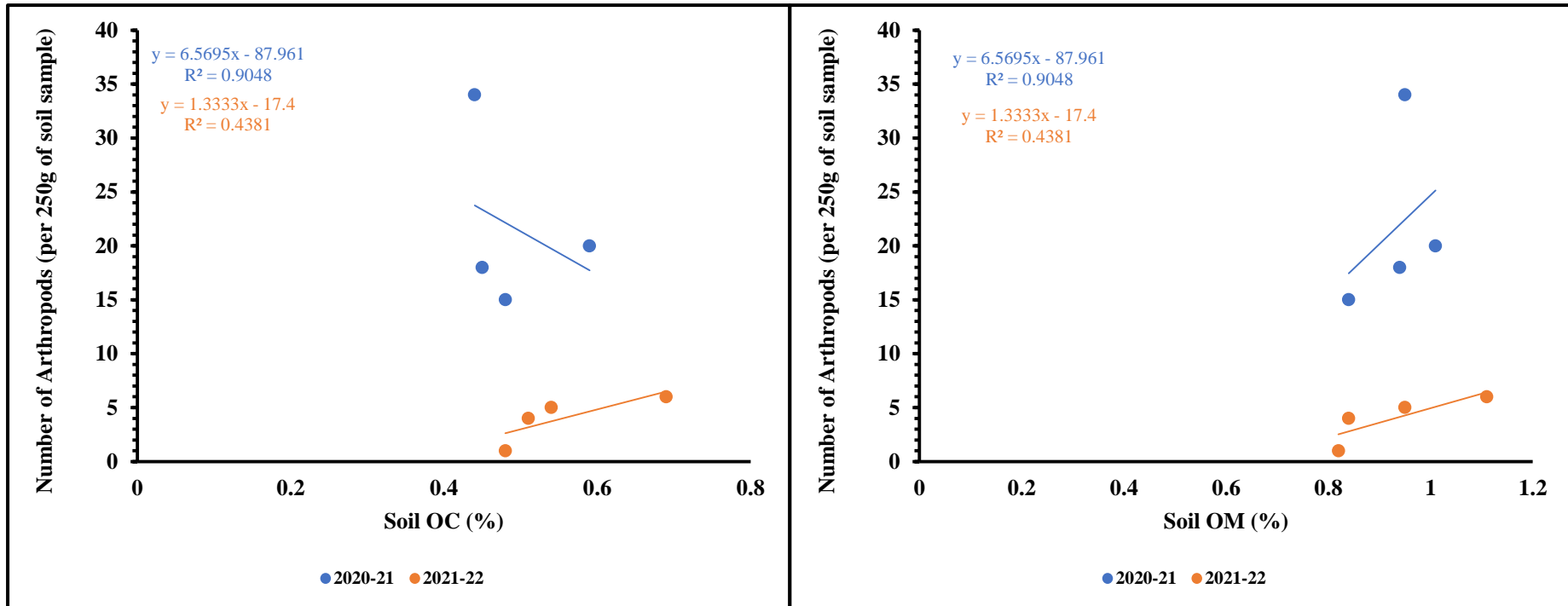


Figure 4.24: Impact of edaphic factors on soil arthropods during two years of study period at Jowar field, Rohtak

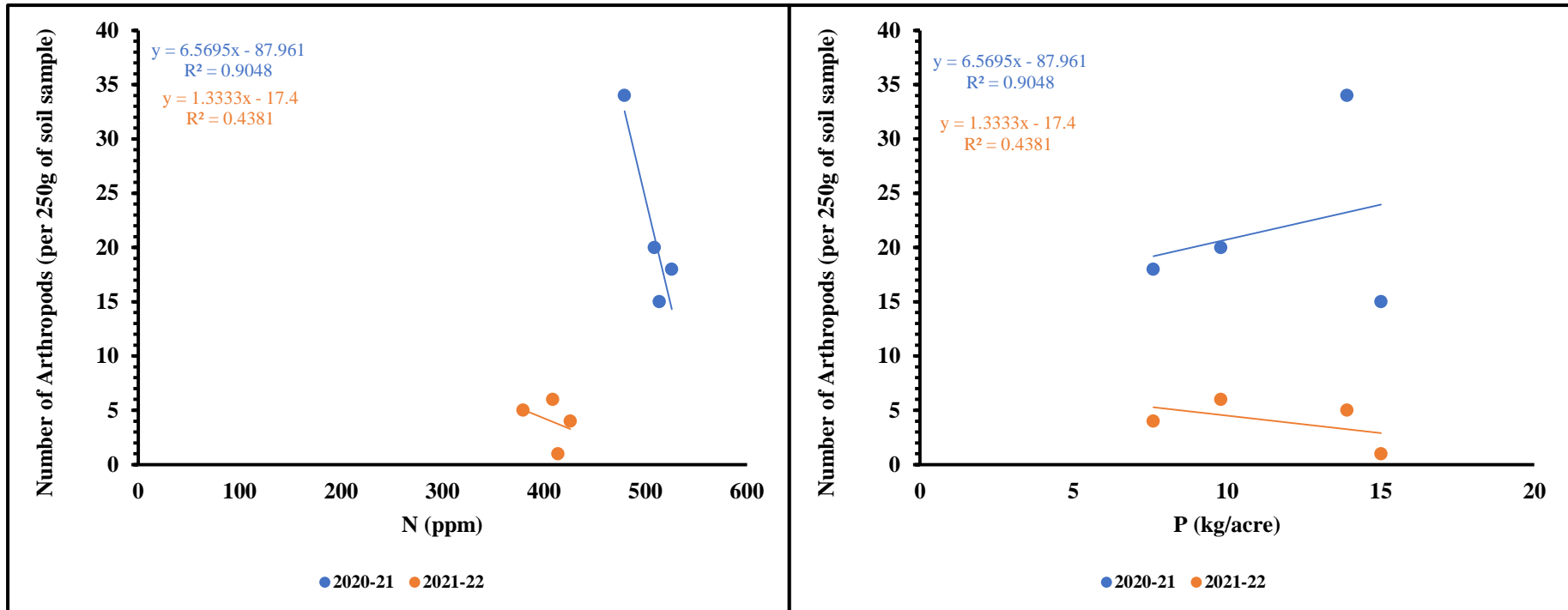


Figure 4.24: Impact of edaphic factors on soil arthropods during two years of study period at Jowar field, Rohtak

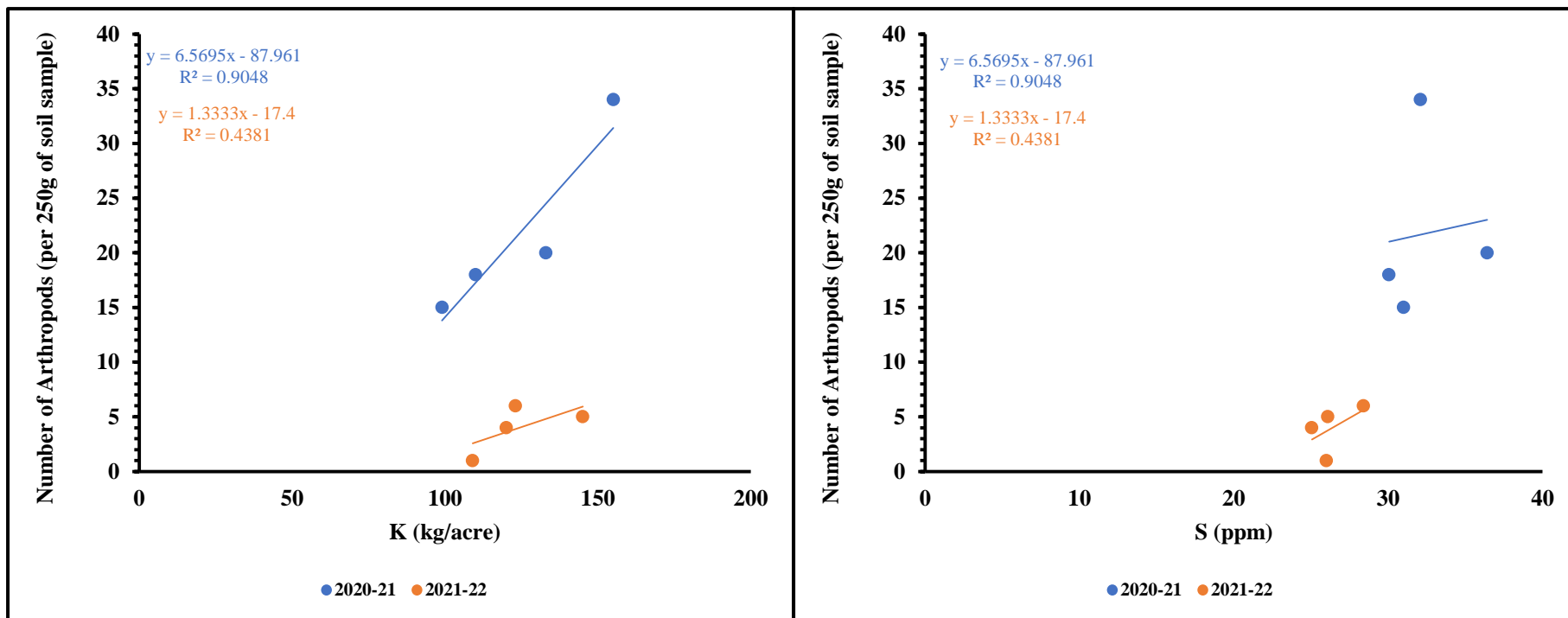


Figure 4.24: Impact of edaphic factors on soil arthropods during two years of study period at Jowar field, Rohtak

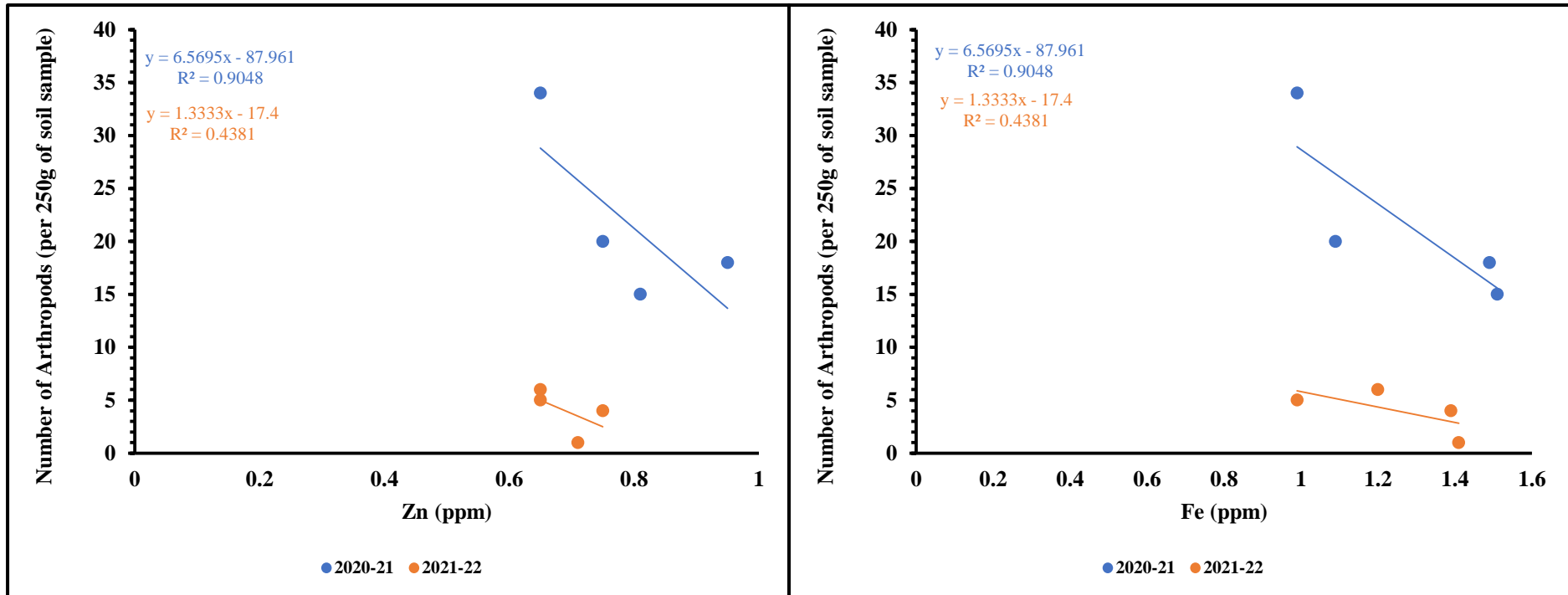


Figure 4.24: Impact of edaphic factors on soil arthropods during two years of study period at Jowar field, Rohtak

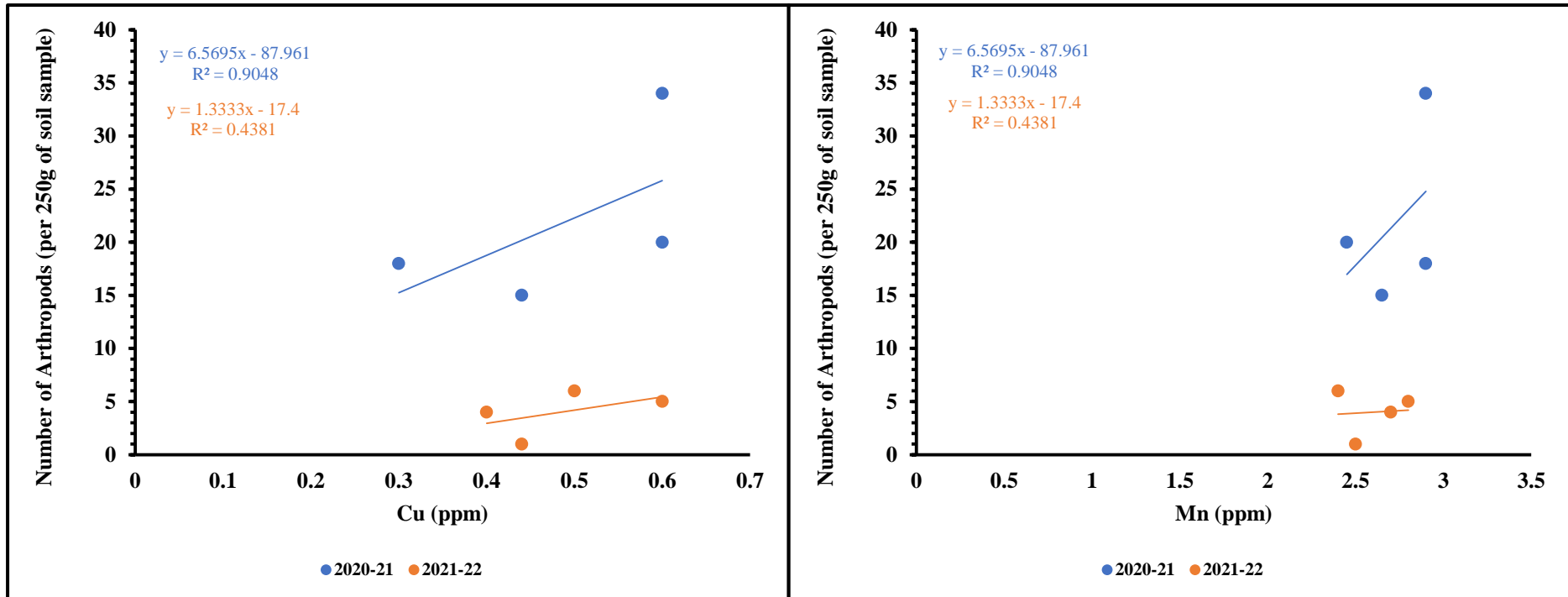


Figure 4.24: Impact of edaphic factors on soil arthropods during two years of study period at Jowar field, Rohtak

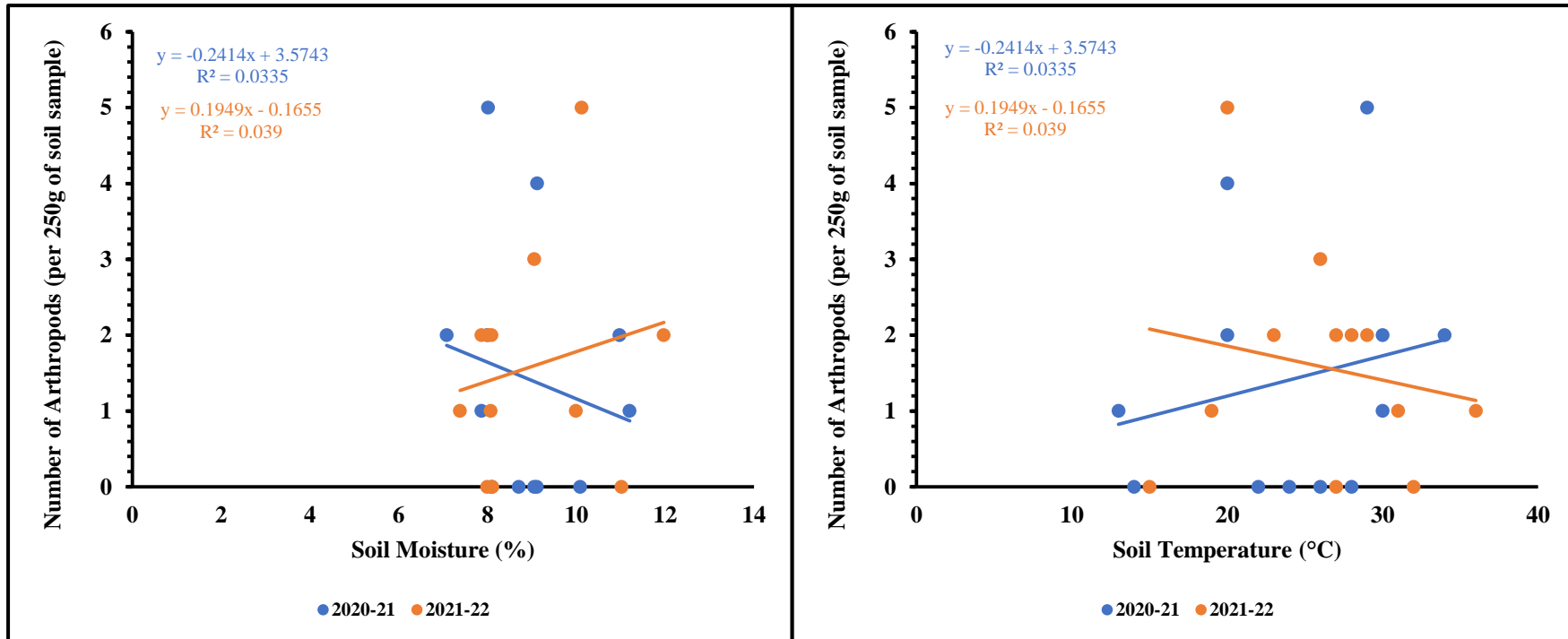


Figure 4.25: Impact of edaphic factors on soil arthropods during two years of study period at Forest land, Panipat

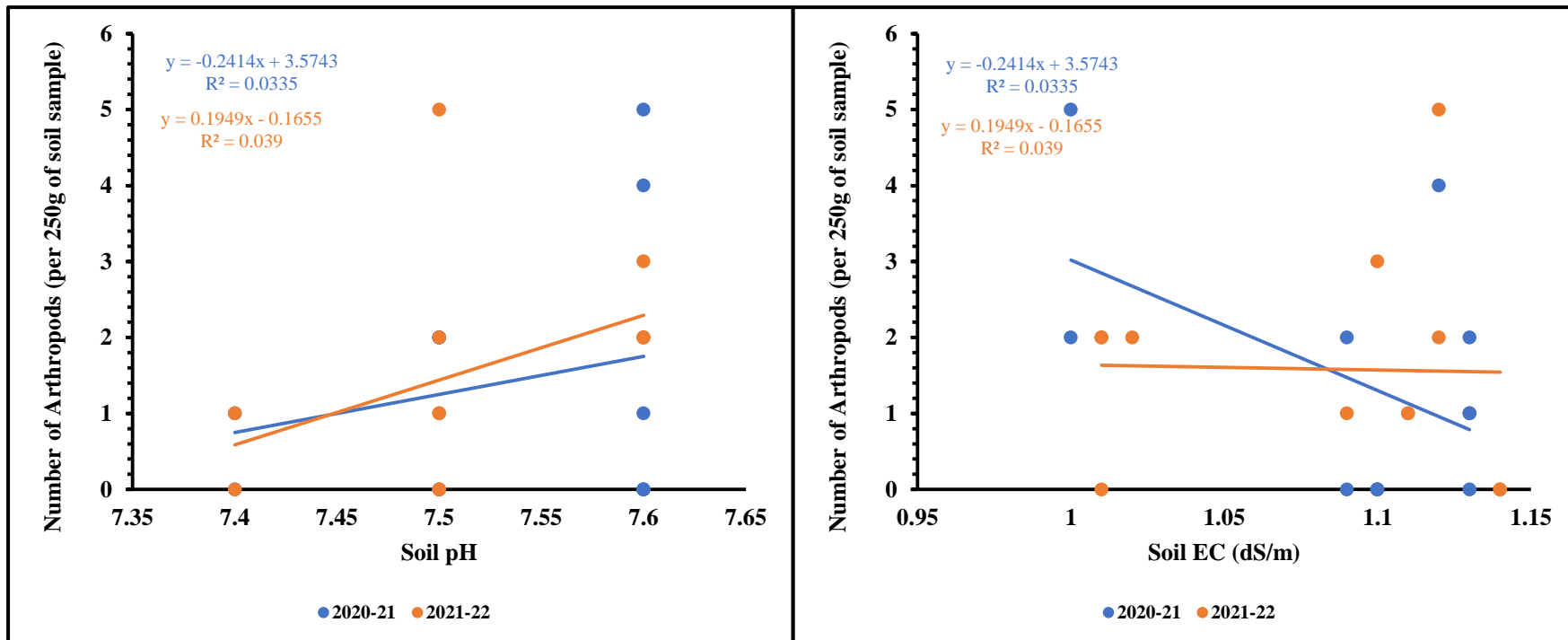


Figure 4.25: Impact of edaphic factors on soil arthropods during two years of study period at Forest land, Panipat

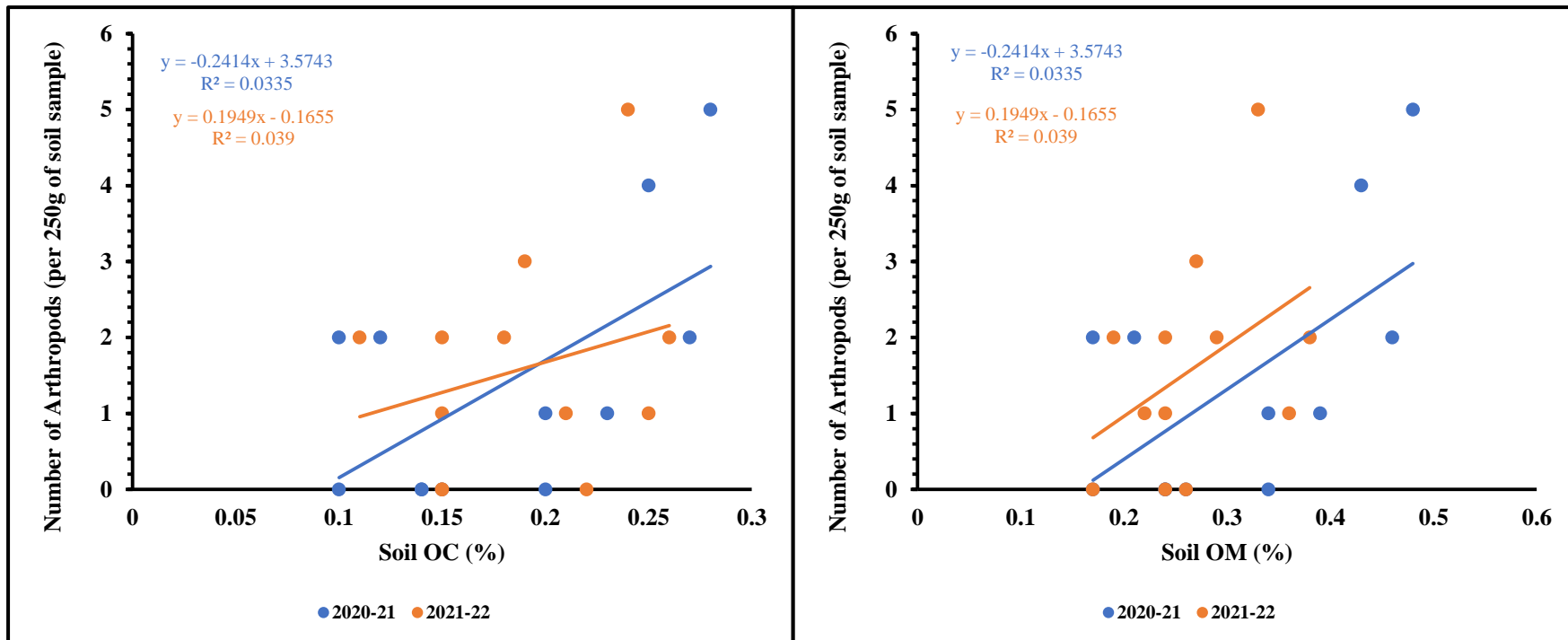
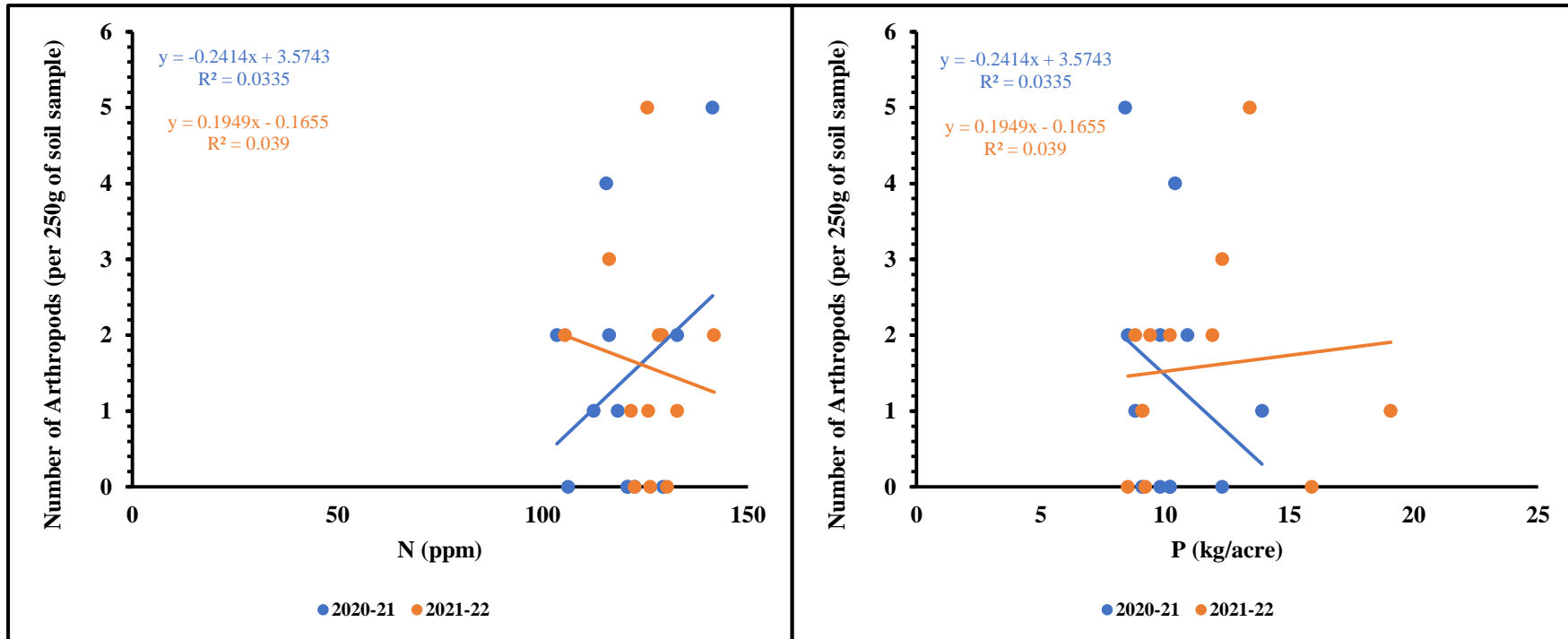


Figure 4.25: Impact of edaphic factors on soil arthropods during two years of study period at Forest land, Panipat



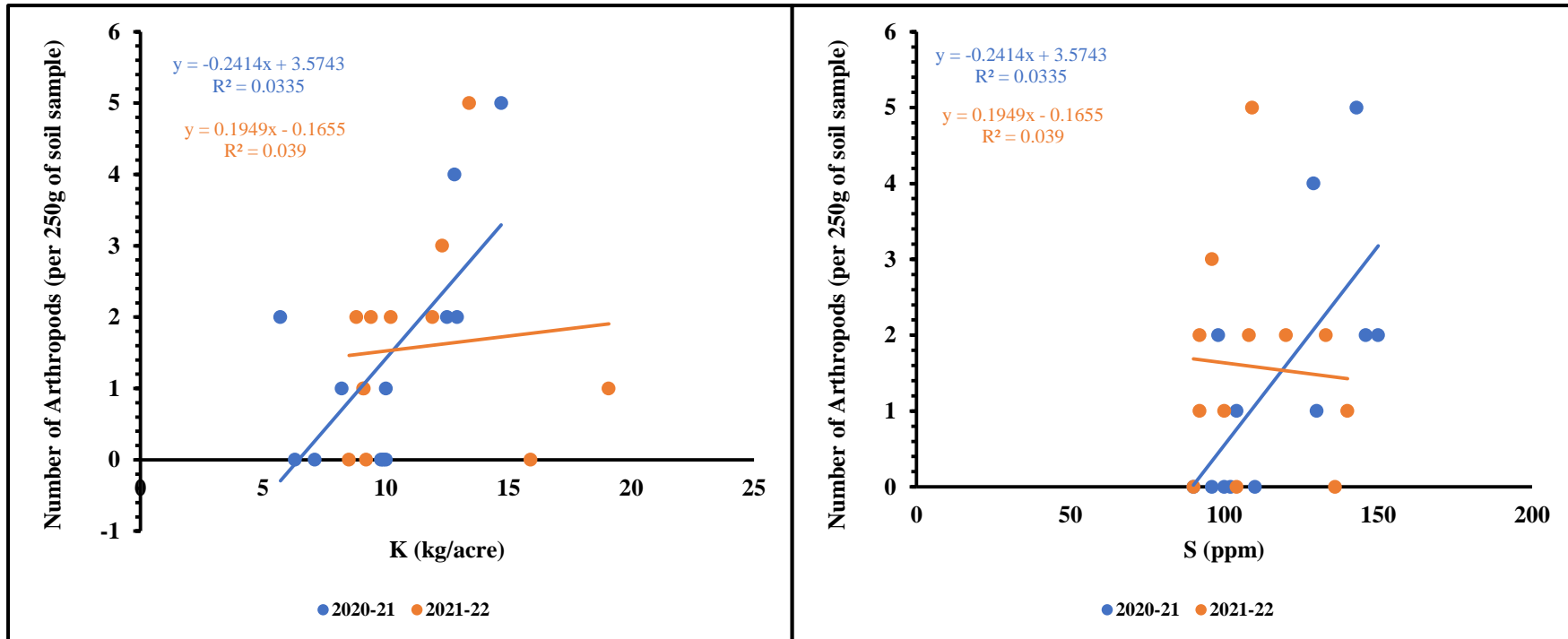


Figure 4.25: Impact of edaphic factors on soil arthropods during two years of study period at Forest land, Panipat

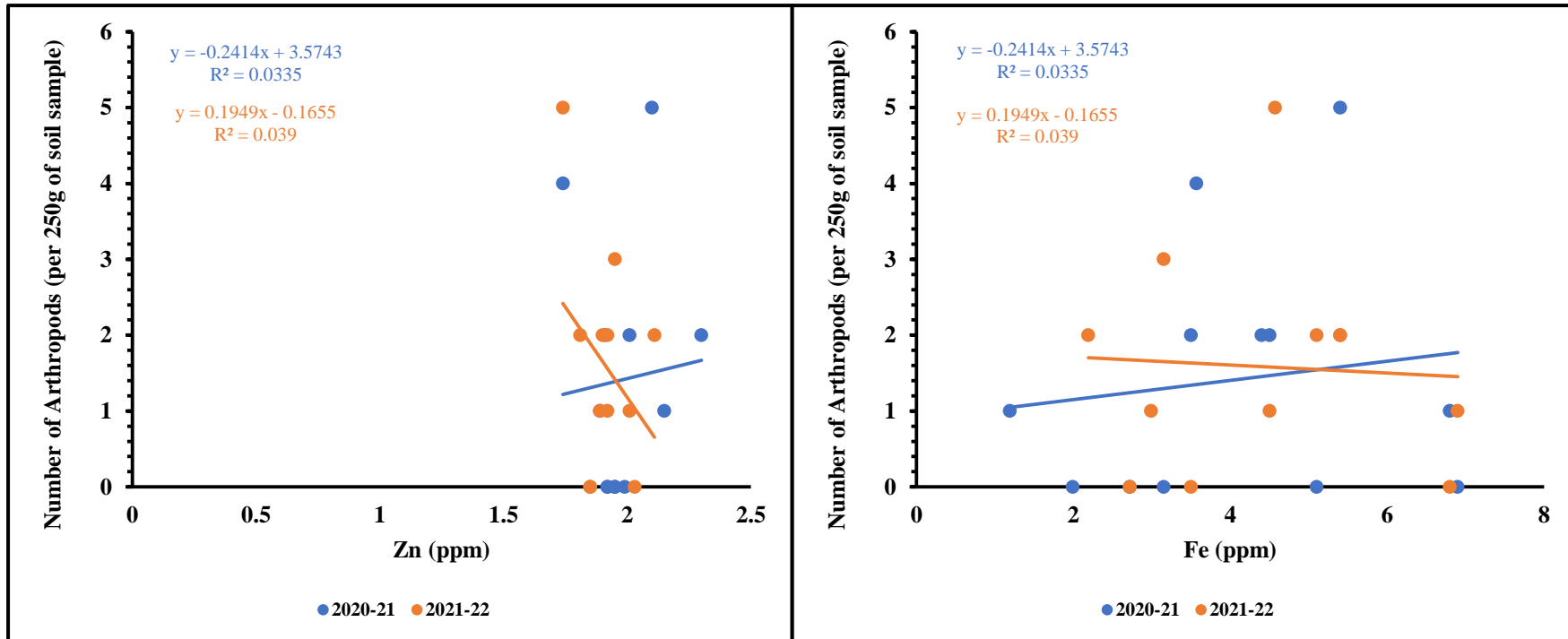


Figure 4.25: Impact of edaphic factors on soil arthropods during two years of study period at Forest land, Panipat

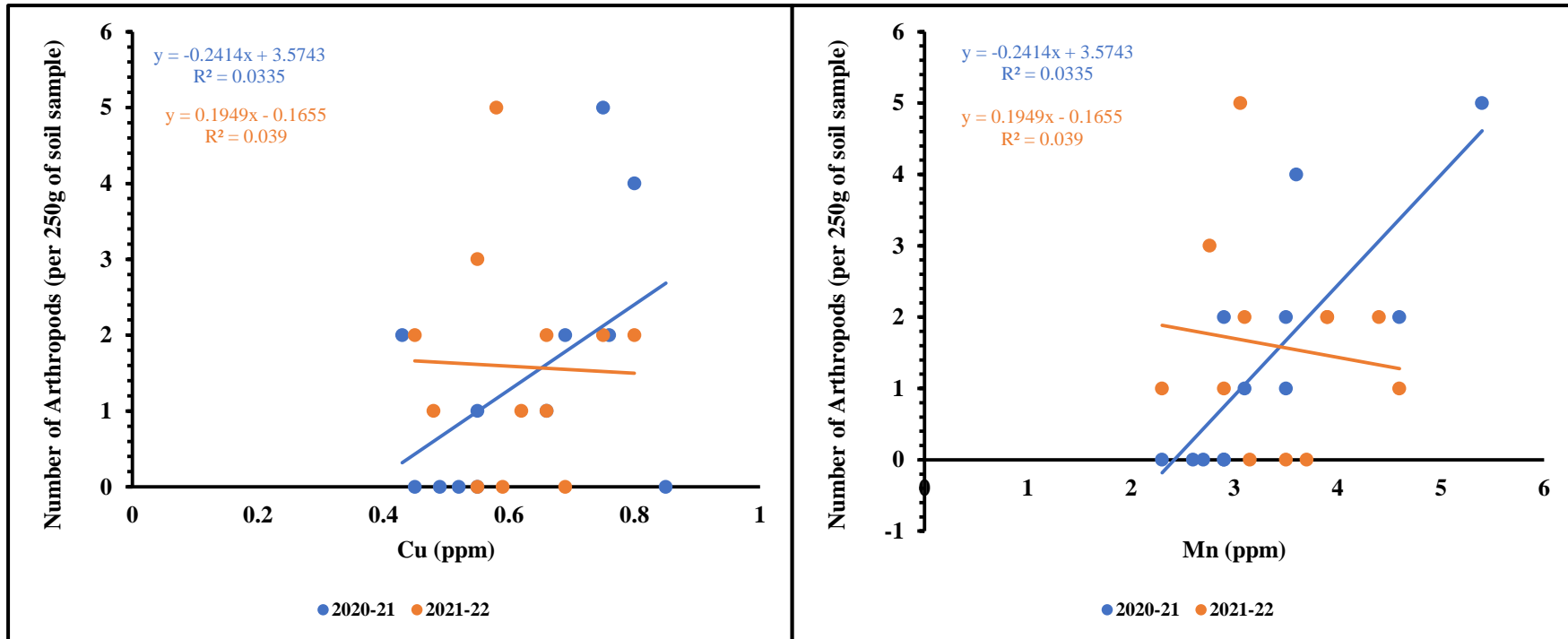


Figure 4.25: Impact of edaphic factors on soil arthropods during two years of study period at Forest land, Panipat

4.4 Discussion

Haryana is a northern region of India. The state has an abundance of natural resources, including minerals and a long history of mining. The soil type in Haryana is predominantly alluvial soil, which is fertile. It is suitable for the cultivation of various crops. The value of a biodiversity analysis of a particular site depends on the quality of basic taxonomic data (Valdecasas & Camacho, 2003). No comprehensive work has been done in this region earlier. So, it is a first attempt to give preliminary knowledge on the current state of soil fauna in this state.

4.4.1 Soil arthropod diversity and distribution

It is typical for soil microarthropods to vary seasonally (Wolda, 1988). Various factors that have been reported in the literature to affect the diversity and distribution of soil microarthropods include soil temperature, pH, moisture, OC, OM, available N, P, K, S, metals, drought, flood, tillage, crop species effect, year effect, and others. In the present investigation, results were based on 7 farming and 2 non-farming lands. Out of seven farming lands, two belonged to Sugarcane fields, Karnal and Yamunanagar; two others to Rice fields, Karnal and Kaithal; the next two to Wheat fields, Sirsa and Hisar; and the remaining one to Jowar fields, Rohtak. And out of two non-farming lands, one belonged to Forest land, Panipat, and the other was an Outskirt of textile industrial land, Panipat.

The overall fauna of soil micro-arthropods (Tables 4.49 – 4.51) showed that their abundance in the first year, i.e., 2020–21, was approximately double (736 in number) when compared with the second year's fauna (399 in number). The year effect is also seen in many other observations of pioneer workers, e.g., In a study (Zheng et al., 2019), there were observable differences in the mite communities across the two research years which may have been caused by fluctuations in annual precipitation, the availability of soil resources, and a variety of other unobserved factors. Similar results were observed (Kautz et al., 2006) by linking differences in precipitation to fluctuations in abundant values over a period of two research years. Our results were also in the same order, showing yearly differences in microarthropod abundance

(Tables 4.49, 4.50, and 4.51). When individual taxa was analyzed, approximately the same pattern (double in the preceding year or half in the succeeding year) was observed (Tables 4.1- 4.8), e.g., abundance of collembola (Table 4.49) in the preceding year was 325 and in the succeeding year observed as 187; mites (Table 4.50) (294, 174); diptera (Table 4.51) (51, 13); thysanuran (Table 4.51) (28, 9); and araneae (Table 4.51) (38, 16). Therefore, it is crucial to consider longer than a year while conducting studies regarding the trends of soil-dwelling microarthropod assemblages, especially in long - term experiments (Tabaglio et al., 2009). When only one year is taken into account, numerous important variables can go unnoticed (Pollierer & Scheu, 2017). It's crucial to employ the same medicines throughout a trial that spans more than one year, though.

However, we were unable to find a connection between microarthropod abundance and yearly variations, suggesting that other variables may be at play. When we compared the arthropod community in terms of relative abundance (Tables 4.49- 4.51), collembolan found 45.11% of total soil arthropods, followed by mites 41.23%, diptera 5.63%, araneae 4.75%, and thysanuran 3.25%. Pitfall traps and Tullgren extractions were used at biweekly intervals to study soil arthropod abundance in connection to an array of meteorological and edaphic parameters and found a more or less recurring pattern of comparable soil arthropod abundance (Shakir & Ahmed, 2015). Out of 79 observed taxa (Tables 4.49 - 4.52), 37 are identified (Tables 4.49 - 4.51), while 42 remain unidentified (Table 4.52). Only 10% of micro-arthropod species and probably 10% of the population as a whole have been defined (Andre et al., 2002). Behind this, more reasons for so many unidentified specimens (Table 4.52) are the presence of very few members of approximately 25% of the taxa, making it impossible to send them to more than one specialist for identification and photos. If they are sent, they will not be able to analyze their anatomy. Even in 5% of cases, specialists were not found, as photos were used to seek permission from specialists. In some cases, permission was granted, and specimens were sent but found to have no outcome. Some approximately 10-15% specimens were damaged during identification by specialists, as seen in their reports (Figures 4.14 - 4.17). Some are photographed and listed but lost during separation from the screened slide. Some specimens were

sent to more than two specialists, but they did not belong to their specialization. There are no instances where the species-level description of the soil biota of a particular region of land has been completed (Whitford, 1992). In our results too, not all the identified taxa have been completely described until the species level, as some are at the order level identified, others at the family level, and the rest at the genus level (Tables 4.49- 4.51). In approximately all of the study fields, the majority of soil arthropods were represented by collembolan and mites only (Tables 4.1- 4.2, 4.7 - 4.8, 4.13 - 4.14, 4.19 - 4.20, 4.25 - 4.26, 4.31 - 4.32, 4.37 - 4.38, and 4.43 - 4.44). Soil microarthropods are mostly comprised of the collembola, acarine groups prostigmata, oribatida, and mesostigmata. In a range of habitats, including equatorial and polar regions, temperate and tropical woods and grasslands, hot and cold deserts, and temperate and tropical climates, these creatures may be the dominating arthropods (Gressitt, 1961; Wallwork, 1982; Curry, 1993; Bandeira & Torres, 1988). They are prevalent in most soils, including those that are being farmed (Hale, 1967; Wallwork, 1967; Behan-Pelletier, 2003). Among soil microarthropods (Abbas & Parwej, 2012), the highest density and abundance are represented by collembola (13.54 and 19.70), followed by hymenopterans (14.83%) and acari (mites) (13.22%). In some fields (Sugarcane and Rice), total arthropods as well as individual taxa (Tables 4.1 - 4.2, 4.7 - 4.8, 4.13 - 4.14, and 4.19 - 4.20) show a peak in the summer season (May - July). Seasonal fluctuation of the soil arthropods in a pine forest (Reddy & Alfred, 1977) was studied and reported that the population peaked in July during the rainy season and peaked in January during the dry season, while at various other locations (Wheat and Jowar fields), the population (Tables 4.25 - 4.26, 4.31 - 4.32) show higher number in the winter season (December - February). According to an investigation (Chaudhary & Roy, 1971a) carried out in an uncultivated and natural plot in West Bengal, the collembolan population peaked between November to January. The average particle size of calcium carbonate and the maximum population have a positive association with carbon from OC content and an unfavorable relationship with soil moisture levels.

The soil arthropods encountered in all the fields (Tables 4.1 - 4.48) belongs to different groups like collembola, acarines, diptera, thysanuran, and araneae. All the

study fields were located in the same geographical subdivision (Figure 3.1, Table 3.1) and encountered more or less the same environmental conditions, although they were different in their arthropodal transformation. Such a difference might be due to local differences in the composition of the substrate and the microclimatic conditions prevailing there. Out of the total identified 37 taxa (Table 4.49 - 4.51), collembolans are found at 45.11%, followed by mites at 41.23%, diptera at 5.63%, araneae at 4.75%, and thysanuran at 3.25%. Thus, collembolans were the most dominant, comprising 45.11% of total identified soil arthropods, and were further represented by 15 taxa (Table 4.49), of which 5 belonged to the order poduromorpha, 9 belonged to the order entomobryomorpha, and the remaining 1 belonged to the order Symphleona. The collembolan arthropods differed in their numerical abundance in different fields but were obtained from all the fields. The genus *Isotomurus* of the family Isotomidae of order Entomobryomorpha occupied the topmost position in numerical abundance and was represented by two unidentified species, of which 17 belonged to sp.1 and the remaining 68 to sp.2. The reason behind the difference in abundance of two species was the occurrence of the first species in only one study field, i.e., Sugarcane field, Yamunanagar, while the second occurred in two study fields, i.e., Sugarcane field, Karnal, as well as Wheat field, Sirsa. Genus 1 of the family Neanuridae of order Poduromorpha occupied the second position and was found at Sugarcane field, Karnal, as well as Rice field, Kaithal. The third position among collembolans was occupied by Genus 1 of the family Tullbergiidae of order Poduromorpha and was found at Wheat field, Sirsa, as well as Hisar. The fourth and fifth positions were occupied by Genus 1 of the family Sminthuridae of order Symphleona and Genus 1 of the family Isotomidae of order Entomobryomorpha, respectively. The former was found at both the Rice fields in Karnal and Kaithal, while the second was found at three fields, namely: Sugarcane fields in Yamunanagar, Jowar fields in Rohtak, and forest land in Panipat. The genus *Proisotoma minuta* of the family Isotomidae of the order Entomobryomorpha also occupied the fifth position and was found at two sites, i.e., Sugarcane field, Yamunanagar, and Wheat field, Sirsa. The sixth and seventh positions were occupied by genus *Cyphoderus* of family Paronullidae of order Entomobryomorpha and genus *Cryptopygus* of family Isotomidae of order Entomobryomorpha, respectively. The other taxa were relatively

low and, to some extent, restricted or localised in their distribution. The various encountered genus of collembola from Haryana study fields were also recorded from different states of India i.e. *Isotomurus* from Andhra Pradesh, Uttrakhand, Andaman and Nicobar Islands, Tripura, Arunachal Pradesh, Manipur, Kerala (Reuter, 1876 and Handschin, 1929); from Jharkhand (Mandal, Suman & Bhattacharya, 2017; Reuter, 1876 and Handschin, 1929); from Odisha, Maharashtra, West Bengal (Stach, 1947; Muller, 1776; Börner, 1906; Reuter, 1876 and Handschin, 1929); *Cryptopygus* from Tamil Nadu (Brown, 1932 and Handschin, 1929); *Proisotoma minuta* from Kerala, Maharashtra (Tullberg, 1871 and Börner, 1903); *Cyphoderus* from Rajasthan, Mizorum, Sikkim, Uttrakhand, West Bengal, Odisha, Andaman and Nicobar Islands, Arunachal Pradesh, Kerala, Maharashtra, Manipur, Assam (Börner, 1906); from Himachal Pradesh (Baijal, 1955); from Jharkhand (Mandal, Suman & Bhattacharya, 2016); from Meghalaya (Mandal, 2018); from Uttar Pradesh (Yadav, 2017).

From the Acarina, the total identified arthropods were 41.23% and were further represented by 14 taxa (Table 50), of which 6 belonged to the order Sarcoptiformes, 4 belonged to the order Trombidiformes, 2 belonged to the order Mesostigmata, and the remaining 1 belonged to Astigmata and Oribatida, respectively. *Scheloribates thermophilus* occupies the topmost position in numerical abundance and was found at Rice field, Kaithal, as well as Wheat field, Hisar. *Epilohmannia minuta aegyptica* occupies the second position and was found at Sugarcane field, Karnal, and Rice field, Karnal, along with Rice field, Kaithal. *Scheloribates curvialatus* occupies the third position and was found at Sugarcane field, Yamunanagar, as well as Sugarcane field, Karnal. *Rhizoglyphus echinopus* was in fourth place and was found at Wheat field, Sirsa, as well as Jowar field, Rohtak. *Protoribates magnus* occupies the fifth position and was found at Sugarcane field, Karnal, and Wheat field, Hisar. *Bdella sp.* occupies the sixth position and was found at Sugarcane field, Yamunanagar, and Jowar field, Rohtak. The remaining eight, *Histiostoma feroniarum*, *Mahunkania hallensis*, *Trachyoribates ovulum*, *Acarus gracillis*, *Mahunkania secunda*, *Eotetranychus carapini*, *Trachygamasus medianus*, and *Cosmolaelaps indicus*, were relatively low and restricted. *Trachyoribates ovulum* was found distributed in West Bengal, Bihar, Tripura, Himachal Pradesh, and Maharashtra (Acharya & Basu, 2014). *Scheloribates*

was found in Darjeeling Himalayas (Ghosh & Mandal, 2017), Meghalaya (Mandal, Das, & Ghosh, 2019 and Hattar et al., 1993). *Epilohmannia* was reported from Himachal Pradesh (Acharya & Dutta, 2019). *Rhizoglyphus* is an aphid that lives on host plants like potatoes, carrots, onions, garlic, and other *Allium* spp. as well as flowers like lilies, gladioli, hyacinths, and freesia. It also lives on grasses like barley, oats, rice, rye, and wheat (Diaz et al., 2000). *Rhizoglyphus* has been collected from wheat flour mills, stored grains (Griffiths et al., 1976), and house dust (Amoli & Cunnington, 1977). This mite was mostly found in wheat storage, flour mills, and poultry feed. Reported from grain stores and flour mills in Punjab (Gill & Kaur, 2014); from stored products, bird nests, house dust, roof gardens, and cattle sheds in South Bengal (Mandal, Das, & Ghosh, 2019); from warehouses and other grain storage facilities in Punjab (Kaur & Dhingra, 2018) and from flour mills in Kashmir (Dehar et al., 2019). *Protoribates magnus* was reported from Nayagarh district's Basaganda point, Bhaluchaba point, Dhobathuba point, Salapadra point, Bugura village, Banigochha East Range, Kaunria Dam Area, Khallikana point, Duisingh Bit area, Angul district's Rangabati point, Tikarpada point, Mankaro Khaikhali point, Purnakote Range, Baghamunda. *Scheloribates curvialatus* from Basaganda point, Baluchaba point, Bugura village, Banigochha east range, Sapapatra point, Banigochha west range, Dabakhali point, Badamali beat of Nayagarh district of Satkosia Basipally Wild Life Sanctuary, Odisha, India (Shelley & Aditi, 2017). The worldwide species *Histiostoma feroniarum* is found in a wide range of habitats with damp, decomposing organic waste, including soil, compost, litter, and bird nests. The modified chelicerae of this mite species, like those of many other histiostomatids, are used to filter microorganisms from the substrate in order to feed on them (Bee Mite ID). *Epilohmannia* was recorded from Tripura (Sarkar & Subias, 1983), the Hawaiian Islands (Aoki, 1965), Meghalaya (Hattar et al., 1993), and the Eastern Himalayas (Ahrens & Hartmann, 2012). *Scheloribates* was also recorded from the same places. The vast abundance of *Scheloribates* in an old rubber plantation and adjacent wasteland area in Ballamukha village of Belonia, South Tripura (Bhattacharya & Chakrabarty, 1995 and Ghosh, 2018), was also reported from Nagaland (Sanyal & Bhaduri, 1986; Mandal, Das, & Ghosh, 2019) and Assam (Ermilov et al., 2014b).

The species diversities and similarities between different sampling months of the same crop were analyzed using the following indices: Shannon Diversity Index (H), Richness Index, Dominance Index, Evenness Index, and Simpson's Index (D). Sugarcane field, Yamunanagar (Table 4.5 - 4.6) is observed with a higher Shannon Diversity Index, Richness Index, Dominance Index, and Evenness Index but a lower Simpson's Index, while Forest Land, Panipat (Table 4.47 - 4.48) is observed with a lower Shannon Diversity Index, Richness Index, Dominance Index, and Evenness Index but a higher Simpson's Index. The forest land, being an area of Reh and Kallar (common or local names for saline soil), has been occupied with poa grass for the last 15 years (Table 3.1). The saturated soil paste's pH is never greater than 8.2 and more often neutral (Abrol et al., 1988); our results (7.4 - 7.5) are in accordance (Figure 4.8, d part). Reduced plant inputs and slower rates of decomposition are two opposing factors that affect the OC content of soil in saline soils. The considerable drop in SOC, OM, total N, and P that was seen (Figure 4.8) may have been caused by this. Salinity of the soil reduces plant productivity and, as a result, soil carbon inputs (Aderoju & Festus, 2013). Thus, our results agree with this zero-plant diversity and no or negligible soil arthropods (Tables 4.43 - 4.44). While the sugarcane land has been growing sugarcane for the last 3 years (Table 3.1). Fertiliser used (Kisan urea, IFFCO, and Shaktiman) only once in June-July (Table 3.1). No pesticide was used (Table 3.1). Loamy soil, which holds plenty of moisture but also drains well, allows sufficient air to reach the roots. As a result, soil arthropods get a favourable environment for their well-being. The crops will grow more vigorously and use up more soil water when the fertiliser is administered. Thus, the crop production was greatly increased with the advancement of agricultural technology, the modification of cropping methods, and the optimization of crop varieties, but the soil moisture was steadily declining (Zhang et al., 2017). In our case too, arthropods related negatively to moisture but positively to OM (Table 4.53). Additionally, as previously indicated by Ferguson & Joly (2002), food competition and consequently temperature as an outcome of climate influenced springtail and mite populations inherently. The same positive correlation with temperature is observed in our results too (Table 4.53). When all the fields were compared in terms of various diversity and similarity indices, then in terms of Shannon diversity or Wiener index (H), a metric for determining the

species diversity in a community; the higher the value of H, the greater the species diversity in that particular community (A community with a value of $H = 0$ has just one species) showed in the order: Outskirts of Textile Land: Panipat (-, -) < Forest Land (Table 4.47- 4.48), Panipat (1.21, 1.21) < Rice field (Table 4.17- 4.18), Karnal (1.38, 1.83) < Rice field (Table 4.23- 4.24), Kaithal (1.85, 1.78) < Jowar field (Table 4.41- 4.42), Rohtak (2.22, 1.99) < Wheat field (Table 4.29- 4.30), Sirsa (2.05, 2.16) < Wheat field (Table 4.35- 4.36), Hisar (2.26, 2.30) < Sugarcane field (Tables 4.11- 4.12), Karnal (2.36, 2.14) < Sugarcane field (Tables 4.5- 4.6), Yamunanagar (2.76, 2.77). The reason for zero or no diversity in the Outskirts of textile land, Panipat lies in the fact that the land is blotted heavily with rinsing chemical water and there is low diversity in forest land. Panipat was explained earlier in terms of saline soil, along with the highest diversity in Sugarcane fields, Yamunanagar in terms of loamy soil, fertiliser used only once, and no use of pesticide (Table 3.1). The intermediate diversity fields were more or less given the same environment except for specific crops, so they were found to have approximately similar diversity indices. The dominance index measures how dominant one or a small number of species are in a community; generally speaking, it has a negative relationship with alpha diversity indices, which include species richness, evenness, diversity, and rarity. Less diverse communities are more prevalent. It followed the sequence: Outskirts of textile Land, Panipat (-, -) < Forest Land (Table 4.47- 4.48), Panipat (0.7292, 0.7167) < Rice field (Table 4.17- 4.18), Karnal (0.76890, 0.8456) < Rice field (Table 4.23- 4.24), Kaithal (0.8447, 0.8184) < Wheat field (Table 4.29- 4.30), Sirsa (0.8668, 0.8865) < Sugarcane field (Table 4.11- 4.12), Karnal (0.8893, 0.8815) < Wheat field (Table 4.35- 4.36), Hisar (0.8943, 0.8976) < Jowar field (Table 4.41- 4.42), Rohtak (0.8959, 0.9137) < Sugarcane field (Table 4.5- 4.6), Yamunanagar (0.9319, 0.9384). In terms of the Richness Index, these are probably more ecologically complicated and might possibly be more significant in terms of the health of the environment and ecosystems. showed in the order: Rice field (Table 4.17- 4.18), Karnal (0.7708, 1.4906) < Rice field (Table 4.23- 4.24), Kaithal (1.659, 1.9107) < Wheat field (Table 4.29- 4.30), Sirsa (1.9147, 2.3459) < Jowar field (Table 4.41- 4.42), Rohtak (2.0153, 2.5247) < Wheat field (Table 4.35- 4.36), Hisar (2.4155, 2.6351) < Sugarcane field (Table 4.11- 4.12), Karnal (3.0778, 2.6161) < Sugarcane field (Table 4.5- 4.6), Yamunanagar (3.8942,

4.091). Reason coincides with Shannon-Diversity Indices. In terms of Evenness Index (the more evenly distributed individuals between species, the more balanced the ecosystem will be): Sugarcane field (Table 4.11- 4.12), Karnal (0.8342, 0.8629) < Forest land (Table 4.47- 4.48), Panipat (0.8697, 0.87) < Rice field (Table 4.23- 4.24), Kaithal (0.8912, 0.8564) < Wheat field (Table 4.29- 4.30), Sirsa (0.8901, 0.9002) < Wheat field (Table 4.35- 4.36), Hisar (0.911, 0.8955) < Sugarcane field (Tables 4.5- 4.6), Yamunanagar (0.908, 0.9254), Jowar field, Rohtak (0.9654, 0.9583), Rice field (Tables 4.17- 4.18), Karnal (0.9938, 0.9392). The reason is hidden in the heterogeneity of the soil. In terms of Simpson's Index (D), Diversity rises together with species richness and evenness: Sugarcane field (Table 4.5- 4.6), Yamunanagar (0.0681, 0.0616) < Jowar field (Table 4.41- 4.42), Rohtak (0.1041, 0.0863) < Wheat field (Table 4.35- 4.36), Hisar (0.1057, 0.1024) < Sugarcane field (Table 4.11- 4.12), Karnal (0.1107, 0.1185) < Wheat field (Table 4.29- 4.30), Sirsa (0.1332, 0.1135) < Rice field (Table 4.23- 4.24), Kaithal (0.1553, 0.1816) < Rice field (Table 4.17- 4.18), Karnal (0.2342, 0.1544) < Forest land (Table 4.47- 4.48), Panipat (0.2708, 0.2833).

When it comes to the outskirts of textile land in Panipat, no soil fauna was observed from the same. The cause is because the textile industry pollutes the soil for a variety of reasons, chief among them the use of azo dyes, heavy metals, and organic chemicals. Soil is contaminated by the toxicity of azo colorants (Kolekar et al., 2008; Imran et al., 2015 and Parveen et al., 2020). Without being broken down into aromatic amines, the same can still cause cancer (Kolekar et al., 2008). Additionally, the biotransformation of bacterial dyes from azo dyes might result in polluted soil (Sriram et al., 2013). Massive levels of heavy metals are also present in the textile sector, which might have an impact on the soil (Norarmi et al., 2020; Singh et al., 2022; Manzoor, 2006 and Dheeba & Sampathkumar, 2012). In order to protect living ecosystems, including plants, animals, and humans, a high concentration of organic molecules has a negative impact on the health of the soil (Singh & Glick, 2020). According to additional research, textile companies worldwide annually produce roughly 280,000 tonnes of industrial effluents, which have a substantial impact on the soil (Annamalai et al., 2018).

The results of the present study make it abundantly clear that, in terms of species composition, the group of soil arthropods presents a very complex and disparate image. Seasonal variation and numerical abundance.

4.4.2 Seasonal Variation of Edaphic Factors

In various soil samples from Haryana, physical and chemical properties were analyzed, which differed broadly, i.e., from loamy to sandy loam texture, low to high OC, i.e., 0.08- 0.93%, 6.8- 9.8 in pH, 0.09- 4.80 dS/m in EC, and were inside the permissible range for electrical conductivity (Malik et al., 2017). In our results too, the same texture, i.e., sandy loam to loamy sand, was observed, as was the same range of SOC, more or less the same range (6.7- 8.1) of pH, in between the range (0.81- 1.90) of EC (Figures 4.1- 4.9). When observed at individual field cover and Sugarcane field, Yamunanagar ranged OC 0.18% - 0.67% (preceding year) while 0.28% - 0.71% (succeeding year) (Figure 4.2, b); pH 6.5 - 7.9 (p) and 6.9 - 7.7 (s) (Figure 4.2, d); EC 0.85 mS/m - 1.7 mS/m (p) and 0.85 mS/m - 1.41 mS/m (s) (Figure 4.2, e). In the case of the Sugarcane field in Karnal, OC is 0.18 % - 0.67 % (p) and 0.28 % - 0.83% (s) (Figure 4.1, b); pH is 6.6 - 7.8 (p) and 6.2 - 7.8 (s) (Figure 4.1, d); EC is 0.87 mS/m - 1.9 mS/m (p) and 0.81 mS/m - 1.31 mS/m (s) (Figure 4.1, e). In the case of the Rice field, Karnal, OC is 0.41 - 0.53% (p) and 0.32 - 0.43% (s) (Figure 4.3, b); pH is 6.8 - 7.2% (p) and 6.7 - 7.1% (s) (Figure 4.3, d); EC is 1.1 mS/m - 1.3 mS/m (p) and 1.1 mS/m - 1.4 mS/m (s) (Figure 4.3, e). In the case of Rice fields in Kaithal, OC is 0.43 - 0.56% (p) and 0.50 - 0.59% (s) (Figure 4.4, b); pH is 7.5 - 8.1% (p) and 7.8 - 8.2% (s) (Figure 4.4, d); EC is 0.93 mS/m - 1.11 mS/m (p) and 0.92 mS/m - 1.16 mS/m (s) (Figure 4.4, e). In the case of the Wheat field, Sirsa, OC is 0.26% - 0.44% (preceding year) while 0.34% - 0.54% (succeeding year) (Figure 4.5, b); pH is 7.1 - 7.5 (p) and 6.8 - 7.1 (s) (Figure 4.5, d); EC is 0.9 mS/m - 1.2 mS/m (p) and 0.91 mS/m - 1.26 mS/m (s) (Figure 4.5, e). In case of Wheat field, Hisar, OC is 0.26 % - 0.44% (preceding year) while 0.24 % - 0.45% (succeeding year) (Figure 4.6, b); pH is 7.1 - 7.5 (p) and 7.1 - 7.4 (s) (Figure 4.6,d); EC is 0.89 mS/m - 1.8 mS/m (p) and 0.86 mS/m - 1.63 mS/m (s) (Figure 4.6,e). In the case of Jowar field, Rohtak, OC is 0.44 - 0.59% (preceding year) while 0.48 - 0.69% (succeeding year) (Figure 4.7,b);

pH is 6.8 - 7.1% (p) and 6.9 - 7.2% (s) (Figure 4.7,d); EC is 0.91 mS/m - 1.50 mS/m (p) and 0.81 mS/m - 1.63 mS/m (s) (Figure 4.7,e). In the case of Forest land, Panipat, OC is 0.1 - 0.27% (preceding year) while 0.11–0.26% (succeeding year) (Figure 4.8,b); pH is 7.4 - 7.6 (p) and 7.4 - 7.6 (s) (Figure 4.8,d); EC is 1.0 mS/m - 1.13 mS/m (p) and 1.01 mS/m - 1.14 mS/m (s) (Figure 4.8,e). In case of Outskirts of textile land, Panipat OC 0.1% - 0.28% (preceding year) while 0.13% - 0.27% (succeeding year) (Figure 4.9,b); pH 7.4 - 7.6 (p) and 7.4 - 7.6 (s) (Figure 4.9,d); EC 1.00 mS/m - 1.13 mS/m (p) and 1.01 mS/m - 1.13 mS/m (s) (Figure 4.9,e).

Soil analysis (Kumar & Singh, 2019) of different states (Rajasthan, Uttar Pradesh, Punjab, and Haryana) depicts that the soils of Punjab and Haryana are good, stable, and rich in farming. Given that Haryana produces the second-most food grains in India, this is evident (Working Group Report on Productivity Enhancement of Crops in Haryana, 2013/ Government of Haryana, Kisan Ayog). In distinct sugarcane-growing edaphic and agro-climatic zones of Haryana, accessible N, P, and K levels varied from 202.8 to 318.9 kg ha⁻¹, 19.5 to 96.5 kg ha⁻¹, and 121.3 to 582.3 kg ha⁻¹, respectively, according to a soil survey (Verma et al., 2014). 7.3 to 8.8, 0.09 to 1.01, respectively, for soil pH values, EC, and OC. In our investigation, two sugarcane-growing fields were taken. At Sugarcane field, Yamunanagar ranged available N 255.1 ppm - 577.6 ppm (p) and 255.1 ppm - 543.1 ppm (s) (Figure 4.2,f); P 37.3 Kg/ac - 70 Kg/ac (p) and 11.02 Kg/ac - 29.6 Kg/ac (s) (Figure 4.2,g); K 9.4 Kg/ac - 34 Kg/ac (p) and 9.4 Kg/ac - 31 Kg/ac (s) (Figure 4.2,g) while in the case of the Sugarcane field, Karnal, available N is 155.1 ppm - 477.6 ppm and 255.1 ppm - 448.3 ppm (Figure 4.1,f); S is 6.5 ppm - 120 ppm and 6.5 ppm - 90.9 ppm (Figure 4.1,f); and P is 10.1 Kg/ac - 36.91 Kg/ac (p) and 18.2 Kg/ac - 38.12 Kg/ac (s) (Figure 4.1,g); K 8.6 Kg/ac - 19.8 Kg/ac (p) and 11.3 Kg/ac - 29.8 Kg/ac (s) (Figure 4.1,g).

Soil types used to cultivate sugarcane in Haryana were classified as having low levels of accessible N, medium levels of P₂O₅, and high levels of K₂O. Zn, Cu, Fe, and Mn were over the essential thresholds for DTPA extraction. The association between OC and accessible N, P₂O₅, K₂O, DTPA-extractable Cu, Zn, Fe, and Mn was shown to be significant and positive ($r = 0.958^*$, 0.597^* , 0.317^* , and 0.429^*). Our findings also

revealed similar outcomes (Table 1). The nutrient index of the Haryana soil revealed that soils are sufficient in DTPA-Mn, Fe, and Cu content but low in DTPA-Zn, which highlights the necessity for Zn treatment to boost crop yield. DTPA-extractable Cu, Zn, and Fe were discovered to have a positive and substantial correlation with SOC content. In all of the soils belonging to various series, pH did not exhibit any association with the amounts of accessible Fe, Zn, Cu, and Mn (Malik et al., 2017). Additionally, it has been demonstrated that cationic micronutrients including Zn, Fe, Mn, and Cu are deficient in several soils all over worldwide (Alloway, 2008) as well as in Indian soils as time passes (Behera & Shukla, 2013). Similar deficiencies were observed in our results too (Tables 4.1 – 4.9). When observed at Sugarcane field, Yamunanagar ranged from Zn 0.65 ppm - 1.4 ppm (p) and 0.75 ppm - 1.43 ppm (s) (Figure 4.2,h); Fe 1.41 ppm - 3.3 ppm (p) and 1.01 ppm - 2.9 ppm (s) (Figure 4.2,h); Cu 0.12 ppm - 0.75 ppm (p) and 0.22 ppm - 0.65 ppm (s) (Figure 4.2,h); and Mn 2.8 ppm - 4.1 ppm (p) and 3.09 ppm - 4.01 ppm (s) (Figure 4.2,h). In case of Sugarcane field, Karnal, Zn 0.85 ppm - 1.15 ppm (p) and 0.75 ppm - 1.27 ppm (s) (Figure 4.1,h); Fe 0.95 ppm - 8.1 ppm (p) and 0.75 ppm - 6.9 ppm (s) (Figure 4.1,h); Cu 0.21 ppm - 0.71 ppm (p) and 0.31 ppm - 0.74 ppm (s) (Figure 4.1,h); Mn 2.1 ppm - 3.94 ppm (p) and 2.002 ppm - 4.08 ppm (s) (Figure 4.1,h). In case of Rice field, Karnal, Zn 0.9 ppm - 1.12 ppm (p) and 0.89 ppm - 1.14 ppm (s) (Figure 4.3,h); Fe 1.31 ppm - 2.03 ppm (p) and 1.41 ppm - 2.3 ppm (s) (Figure 4.3,h); Cu 0.12 ppm - 0.52 ppm (p) and 0.15 ppm - 0.51 ppm (s) (Figure 4.3,h); Mn 2.8 ppm - 3.9 ppm (p) and 2.89 ppm - 3.7 ppm (s) (Figure 4.3,h). In case of Rice field, Kaithal, Zn 0.89 ppm - 1.22 ppm (p) and 0.79 ppm - 1.25 ppm (s) (Figure 4.4,h); Fe 1.41 ppm - 2.3 ppm (p) and 1.31 ppm - 2.03 ppm (s) (Figure 4.4,h); Cu 0.12 ppm - 0.31 ppm (p) and 0.20 ppm - 0.32 ppm (s) (Figure 4.4,h); Mn 2.7 ppm - 3.21 ppm (p) and 2.75 ppm - 3.52 ppm (s) (Figure 4.4,a). In case of Wheat field, Sirsa, Zn 0.8 ppm - 1.35 ppm (p) and 0.75 ppm - 1.23 ppm (s) (Figure 4.5,h); Fe 1.11 ppm - 2.6 ppm (p) and 1.4 ppm - 2.8 ppm (s) (Figure 4.5,h); Cu 0.17 ppm - 0.80 ppm (p) and 0.37 ppm - 0.78 ppm (s) (Figure 4.5,h); Mn 3.7 ppm - 4.5 ppm (p) and 3.5 ppm - 4.15 ppm (s) (Figure 4.5,h). In case of Wheat field, Hisar, Zn 0.79 ppm - 1.48 ppm (p) and 0.68 ppm - 1.41 ppm (s) (Figure 4.6,h); Fe 1.15 ppm - 3.6 ppm (p) and 1.65 ppm - 3.06 ppm (s) (Figure 4.6,h); Cu 0.48 ppm - 0.80 ppm (p) and 0.37 ppm - 0.65 ppm (s) (Figure 4.6,h); Mn 3.15

ppm - 4.5 ppm (p) and 3.45 ppm - 4.53 ppm (s) (Figure 4.6,h). In case of Jowar field, Rohtak, Zn 0.65 ppm - 0.95 ppm (p) and 0.65 ppm - 0.75 ppm (s) (Figure 4.7,h); Fe 0.99 ppm - 1.51 ppm (p) and 0.99 ppm - 1.41 ppm (s) (Figure 4.7,h); Cu 0.3 ppm - 0.6 ppm (p) and 0.4 ppm - 0.6 ppm (s) (Figure 4.7,h); Mn 2.45 ppm - 2.9 ppm (p) and 2.4 ppm - 2.8 ppm (s) (Figure 4.7,h). In case of Forest land, Panipat, Zn 1.74 ppm - 2.3 ppm (p) and 1.74 ppm - 2.3 ppm (s) (Figure 4.8,h); Fe 1.19 ppm - 6.9 ppm (p) and 2.19 ppm - 6.9 ppm (s) (Figure 4.8,h); Cu 0.43 ppm - 0.85 ppm (p) and 0.45 ppm - 0.80 ppm (s) (Figure 4.8,h); Mn 2.3 ppm - 5.4 ppm (p) and 2.3 ppm - 4.6 ppm (s) (Figure 4.8,h). In case of Outskirts of textile land, Panipat, Zn 1.43 ppm - 1.99 ppm (p) and 1.74 ppm - 2.33 ppm (s) (Figure 4.9,h); Fe 2.72 ppm - 4.9 ppm (p) and 1.72 ppm - 3.9 ppm (s) (Figure 4.9,h); Cu 0.63 ppm - 0.96 ppm (p) and 0.63 ppm - 0.98 ppm (s) (Figure 4.9,h); Mn 2.7 ppm - 3.9 ppm (p) and 2.3 ppm - 3.9 ppm (s) (Figure 4.9,h).

4.4.3 Impact of edaphic factors on soil arthropods

One of the most contentious issues in soil ecology involves the drivers of soil-dwelling microarthropods, and various findings have been documented in the literature. The results of this investigation exhibit very close similarities as well as remarkably striking differences with the observations of pioneer researchers. The differences observed may be due to the occurrence of variations in the microclimatic situation, which in turn exerts profound influence on the population structure both quantitatively and qualitatively. Correlation (Tables 4.53 - 4.60) and regression values (Figures 4.18 - 4.25) revealed that the population of arthropods may have been affected cumulatively in either a good or negative way by soil variables. There are numerous papers that go into detail into the impact of abiotic or edaphic factors on the quantity and distribution of soil fauna in site-specific ecosystems. The majority of these research focus on edaphic elements, such as soil type, soil moisture (Usher 1976; Wallwork 1970; Badejo 1982; Kamill et al., 1985; Steinberger et al., 1984; Vannier 1987; Asikidis & Stamou 1991; Whitford 1989; Ali-Shtayeh & Salahat 2010 and Bean et al., 1994;), soil pH (Hagvar & Abrahamsen 1980; Rentao et al., 2013 and Klausman 2006;), soil temperature (Sulkava & Huhta 2003; Usher 1976; Asikidis &

Stamou 1991; Whitford 1989; Cancela Da Fonseca 1995 and Cakir & Makineci 2013), rainfall (Anu et al., 2009 and Yang & Tang 2004;), SOM (Ponce et al., 2011; Fujikawa 1970; Anderson 1988; Santos et al., 1978 and Scheu & Schulz 1996;), vegetation (Speight & Lawton 1976), and type of crop (Robertson et al., 2012). In order to anticipate the difficulties of climatic interference, which causes populations of soil microarthropods to fluctuate in a highly diversified manner, there is therefore great space for inquiry on the edaphic parameters in the context of soil microarthropod populations.

In some fields (Sugarcane and Rice), total arthropods as well as individual taxa (Tables 4.1 - 4.2, 4.7 - 4.8, 4.13 - 4.14, and 4.19 - 4.20) show peak in the summer season (May - July) while at other fields (Wheat and Jowar), the same (Tables 4.25 - 4.26, 4.31 - 4.32) show peak in the winter season (December - February). According to Wallwork (1970), preference for temperature is species - specific. Although temperature and abundance were closely connected (Sulkava & Huhta, 2003), however, excessive heat in June and July was detrimental to soil arthropods. Various studies (Ali-Shtayeh & Salahat, 2010 and Zhimomi et al., 2009 in rice fields; Sulkava & Huhta, 2003, Asikidis & Stamou, 1991, Ospina et al., 2003, Butcher et al., 1971, Christiansen 1964, Williams 1999, Hopkins 1997, and Brahmam et al., 2010 in Bt Cotton) stress the positive relationship between temperature and soil arthropod diversity because it was discovered that the abundance of dominating microarthropods was highest in May to September and lowest in January. Additionally, the main producers of soil arthropod abundance - collembola, mites, ants, and millipedes - were virtually missing from the samples throughout the winter which caused the quantity to drop drastically. When the pH of the soil samples was observed, it was found that it did not exhibit a very wide range of variation (6.5 - 7.8), being well within the tolerance range of most of the dominant groups. The statistical analysis revealed that the pH values in most cases exhibited either a negative or weak positive correlation (Table 4.53 - 4.60) with the arthropod population (Choudhuri & Roy, 1972; Hazra, 1976; Choudhuri & Banerjee, 1977; Ghatak, 1978; Sanyal, 1994; and Ghosh, 1995). Of all the soil factors studied, soil moisture exhibited a rather wide range of correlations (from strong negative to strong positive) with the arthropod population

(Tables 4.53 - 4.60). Workers (Choudhuri & Banerjee, 1977; Joy & Bhattacharya, 1981; and Sanyal, 1981) observed a strong positive correlation with the arthropod population in some sampling sites, while researchers (Choudhuri & Pande, 1982; and Sarkar, 1991; Sanyal & Sarkar, 1993; and Ghosh, 1995) reported a negative correlation between soil moisture and population. So, it appears that the impact of soil moisture on the arthropod population is still in a state of confusion. Moreover, the capacity to withstand the condition of drought or desiccation as well as a higher moisture level varies from species to species or group to group, which might be considered a reason for population fluctuation. All soil microarthropods' physiological activity, nutrition, and habitats are directly and indirectly impacted by seasonal variations in soil temperature, pH, and moisture content. These elements are in turn influenced by transient phenomena like rainfall, etc. (Killham, 1994). Contrary to assertion (Ferguson & Joly, 2002) that warmth as a function of climate and competition for food were the primary determinants of collembola and mite populations, it was claimed (Maclagen, 1932) that soil temperature, soil moisture, and soil pH had a noticeable impact on the growth, development, and fecundity of collembola. OM, being an important constituent of soil, was supposed to have some promising bearing upon the fluctuation of soil-dwelling arthropods and other physicochemical properties of soil. Additionally, it has been documented that populations grow quantitatively as OM concentrations rise (Choudhuri & Roy, 1972; Choudhuri & Banerjee, 1977; Hazra, 1978a, b; Ghatak, 1978; Roy & Ghatak, 1980; Joy & Bhattacharya, 1981; Choudhuri & Pande, 1982; Banerjee & Sanyal, 1991; Ghosh, 1995; Sanyal et al., 1999, Scheu & Schulz, 1996; Fujikawa, 1970; Santos, 1974; Anderson, 1988; Tripath et al., 2006; Vreeken-Buijs et al., 1998; Haarlov, 1960; Christensen, 1970; Davis, 1963; Singh, 1970; Darlong & Alfred, 1982; Huhta & Milkkonen, 1982). And as stated earlier, the microclimate of specific fauna is also very important, and some results show remarkably striking differences with the observations of pioneer researchers. According to a study (de Graaff et al., 2019), excessive intake of organic or mineral nutrients has varying consequences on soil microarthropods in agricultural fields. Similar to prior research (Zheng et al., 2019), when soil parameters were taken into account as covariates, fertilization did not substantially correlate with the quantity of soil - dwelling mites and collembolans.

Numerous studies found no differences in collembolan assemblages or acari groups between croplands managed with mineral N fertilisation and unfertilised control plots (Artemjeva & Gatilova, 1975; Tabaglio et al., 2009; Kautz et al., 2006; and Coulibaly et al., 2017). According to other studies (Sun et al., 2017; Artemjeva & Gatilova, 1975; Tabaglio et al., 2009; and Zhu & Zhu, 2015), N fertilization either had a detrimental or a positive effect on collembolan or mite groups. These inconsistencies could be explained by variations in the amount of fertilizer used (low or high dosages; de Graaff et al., 2019), and the type of fertilizer used (organic or mineral). Similar to this, the length of time (a year or longer) that a particular treatment has been used is also significant (de Graaff et al., 2019). Following fertilizer application, workers (Lindo & Winchester, 2008) found no differences in the availability of nitrate and ammonium ions in the soil. In addition, there were no variations in the total N of soil (Zhu & Zhu, 2015, Kautz et al., 2006; Cao et al., 2011; Tabaglio et al., 2009; and Bosch-Serra et al., 2014;) or organic content (Tabaglio et al., 2009; Cao et al., 2011; and Bosch-Serra et al., 2014). While this was going on, additional research found that fertilization had a considerable impact on the soil nitrate concentration (Bosch-Serra et al., 2014), accessible N (Zhu & Zhu, 2015), and total N (Sun et al., 2017). Fertilization presumably modifies the chemical characteristics of soil, which may therefore have an impact on the microbiota that lives there (Ai et al., 2018). Since microarthropods facilitate microbial processes of decomposition and consume microbiota, collembolans and mites have a close relationship with soil microbial populations (Bonkowski et al., 2000). Changes in the microbiota that lives in the soil may affect the microarthropods that inhabit it. Additionally, this finding refutes the notion that phosphate is a significant soil component for soil-dwelling mites in fertilized croplands (Cao et al., 2011) or that phosphate reduces mite and collembolan abundance (Sun et al., 2017). According to our observations, the quantity of soil arthropods correlates with the amount of phosphate accessible in both a positive and a negative way (Tables 4.53 - 4.60). The density of acari and collembola dramatically decreased with the rise in Mn and Zn levels (Santamara et al., 2012). In comparison to collembolans, mites proved to be more vulnerable to heavy metal contamination. In addition, these microarthropods were less abundant in the soils with increased N contents. Acarina, collembola, and total arthropods have a negative connection with

Zn, Mn, and accessible N content, with the exception of some sites where it is also positive, according to our observations (Tables 4.53 - 4.60). According to some studies (Khalil et al., 2009, and Steiner, 1995), the loss of species that are sensitive to metal pollution is frequently offset by an increase in opportunistic or tolerant species, having little impact on the diversity of all species as a whole. Additionally, compared to the reference locations, several scientists have shown increased densities and species richness in contaminated areas (Migliorini et al., 2005; Seniczak et al., 1997). Some studies showed that (Klausman, 2006, and Logah et al., 2010) SOC is positively correlated with soil microbial biomass carbon, which in turn (Aciego Pietri et al., 2008) reaches its optimal level when the soil pH is between 5.00 and 6.00 and declines when lower than 5.00. Additionally, pH influences the availability of nutrients in the soil, which has an indirect impact on the organization of microbial communities (Qi et al., 2018). However, in all the soils in Haryana belonging to various types of alluvial soils, soil pH and EC did not exhibit any association with the available Zn, Cu, Fe, and Mn (Malik et al., 2017; and Pati & Mukhopadhyaya, 2011). Instead, a lack of cationic micronutrients including Zn, Fe, Mn, and Cu has been observed over time in Indian soils (Singh & Behera, 2011) as well as other soils throughout the world (Alloway, 2008). However, it was discovered that there was a substantial positive correlation between OC and Fe and Cu availability (Malik et al., 2017). Because of this dependency, it has been difficult for us to determine how specific edaphic conditions relate to the variety of soil arthropods. Agroecosystems are communities that are predominantly shaped by agricultural techniques like crop rotation, tillage, etc. A study correlates an increase in total OC with an increase in Cu (Hossam, 2001). Soil characteristics like as saturation, compaction, poor aeration, the presence of other nutrients, leaching, and soil erosion have an impact on the amount of Fe in the soil as well (Bill, 2010). So, all these studies let us stand alone in a tumbled scenario, remembering the concept of the food web (real scenario) and the food chain (hypothetic scenario). What the situation actually is, there are so many and so many infinite and undefined factors whose cumulative effect let soil arthropods grow, develop, reproduce, increase or decrease, be diverse or few, flourish or finish, migrate or remain native, and so on. Therefore, it seems purely hypothetical to investigate the effects of specific edaphic conditions on the variety of soil arthropods.

A study (Sinha et al., 1988) discovered that controlling the seasonal periodicity of soil mesofauna is not the result of a single factor, but rather the cumulative action of a number of factors.

4.4.4 Impact of other than edaphic factors on soil arthropods

In numerous observations of early settlers, the year effect can also be detected, for example. In an investigation (Zheng et al., 2019), there were observable differences in mite assemblages across the two study years., which may have been caused by fluctuations in annual precipitation, the availability of soil resources, and a variety of other unobserved factors. Similar to this study, another worker (Kautz et al., 2006), found variations in abundance values over the course of two research years with changes in precipitation. Our results were also in the same order, showing yearly differences in microarthropod abundance, i.e., When compared to the first year (736 microarthropods), the overall abundance decreased by about half in the second year (399 microarthropods). When individual taxa were analyzed, approximately the same pattern (half in the second year) was observed, e.g., abundance of Collembola in the previous year was 325 and in the succeeding year it was observed as 187, Mites (294, 174), Diptera (51, 13), Thysanura (28, 9) and Araneae (38, 16). Therefore, it is crucial to consider longer than a year in study examining the trends of soil-dwelling microarthropod assemblages, especially in long-term studies. (e.g., Tabaglio et al., 2009). When only one year is taken into account, numerous important variables can go unnoticed (Pollierer & Scheu, 2017). It's crucial to employ the same medicines throughout a trial that spans more than one year, though. According to collembolans' seasonal distribution, several species attain their highest and lowest populations at various times of the year at various locations (Hale, 1966). Since we couldn't find a connection between microarthropod abundance and yearly variations, it must be the result of unknown variables. Because the impact of crop species was thought to be related to the persistence of plant leftovers in the soil, which, when they decompose, offer favorable habitats as food for soil mite and springtails, microarthropod groups were observed to be significantly associated with crop species effect (however, to a lesser extent). Crop type is also important in affecting arthropod abundance, as the

carbon uptake of soil fauna is from roots (Pollierer, 2007). When compared to sugar beets, wheat plants have a more intricate root system, related microbes, and more exudates, which implies the wheat rhizosphere offers a wider variety of food alternatives for soil fauna (Weigel, 2005). Contrary to popular belief, a worker (Holland, 2000) argued that no species has ever been connected to a specific agricultural plant since spring-planted crops, such as potatoes, sugar beets, maize, and carrots, were less abundant and diverse than winter-planted crops (cereals, oilseed rape). Thus, the abundance pattern of microarthropods follows seasonal crop types. In our result, the Sminthuridae family of Symphypleona order, the Neanuridae family of Poduromorpha order, and the Paronullidae family (e.g., *Cyphoderus sp.*) of Entomobryomorpha order constituted the taxa strictly associated with the Rice field (Karnal as well as Kaithal); the Hypogastruridae family of Poduromorpha order with Jowar field (Rohtak district) as well as Forest Land (Panipat District); and the Tullbergiidae family of Poduromorpha order of Class Collembola with Wheat field (Sirsa as well as Hisar district). Similarly, in the case of Acarina, taxa of the Histiostomatidae family (e.g., *Histiostoma feroniarum*) of the Astigmata order along with Haplozetidae family (e.g., *Trachyoribates ovulum*) of the Oribatida order are associated with Wheat fields (former in Sirsa district while latter in Hisar district); Laelapidae family (e.g., *Cosmolaelaps indicus*) of the Mesostigmata order with Jowar (Rohtak district); Parasitidae family (e.g., *Trachygamasus medianus*) of the same order along with Tetranychidae family (e.g., *Eotetranychus Carapini*) of the Trombidiformes order with Sugarcane field (Yamunanagar district). Thus, some microarthropods was observed associated strictly with one crop species while on the other side, some other microarthropods are associated with two or more crop species e.g. Acaridae family (e.g. *Acarus gracillis*, *Rhizoglyphus echinopus*) of Sarcoptriformes order with Wheat field (Sirsa district) as well as Jowar field (Rohtak district); Epilohmanniidae family (e.g. *Epilohmannia minuta aegyptica*) of same order with Sugarcane (Karnal district) as well as Rice field (Karnal and Kaithal both districts); Protoribatidae family (e.g. *Protoribates magnus*) of same order with Sugarcane field (Karnal district) and Wheat field (Hisar district); Scheloribatidae family (e.g. *Scheloribates curvialatus*, *Scheloribates thermophilus*) of same order with Wheat field (Hisar district), Rice field (Kaithal district) and Sugarcane field

(Karnal and Yamunanagr districts); Bdellidae family (e.g. *Bdella* sp.) of Trombidiformes order with Sugarcane field (Yamunanagar district) and Jowar field (Rohtak district); Pygmephoridae family (e.g. *Mahunkania hallensis*, *Mahunkania secunda*) of Trombidiformes order with Rice field (Karnal district), Sugarcane field (Yamunanagar and Karnal districts) and Jowar field (Rohtak district). Linyphiidae family of Araneae order of Class Insecta with Rice field (Karnal and Kaithal districts), Sugarcane field (Yamunanagar district), and Wheat field (Sirsa and Hisar district); Diptera order of Class Insecta with Rice field (Karnal and Kaithal districts) and Sugarcane field (Yamunanagar and Karnal districts); and Thysanura order of Class Euchelicerata with Sugarcane field (Yamunanagar and Karnal district) and Rice field (Karnal district). However, several eurytopic species showed no preference for a particular crop and were present in all crop plantations., e.g. Taxa of the Isotomidae family (e.g., *Isotomurus* sp. 1, *Isotomurus* sp. 2, *Cryptopygus* sp. 1, *Proisotoma minuta* (Tullberg, 1871)) of the Entomobryomorpha order of Class Collembola are observed in each and every field. Further, when arthropod abundance was compared with their respective crop life cycle, i.e., from sowing to harvesting time period, jowar showed maximum abundance after one month of sowing, while sugarcane showed maximum abundance after three months of sowing, Wheat showed after four months, and rice showed just after sowing. Thus, our hypothesis that crop life cycles affect arthropod abundance proves wrong.

Crop stress will rise with predicted longer drought periods between rainfall events, and changes in rainfall volume and timing will impact biomass production and crop yields (Alexandrov et al., 2002; Eitzinger et al., 2001; and Thaler et al., 2008). The accompanying arthropods will be impacted by these changes in soil quality and vegetation structure (Andow, 1991). Agricultural practices that affect the abundance and species composition of Collembola include ploughing methods (Bertolini et al., 1989; Loring et al., 1981; Rickett 1986; and Rickerl et al., 1989) and harvesting conditions (Akkerhuis et al., 1988; Lagerlof et al., 1985a; Blackith 1974; Gama et al., 1991, 1994; Huhta & Milkkonen 1982; Jordana et al., 1987; and Reddy & Venkataiah 1990a and 1990b). Greater edaphic biological variety and the existence of all functional groups, especially those species that have no equivalent trophic role, would

be ensured by the increased environmental variability beneath the soil surface given by plant roots (Santiago et al., 2009). Thus, by increasing the competitive interactions between various functional qualities, diversity could be increased, and ultimately, the biological diversity of soil microarthropods may increase due to better-performing management, either organic or conventional.

Numerous environmental restrictions modify the amounts of OM (the substrate), which in turn affects the rate of decomposition reactions. In contrast, a study (Wardle, 1995) documents a number of instances where traditional farming techniques promote the richness of soil fauna. Due to the fact that OM and OC serve as the majority of the soil microarthropods' primary food and nutritional supplies, this may contribute to lowering their concentrations at the site in question. On the other hand, a single taxon may serve several different purposes, despite the fact that additional taxa may appear to serve related purposes. Taxa performing the same function are frequently isolated by space, time, or preference for a particular microhabitat, therefore they may not necessarily be redundant (Beare et al., 1995). Mechanical tillage removes the pre-existing vegetational ground cover or plant cover, which can change the composition of the soil and the living creature population which lives there (Darlong & Alfred 1982; and Gilarov 1973). The presence of a sizable mite population meant that plow-related impacts on oribatids had not been negative, which is consistent with the beneficial effects of plow-related effects on soil structure. As a result of the widespread usage of inorganic fertilizers, collembolan as well as soil microarthropod populations suffered. Farmers' management techniques have a direct impact on the role of soil microarthropods since they must foster favorable circumstances for soil life. The population dynamics of the field, which was maintained traditionally and unconventionally, are very different. The use of hand hoes, animal-drawn and motorized ploughs, and harrows in conventional tillage techniques is likely to degrade soil structure and leave the soil vulnerable to compaction and erosion. Compacted soil can be the result of heavy wheel activity, vehicle exhaust, and human foot movement. When soil aggregates that are damp or wet are compressed together, less pore space exists between them. This is known as compaction. Compaction alters the pore size and continuity of the soil, as well as its bulk density. It lessens the soil's ability to

retain water, and because there is less water available for plant growth, there are fewer soil organisms. We therefore came to the conclusion that tillage had a detrimental effect on the overall number of soil microarthropods based on our observations. Natural predators like mites, dipteran and coleopteran larvae, as well as decomposers like collembolans, gain right away from no tillage. The accumulation of plant residues on the soil surface that results from no tillage management, as opposed to ploughed systems, slows the rate at which crop material decomposes and hence aids in maintaining healthy SOM levels. Therefore, one of the unobserved faunal variety in almost all agricultural soils is represented by soil microarthropods, primarily mites and collembolans. Microarthropods are a part of the intricate food chains in soils, but their significance is rarely recognized (1992, Crosley et al.). It has long been undervalued to research soil creatures, particularly in India. According to Usher in 1985, this is due to the invisibility of the system and a lack of attractive species (cute, cuddly, and entertaining). Furthermore, soil groups have been referred to as the poor man's tropical rainforest because they appear to sustain a high biodiversity (Usher et al., 1979). The changing patterns and makeup of these communities are poorly understood, and only a small portion of the species in question have been reported.

Inorganic fertilizers in particular have disrupted the microarthropod niches required for nutrient recycling in addition to changing the soil's pH, structure, and texture (Moreira et al., 2006; and Ponce et al., 2011). The intensification of agriculture involving significant fertilizer application to restore soil fertility has also caused these changes. That is why we took crop land soil, which had been used for crop production without replacing OM and nutrient contents and preserving a decent structure. Nutrient cycles are disrupted, soil fertility diminishes, and the agro-ecosystem's balance is shattered.

CONCLUSION

CHAPTER 5: CONCLUSION

The present thesis, entitled "Diversity and Distribution of Soil Arthropods in Farming and Non - Farming Land of Haryana and their Correlation with Edaphic Factors," reveals the results of edaphic factor analysis, diversity of soil arthropods, correlation, and regression from different farming and non - farming study fields of Haryana (India) during the period from 2020 to 2022. The referred thesis, however, embodies 376 pages including 89 tables and 29 figures. No comprehensive work has been done in this region earlier. So, it is a first attempt to give preliminary knowledge on the current state of soil fauna in this state. Keeping in view of such difficulty, an effort has been made to fulfil the following objectives: 1. Soil physical and chemical parameters for the first two years after inception 2. Arthropod diversity of soil in different farming (Sugarcane, Rice, Wheat and Jowar) and non - farming (Forest and Industrial) areas 3. Identification of arthropods through morphological and/or molecular techniques 4. Seasonal distribution and correlation of the arthropod's diversity with different edaphic factors However, the salient features of the results obtained from the study are as follows:

1. Results of present investigation gave us comparable arthropod diversity and variation in edaphic factors from farming and non-farming lands. For farming lands, Sugarcane fields from Karnal and Yamunanagar; Rice fields from Karnal and Kaithal; Wheat fields from Sirsa and Hisar; and Jowar fields from Rohtak were chosen. And for non-farming lands, forest land, and an outskirts of textile land, Panipat were chosen.
2. For sampling, soil samples were taken from a depth of 15 cm. Sampling took place from November 2020 to October 2022. The sampled soil was collected from 5 independent points (250 g) per plot and then mixed to a volume of 1.25 kg per plot. This procedure was repeated in three different fields of the same crop. Collected soil samples were immediately stored in labelled plastic bags with appropriate sample information (e.g., project, date, plot, variate) at 0 °C in the laboratory for arthropod extraction and estimation of soil parameters

such as soil temperature, moisture, pH, electrical conductivity, SOC content, SOM content, soil available P, N, K, and metal analysis.

3. The total soil fauna showed their abundance in the first year, i.e. 2020 - 21, was approximately double (736 in number) compared to the second year, i.e. 2021 - 2022, fauna (399 in year number). When individual taxa were analyzed, approximately the same pattern was observed (doubled in the first year or half in the second year), e.g. collembola abundance (Table 49) was 325 in the first year and 187 in the second year; mites (294, 174); Diptera (51, 13); thysanurane (28, 9); and araneae (38, 16). When we compared the arthropod community in terms of relative abundance, Collembolan found 45.11% of the total soil arthropods, followed by mites (41.23%), dipterans (5.63%), araneae (4.75%) and thysanurans (3.25 %).
4. The reason for so many unidentified specimens (more than half) (Table 4.52) is the presence of a very small number of representatives of approximately 25% of the taxa, so we cannot send them to more than one specialist for identification and photography. If we send them, we are unable to analyze their anatomy. Even in 5% of cases, specialists were not found because photographs were used to obtain permission from specialists. In some cases, permission was granted and samples were sent but were found to have no result. Approximately 10-15% of samples were damaged during specialist identification as seen in their reports. Some are photographed and listed but lost during separation from the projected slide. Some specimens were sent to more than two specialists, but they did not belong to their specialism.
5. The maximum soil temperature was recorded in the month of June, and it reached the minimum level in the month of January during the study years. Soil moisture ranged 5.1% - 20.3%, pH 6.2 - 8.2%, EC 0.81 mS/m - 1.9 mS/m, OC 0.1% - 1.69 %, OM 0.16 - 1.11 %, available N 103.45 ppm - 577.00 ppm, K 8.6 - 155 ppm, P 5.7 - 90.01 ppm, S 6.5 - 133 ppm, Zn 0.65 - 2.3 ppm, Fe 0.75 - 6.9 ppm, Cu 0.12 - 0.98 ppm, and Mn 2.00 - 5.4 ppm.
6. 15 taxa from collembolans were observed, of which 5 were from the Order Poduromorpha, 9 from the Order Entomobryomorpha, and the remaining 1 from the Order Symphlepleona. 14 taxa observed from Acarina, of which 6

from the Order Sarcoptiformes, 4 from the Order Trombidiformes, 2 from Mesostigmata, and the remaining 1 from Astigmata and Oribatida respectively.

7. The effect of plant species was shown to be highly related to the groups of micromembers (albeit to a lesser extent), as it was evidently associated with the preservation of plant residues in the soil, which after decomposition provide ideal habitat and food for soil mites and tails.
8. At last, but not least, this investigation will surely open new roads for all those working in soil entomology, farmers, projects in agriculture, and taxonomists.

APPENDIX

APPENDIX

Table A.1: Physicochemical analysis of edaphic factors during 2020 - 21 at Sugarcane field, Yamunanagar

Month	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
February	11.5 ±	21 ±	7.1 ±	0.98 ±	0.67 ±	0.7 ±	577.6 ±	46.6 ±	16 ±	120 ±	1.12 ±	1.95 ±	0.65 ±	4.1 ±
	0.72	0.72	0.32	0.05	0.01	0.01	10.67	1.67	0.67	9.67	0.003	0.023	0	0.006
March	10.6 ±	22 ±	7 ±	1.12 ±	0.51 ±	0.29 ±	439.6 ±	61 ±	31 ±	123 ±	1.4 ±	2.1 ±	0.75 ±	3.9 ±
	0.63	0.63	0.23	0.08	0.02	0.03	12.11	2.11	0.11	8.11	0.001	0.001	0.001	0.053
April	8.1 ±	29 ±	7.8 ±	1.1 ±	0.18 ±	0.8 ±	355.1 ±	40.1 ±	12.6 ±	17.3 ±	0.65 ±	2.3 ±	0.6 ±	3.81 ±
	0.71	0.71	0.31	0.04	0.02	0.02	9.16	1.16	1.16	7.16	0.002	0.001	0.006	0.012
May	7.4 ±	40 ±	6.5 ±	1.3 ±	0.6 ±	0.93 ±	517.2 ±	37.3 ±	17.3 ±	73.49 ±	1.16 ±	1.8 ±	0.7 ±	3.6 ±
	0.51	0.51	0.11	0.03	0.01	0.03	10.99	1.99	0.99	8.99	0.001	0.001	0.001	0.011

June	6.1 ± 0.41	41 ± 0.41	7 ± 0.21	1.1 ± 0.05	0.3 ± 0.02	0.94 ± 0.02	358.6 ± 11.12	70 ± 1.12	34 ± 0.12	140 ± 10.12	1.12 ± 0.013	1.41 ± 0.002	0.28 ± 0.005	3.7 ± 0.011
July	10 ± 0.95	39 ± 0.95	6.7 ± 0.15	1.7 ± 0.02	0.7 ± 0.03	0.8 ± 0.05	503.4 ± 13.11	51.4 ± 1.11	29.6 ± 1.11	19.4 ± 11.11	1.11 ± 0.023	1.51 ± 0.002	0.19 ± 0.002	3.9 ± 0.011
August	12.2 ± 1.02	32 ± 1.02	7.9 ± 0.32	1.5 ± 0.03	0.6 ± 0.06	0.77 ± 0.04	517.2 ± 12.11	62.91 ± 2.11	19.8 ± 0.11	19.03 ± 10.11	0.99 ± 0.076	1.52 ± 0.001	0.12 ± 0.017	3.81 ± 0
September	8.9 ± 0.41	30 ± 0.41	7 ± 0.21	1.12 ± 0.04	0.23 ± 0.02	0.67 ± 0.02	398.3 ± 12.12	50.74 ± 2.12	16 ± 1.12	20.39 ± 11.12	0.9 ± 0.032	2.01 ± 0.011	0.31 ± 0.005	3.01 ± 0.006
October	10.5 ± 0.61	25 ± 0.61	7.7 ± 0.31	1.6 ± 0.06	0.63 ± 0.04	0.5 ± 0.02	543.1 ± 13.02	46.91 ± 3.02	9.4 ± 1.02	60.5 ± 12.02	0.9 ± 0.065	3.3 ± 0.112	0.5 ± 0.067	2.8 ± 0.132
November	7.7 ± 0.34	18 ± 0.34	7.7 ± 0.24	0.85 ± 0.05	0.52 ± 0.05	0.46 ± 0.01	448.3 ± 12.32	41.9 ± 2.32	11.3 ± 0.62	8.72 ± 11.32	0.8 ± 0	2.4 ± 0.101	0.5 ± 0	3.4 ± 0.212

Table A.2: Physicochemical analysis of edaphic factors during 2021 - 22 at Sugarcane field, Yamunanagar

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
February	13.5 ±	23 ±	7.3 ±	0.97 ±	0.69 ±	0.61 ±	477.6 ±	29.6 ±	26 ±	100 ±	1.32 ±	1.85 ±	0.55 ±	4.01 ±
	0.62	0.62	0.12	0.03	0.03	0.01	12.67	2.67	0.67	11.67	0.01	0.111	0.115	0.033
March	12.6 ±	20 ±	7 ±	1.11 ±	0.61 ±	0.57 ±	339.6 ±	23.9 ±	42 ±	103 ±	1.43 ±	1.91 ±	0.65 ±	3.09 ±
	0.53	0.53	0.13	0.04	0.03	0.04	11.11	1.11	0.11	10.11	0.031	0.017	0.057	0.066
April	7.1 ±	27 ±	7.7 ±	1.1 ±	0.28 ±	0.39 ±	255.1 ±	18.1 ±	22.6 ±	57.3 ±	0.75 ±	2.9 ±	0.54 ±	3.82 ±
	0.91	0.91	0.31	0.03	0.01	0.03	10.16	1.16	1.16	11.16	0.112	0.111	0.111	0.003
May	6.4 ±	38 ±	7.5 ±	1.13 ±	0.63 ±	0.73 ±	417.2 ±	27.3 ±	27.3 ±	75.49 ±	1.06 ±	1.78 ±	0.57 ±	3.26 ±
	1.01	1.01	0.21	0.05	0.03	0.02	9.99	0.99	1.09	10.99	0.01	0.072	0.077	0.123
June	5.1 ±	45 ±	7.1 ±	1.12 ±	0.33 ±	0.44 ±	258.6 ±	11.02 ±	34.44 ±	100 ±	1.12 ±	1.42 ±	0.38 ±	3.37 ±
	1.03	1.03	0.43	0.06	0.03	0.01	14.12	1.12	1.12	11.12	0.003	0.077	0.032	0.134

July	7.5 ± 0.75	44 ± 0.75	6.9 ± 0.25	1.15 ± 0.05	0.71 ± 0.02	0.78 ± 0.02	403.4 ± 11.11	17.4 ± 1.11	19.6 ± 0.11	49.4 ± 9.11	1.11 ± 0.001	1.41 ± 0.077	0.29 ± 0.011	3.59 ± 0.118
August	12.2 ± 0.62	33 ± 0.62	6.9 ± 0.22	1.41 ± 0.05	0.61 ± 0.04	0.67 ± 0.03	417.2 ± 13.11	19.91 ± 2.01	29.8 ± 0.11	33.03 ± 9.11	0.99 ± 0.02	1.52 ± 0.021	0.22 ± 0.012	3.71 ± 0.102
September	7.9 ± 0.51	32 ± 0.51	7 ± 0.11	1.12 ± 0.04	0.23 ± 0.02	0.67 ± 0.02	298.3 ± 13.12	10.74 ± 1.12	16 ± 0.12	40.39 ± 8.12	0.92 ± 0.113	1.01 ± 0.117	0.31 ± 0.017	3.62 ± 0.201
October	9.5 ± 0.41	28 ± 0.41	7.7 ± 0.31	1.6 ± 0.05	0.63 ± 0.06	0.5 ± 0.02	543.1 ± 12.02	16.91 ± 2.02	9.4 ± 1.02	36.5 ± 8.02	0.91 ± 0.112	2.3 ± 0	0.5 ± 0.011	3.78 ± 0.201
November	8.7 ± 0.94	23 ± 0.94	7.7 ± 0.14	0.85 ± 0.04	0.52 ± 0.05	0.46 ± 0.04	448.3 ± 11.32	11.9 ± 1.32	11.3 ± 0.32	38.72 ± 9.32	0.89 ± 0.111	2.14 ± 0.001	0.5 ± 0.001	3.71 ± 0

Table A.3: Physicochemical analysis of edaphic factors during 2020 - 21 at Sugarcane field, Karnal

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
February	17.5 ± 0.001	22 ± 0.011	7 ± 0	1 ± 1.732	0.67 ± 0.012	0.7 ± 0.002	477.6 ± 0.577	17.6 ± 0.023	16 ± 0.156	110 ± 0.001	1.11 ± 0.003	0.95 ± 0.023	0.55 ± 0	2.1 ± 0.006
March	12.6 ± 0.01	23 ± 0.577	7.1 ± 0.001	1.14 ± 1.112	0.51 ± 0.11	0.29 ± 0.001	439.6 ± 0.234	20.1 ± 0.623	25 ± 0.923	102 ± 0.002	1.14 ± 0.001	8.1 ± 0.001	0.65 ± 0.001	3.7 ± 0.453
April	7.1 ± 0.001	30 ± 0.567	7.7 ± 0.002	1.3 ± 1.001	0.18 ± 0.111	0.8 ± 0.012	155.1 ± 0.003	10.1 ± 0.654	8.6 ± 0.001	17.3 ± 0.001	0.85 ± 0.002	5.9 ± 0.001	0.64 ± 0.006	3.8 ± 0.912
May	12.4 ± 0.005	41 ± 1.622	6.6 ± 0.01	1.5 ± 0.112	0.6 ± 0.123	0.93 ± 0.003	417.2 ± 0.001	16.3 ± 0.172	13.3 ± 0.234	73.49 ± 0.001	1.15 ± 0.001	2.8 ± 0.001	0.71 ± 0.001	3.79 ± 0.611

June	8.1 ± 1.723	46 ± 0.923	6.9 ± 0	1.3 ± 0.003	0.3 ± 0	0.94 ± 0.001	158.6 ± 0.01	38 ± 0.234	44 ± 1.732	120 ± 0.577	1.2 ± 0.113	2.41 ± 0.002	0.48 ± 0.005	3.69 ± 0.911
July	12 ± 0.577	35 ± 0.002	6.8 ± 0.002	1.9 ± 0.005	0.7 ± 0.003	0.8 ± 0.112	403.4 ± 0.005	17.4 ± 0.002	14.6 ± 0.912	19.4 ± 0.231	1.3 ± 0.123	2.51 ± 1.112	0.29 ± 0.502	3.8 ± 0.511
August	15.2 ± 0.112	33 ± 0	7.8 ± 0.005	1.7 ± 1.002	0.6 ± 0.005	0.77 ± 0.112	417.2 ± 0.001	36.91 ± 0.002	19.8 ± 0.002	19.03 ± 1.711	0.97 ± 0.576	1.55 ± 0.001	0.32 ± 0.577	3.1 ± 0
September	10.9 ± 0.117	33 ± 0.112	7.1 ± 0.001	1.14 ± 1.112	0.23 ± 0.11	0.67 ± 0.112	298.3 ± 0	19.74 ± 0.002	16 ± 0.005	20.39 ± 1.732	0.9 ± 0.932	1.01 ± 1.711	0.21 ± 0.005	3.01 ± 0.006
October	12.5 ± 0.115	29 ± 0.621	7.6 ± 0	1.8 ± 1.123	0.63 ± 0.005	0.5 ± 0.001	443.1 ± 0.001	19.91 ± 0.001	9.4 ± 0.577	6.5 ± 0.005	0.89 ± 1.765	2.3 ± 0.612	0.52 ± 0.567	3.8 ± 0.932
November	9.7 ± 0	19 ± 0.002	7.8 ± 0.11	0.87 ± 0.667	0.52 ± 0.001	0.46 ± 0.111	448.3 ± 0.002	18.9 ± 0	11.3 ± 0.502	8.72 ± 0.003	0.87 ± 0	1.4 ± 1.101	0.4 ± 0	3.94 ± 0.812

Table A.4: Physicochemical analysis of edaphic factors during 2021 - 22 at Sugarcane field, Karnal

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
February	16.5 ± 0.015	25 ± 0.577	7.2 ± 0.057	1.11 ± 0.017	0.61 ± 0.005	0.67 ± 0.005	377.6 ± 1.732	29.6 ± 0.115	26 ± 0.577	90.9 ± 1.732	1.17 ± 0.01	0.75 ± 0.111	0.45 ± 0.115	2.002 ± 0.033
March	14.6 ± 0.011	27 ± 0.115	7 ± 0.115	1.1 ± 0.011	0.59 ± 0.011	0.39 ± 0.011	339.6 ± 0.577	38.12 ± 4.618	31 ± 0.577	86.02 ± 0.003	1.12 ± 0.231	5.1 ± 0.017	0.55 ± 0.057	3.03 ± 0.566
April	17.1 ± 0	32 ± 0	7.17 ± 0	1.13 ± 0.011	0.28 ± 0.005	0.81 ± 0.017	255.1 ± 1.732	18.1 ± 0.003	12.6 ± 0.115	77.3 ± 0.005	1.05 ± 0.112	6.9 ± 0.111	0.74 ± 0.111	4.08 ± 0.003
May	10.4 ± 0.005	34 ± 0	6.9 ± 0.005	1.15 ± 0.003	0.61 ± 0.005	0.83 ± 0.005	317.2 ± 0.115	26.3 ± 0.057	23.3 ± 0.577	53.49 ± 0.005	0.75 ± 0.01	3.8 ± 0.172	0.68 ± 0.577	3.09 ± 0.923
June	18.1 ± 0.012	45 ± 0.003	6.7 ± 0.011	1.31 ± 0.005	0.38 ± 0.002	0.74 ± 0.011	258.6 ± 0.033	31.01 ± 0.577	24 ± 0.003	79.01 ± 0.057	1.02 ± 0.003	3.41 ± 0.577	0.58 ± 1.732	3.09 ± 0.234

July	12.6 ± 0.003	37 ± 0.003	6.2 ± 0.003	1.19 ± 0.017	0.77 ± 0.003	0.81 ± 0.003	303.4 ± 0.115	27.4 ± 0.0577	19.6 ± 0.923	69.4 ± 0.057	0.85 ± 0.001	2.91 ± 0.577	0.39 ± 0.011	3.81 ± 0.618
August	15.4 ± 0.173	35 ± 0	7.7 ± 0.071	1.21 ± 0.115	0.67 ± 0.017	0.76 ± 0.005	317.2 ± 0.057	36.91 ± 0.023	29.8 ± 0.003	49.03 ± 0.011	1.27 ± 0.02	1.5 ± 0.221	0.32 ± 0.112	3.21 ± 1.002
September	14.9 ± 0.001	32 ± 0.015	7.2 ± 0.011	1.4 ± 0	0.73 ± 0.005	0.57 ± 0.005	198.3 ± 0.173	29.74 ± 0.005	16.9 ± 0.577	10.39 ± 0.005	0.98 ± 0.113	1.05 ± 0.11	0.31 ± 0.577	3.11 ± 1.001
October	12.5 ± 0.01	29 ± 0.846	7.6 ± 0.057	0.81 ± 0.005	0.83 ± 0.001	0.5 ± 0	443.1 ± 0.057	19.91 ± 0.005	14.4 ± 0.115	6.5 ± 0.005	0.79 ± 0.112	3.3 ± 0	0.72 ± 0.011	2.8 ± 1.01
November	9.7 ± 0.01	19 ± 0.002	7.8 ± 0.057	0.81 ± 0.849	0.54 ± 0.005	0.46 ± 0.005	448.3 ± 3.464	18.9 ± 0.173	11.3 ± 0.115	8.72 ± 0.005	0.97 ± 0.311	2.4 ± 0.001	0.54 ± 0.001	2.94 ± 0

Table A.5: Physicochemical analysis of edaphic factors during 2020 - 21 at Rice field, Karnal

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
June	8.1 ±	45 ±	6.9 ±	1.1 ±	0.51 ±	0.87 ±	439.6 ±	8.4 ±	24 ±	14 ±	1.12 ±	1.31 ±	0.28 ±	3.7 ±
	0.22	0.82	0.05	0.05	0.02	0.01	9.01	1.02	0.99	1.23	0.02	0.13	0.013	0.13
July	12 ±	34 ±	6.8 ±	1.2 ±	0.42 ±	0.72 ±	462 ±	9.91 ±	19.6 ±	19.4 ±	1.11 ±	1.49 ±	0.19 ±	3.9 ±
	0.34	0.74	0.04	0.04	0.02	0.03	10.5	0.99	0.97	1.98	0.07	0.12	0.023	0.12
August	15.2 ±	32 ±	6.8 ±	1.3 ±	0.41 ±	0.71 ±	510.2 ±	10.74 ±	16 ±	19.03 ±	0.99 ±	1.51 ±	0.12 ±	3.81 ±
	0.5	0.51	0.05	0.05	0.03	0.02	11.02	1.01	0.89	1.77	0.06	0.09	0.028	0.09
September	10.9 ±	32 ±	7.1 ±	1.3 ±	0.43 ±	0.73 ±	470.6 ±	13.71 ±	14.94 ±	20.39 ±	0.91 ±	1.31 ±	0.31 ±	3.01 ±
	0.23	0.63	0.03	0.03	0.02	0.03	15.01	1.07	0.91	1.29	0.065	0.078	0.041	0.078
October	9.7 ±	31 ±	7.2 ±	1.2 ±	0.53 ±	0.78 ±	543.1 ±	11.9 ±	13.3 ±	15.5 ±	0.9 ±	2.03 ±	0.52 ±	2.8 ±
	0.21	0.41	0.03	0.03	0.03	0.02	14.09	0.97	0.88	1.29	0.03	0.081	0.051	0.081

Table A.6: Physicochemical analysis of edaphic factors during 2021 - 22 at Rice field, Karnal

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
June	7.1 ±	45 ±	6.8 ±	1.1 ±	0.41 ±	0.77 ±	309.6 ±	7.4 ±	26 ±	15.44 ±	1.14 ±	1.41 ±	0.3 ±	3.5 ±
	0.21	0.61	0.03	0.03	0.01	0.03	8.01	0.99	1.02	1.23	0.03	0.024	0.052	0.024
July	10.01 ±	42 ±	6.7 ±	1.2 ±	0.32 ±	0.62 ±	362 ±	8.91 ±	22.6 ±	20.14 ±	1.1 ±	1.51 ±	0.22 ±	3.7 ±
	0.21	0.81	0.02	0.02	0.03	0.03	9.5	0.97	0.99	0.98	0.03	0.079	0.051	0.079
August	14.2 ±	32 ±	6.7 ±	1.3 ±	0.31 ±	0.61 ±	417.2 ±	9.74 ±	18 ±	21.01 ±	0.89 ±	1.52 ±	0.15 ±	3.61 ±
	0.29	0.79	0.04	0.04	0.01	0.02	10.02	0.89	1.01	0.77	0.028	0.086	0.048	0.086
September	11.9 ±	32 ±	7 ± 0.02	1.4 ±	0.33 ±	0.63 ±	370.6 ±	12.91 ±	17.4 ±	20.09 ±	0.91 ±	2.01 ±	0.33 ±	3.21 ±
	0.32	0.62		0.02	0.02	0.02	12.01	0.91	1.07	0.29	0.03	0.091	0.05	0.091
October	10.7 ±	31 ±	7.1 ±	1.2 ±	0.43 ±	0.68 ±	443.1 ±	10.9 ±	14.3 ±	16.5 ±	0.9 ±	2.3 ±	0.51 ±	2.89 ±
	0.13	0.43	0.03	0.03	0.01	0.02	13.09	0.88	0.97	0.29	0.024	0.082	0.047	0.082

Table A.7: Physicochemical analysis of edaphic factors during 2020 - 21 at Rice field, Kaithal

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
June	16.1 ±	41 ±	7.7 ±	0.99 ±	0.53 ±	0.87 ±	339.6 ±	10.4 ±	24 ±	12 ±	1.22 ±	1.41 ±	0.28 ±	2.7 ±
	0.99	0.77	0.05	0.02	0.03	0.02	14.11	0.67	0.72	1.98	0.02	0.13	0.013	0.13
July	10 ±	34 ±	7.5 ±	0.97 ±	0.52 ±	0.79 ±	332 ±	11.91 ±	19.6 ±	19.4 ±	1.11 ±	1.51 ±	0.19 ±	2.9 ±
	0.91	0.68	0.04	0.03	0.02	0.03	15.02	0.71	0.65	1.88	0.07	0.12	0.023	0.12
August	12.2 ±	32 ±	8 ±	0.93 ±	0.56 ±	0.83 ±	417.2 ±	12.74 ±	16 ±	19.03 ±	0.99 ±	1.52 ±	0.12 ±	3.21 ±
	0.71	0.56	0.03	0.04	0.02	0.02	11.09	0.65	0.88	0.96	0.06	0.09	0.028	0.09
September	11.9 ±	32 ±	8.1 ±	1.11 ±	0.43 ±	0.83 ±	370.6 ±	14.91 ±	19.4 ±	19.39 ±	0.91 ±	2.01 ±	0.31 ±	3.01 ±
	0.69	0.48	0.04	0.03	0.03	0.01	12.98	0.91	0.91	0.79	0.065	0.078	0.041	0.078
October	10.7 ±	31 ±	8.1 ±	1.06 ±	0.53 ±	0.98 ±	413.1 ±	13.9 ±	14.73 ±	16.5 ±	0.89 ±	2.3 ±	0.5 ±	2.8 ±
	0.89	0.67	0.03	0.04	0.03	0.03	13.09	0.89	0.79	0.98	0.03	0.081	0.051	0.081

Table A.8: Physicochemical analysis of edaphic factors during 2021 - 22 at Rice field, Kaithal

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
June	18.1 ±	42 ±	7.9 ±	0.99 ±	0.51 ±	0.86 ±	320.6 ±	9.4 ±	26 ±	15 ±	1.25 ±	1.31 ±	0.27 ±	2.75 ±
	0.89	0.39	0.03	0.03	0.02	0.03	13.55	0.72	0.67	0.45	0.03	0.024	0.052	0.024
July	12.6 ±	39 ±	7.8 ±	0.98 ±	0.5 ±	0.82 ±	312 ±	11.91 ±	20.06 ±	20.4 ±	1.21 ±	1.41 ±	0.2 ±	2.89 ±
	0.81	0.57	0.04	0.03	0.03	0.02	14.12	0.65	0.71	1.98	0.03	0.079	0.051	0.079
August	13.2 ±	33 ±	8.2 ±	0.92 ±	0.55 ±	0.83 ±	397.2 ±	12.74 ±	18 ±	20.03 ±	0.97 ±	1.32 ±	0.32 ±	3.52 ±
	0.91	0.58	0.03	0.04	0.03	0.01	12.5	0.88	0.65	4.67	0.028	0.086	0.048	0.086
September	10.9 ±	33 ±	8.1 ±	1.01 ±	0.53 ±	0.84 ±	369.6 ±	13.91 ±	20.04 ±	20.39 ±	0.9 ±	2 ±	0.29 ±	3.21 ±
	0.79	0.67	0.03	0.02	0.02	0.02	15	0.91	0.91	2.21	0.03	0.091	0.05	0.091
October	9.7 ±	30 ±	8.1 ±	1.16 ±	0.59 ±	0.94 ±	403.1 ±	13.9 ±	13.3 ±	18.5 ±	0.79 ±	2.03 ±	0.25 ±	2.9 ±
	0.9	0.49	0.03	0.02	0.02	0.03	11.99	0.79	0.89	3.14	0.024	0.082	0.047	0.082

Table A.9: Physicochemical analysis of edaphic factors during 2020 - 21 at Wheat field, Sirsa

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
November	13.9 ± 0.91	20 ± 0.65	7.5 ± 0.02	0.9 ± 0.04	0.26 ± 0.02	0.61 ± 0.03	231 ± 13.33	31.09 ± 1.66	116.5 ± 3.11	16.3 ± 1.76	1.35 ± 0.03	1.4 ± 0.03	0.8 ± 0.03	4.15 ± 0.03
December	12.9 ± 0.88	19 ± 0.97	7.2 ± 0.03	1.2 ± 0.05	0.29 ± 0.03	0.62 ± 0.02	250 ± 14.22	50.14 ± 2.11	120.11 ± 2.01	8.16 ± 1.32	1.18 ± 0.02	1.11 ± 0.02	0.75 ± 0.02	3.95 ± 0.02
January	13.7 ± 0.61	24 ± 0.56	7.4 ± 0.02	0.96 ± 0.03	0.41 ± 0.02	0.65 ± 0.02	353.4 ± 15.23	30 ± 2.54	130 ± 1.21	11.9 ± 0.99	1.21 ± 0.03	1.15 ± 0.03	0.17 ± 0.03	4.15 ± 0.03
February	17.9 ± 0.56	20 ± 0.73	7.3 ± 0.03	0.9 ± 0.02	0.44 ± 0.015	0.53 ± 0.01	379.3 ± 12.67	66 ± 1.53	141 ± 2.01	14.73 ± 0.78	1.25 ± 0.032	2.6 ± 0.032	0.65 ± 0.032	3.7 ± 0.032
March	20.3 ± 0.56	28 ± 0.65	7.1 ± 0.04	1.2 ± 0.03	0.31 ± 0.01	0.5 ± 0.02	267.2 ± 11.32	50.01 ± 1.34	100 ± 1.99	8.03 ± 0.76	0.8 ± 0.042	2.18 ± 0.042	0.5 ± 0.042	4.15 ± 0.042
April	19.2 ± 0.71	27 ± 0.45	7.1 ± 0.02	0.9 ± 0.02	0.24 ± 0.02	0.6 ± 0.02	206.9 ± 10.45	30.01 ± 2.21	135 ± 2	9.15 ± 0.87	0.99 ± 0.02	2.3 ± 0.02	0.48 ± 0.02	4.5 ± 0.02

Table A.10: Physicochemical analysis of edaphic factors during 2021 - 22 at Wheat field, Sirsa

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
November	16.9 ± 0.88	23 ± 0.67	7 ± 0.03	1.19 ± 0.04	0.36 ± 0.01	0.71 ± 0.03	331 ± 13.33	41.09 ± 2.11	106.5 ± 2.11	26.3 ± 0.67	1.23 ± 0.03	1.4 ± 0.03	0.78 ± 0.04	4.15 ± 0.03
December	13.9 ± 0.67	20 ± 0.78	6.9 ± 0.04	1.26 ± 0.02	0.39 ± 0.02	0.72 ± 0.03	350 ± 14.22	60.14 ± 1.98	102.11 ± 1.22	18.16 ± 1.87	1.12 ± 0.02	2.11 ± 0.023	0.75 ± 0.03	3.95 ± 0.02
January	14.7 ± 0.45	18 ± 0.66	7.1 ± 0.03	0.95 ± 0.03	0.51 ± 0.02	0.76 ± 0.01	453.4 ± 15.23	40 ± 1.32	90 ± 2.01	17.9 ± 1.03	1.17 ± 0.03	2.15 ± 0.033	0.37 ± 0.023	4.15 ± 0.01
February	16.9 ± 0.56	20 ± 0.54	7.1 ± 0.02	0.91 ± 0.05	0.54 ± 0.01	0.73 ± 0.03	479.3 ± 12.67	86 ± 1.98	131 ± 1.76	16.73 ± 1.03	1.2 ± 0.032	2.8 ± 0.039	0.55 ± 0.002	3.7 ± 0.03
March	18.3 ± 0.93	30 ± 0.66	6.8 ± 0.03	1.18 ± 0.03	0.39 ± 0.02	0.75 ± 0.01	367.2 ± 11.32	90.01 ± 2.11	126 ± 1.87	11.03 ± 0.98	0.75 ± 0.042	1.98 ± 0.032	0.52 ± 0.032	3.65 ± 0.022
April	17.2 ± 0.66	34 ± 0.71	6.8 ± 0.04	0.95 ± 0.01	0.34 ± 0.03	0.6 ± 0.01	306.9 ± 10.45	50.01 ± 1.96	115 ± 2.11	9.15 ± 0.88	0.89 ± 0.02	1.93 ± 0.021	0.49 ± 0.02	3.5 ± 0.02

Table A.11: Physicochemical analysis of edaphic factors during 2020 - 21 at Wheat field, Hisar

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
November	15.9 ±	22 ±	7.4 ±	0.9 ±	0.26 ±	0.61 ±	131 ±	31.09 ±	96.5 ±	15.3 ±	1.35 ±	2.4 ±	0.8 ±	4.15 ±
	0.9	0.99	0.02	0.037	0.01	0.03	7.12	3.09	4.04	1.32	0.03	0.03	0.03	0.03
December	13.9 ±	21 ±	7.2 ±	1.6 ±	0.29 ±	0.62 ±	150 ±	40.14 ±	100.11 ±	9.16 ±	1.48 ±	2.1 ±	0.75 ±	3.95 ±
	0.76	0.76	0.03	0.028	0.03	0.02	6.99	4.01	2.99	1.09	0.02	0.02	0.02	0.02
January	11.7 ±	19 ±	7.4 ±	0.96 ±	0.41 ±	0.65 ±	253.4 ±	20 ±	120 ±	13.9 ±	1.31 ±	1.15 ±	0.17 ±	4.15 ±
	0.66	0.62	0.02	0.031	0.02	0.02	7.02	3.44	2.97	0.99	0.03	0.03	0.03	0.03
February	18.9 ±	21 ±	7.5 ±	0.91 ±	0.44 ±	0.53 ±	260.3 ±	66 ±	131 ±	15.73 ±	1.35 ±	3.6 ±	0.55 ±	3.7 ±
	0.54	0.72	0.01	0.021	0.023	0.01	8.01	3.09	3.55	0.94	0.032	0.032	0.032	0.032

March	20.3 ± 0.53	29 ± 0.52	7.2 ± 0.02	1.8 ± 0.032	0.31 ± 0.021	0.51 ± 0.02	197.2 ± 7.68	60.01 ± 4.65	104 ± 3.87	9.03 ± 1.22	0.98 ± 0.042	1.18 ± 0.042	0.5 ± 0.042	3.15 ± 0.042
April	17.2 ± 0.66	31 ± 0.44	7.1 ± 0.01	0.89 ± 0.04	0.24 ± 0.01	0.57 ± 0.01	146.9 ± 8.03	40.01 ± 4.11	125 ± 4.1	10.15 ± 1.02	0.79 ± 0.02	2.3 ± 0.02	0.48 ± 0.02	4.5 ± 0.02

Table A.12: Physicochemical analysis of edaphic factors during 2021 - 22 at Wheat field, Hisar

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
November	14.9 ±	23 ±	7.3 ±	0.89 ±	0.36 ±	0.71 ±	136 ±	33.09 ±	98.5 ±	25.3 ±	1.37 ±	2.41 ±	0.48 ±	4.25 ±
	0.29	0.64	0.03	0.042	0.03	0.01	6.09	3.8	4.01	0.89	0.03	0.03	0.04	0.03
December	12.9 ±	20 ±	7.1 ±	1.63 ±	0.39 ±	0.72 ±	170 ±	42.14 ±	107.11 ±	19.16 ±	1.38 ±	2.21 ±	0.65 ±	3.75 ±
	0.34	0.63	0.02	0.036	0.021	0.03	7.98	2.99	4.26	0.21	0.02	0.023	0.03	0.02
January	11.9 ±	18 ±	7.3 ±	0.86 ±	0.43 ±	0.75 ±	258.4 ±	21 ±	117 ±	23.9 ±	1.41 ±	1.65 ±	0.37 ±	4.25 ±
	0.45	0.71	0.01	0.029	0.012	0.02	8.26	2.87	3.78	1.02	0.03	0.033	0.023	0.01
February	17.9 ±	25 ±	7.4 ±	0.92 ±	0.45 ±	0.63 ±	279.3 ±	56 ±	121 ±	25.73 ±	1.37 ±	3.06 ±	0.65 ±	3.76 ±
	0.56	0.52	0.02	0.023	0.022	0.023	3.02	2.98	3.67	0.27	0.032	0.039	0.002	0.03

March	10.3 ± 0.43	31 ± 0.42	7.2 ± 0.03	1.28 ± 0.04	0.31 ± 0.012	0.52 ± 0.021	167.2 ± 5.93	50.01 ± 3.94	94 ± 2.99	19.03 ± 0.68	0.68 ± 0.042	1.58 ± 0.032	0.55 ± 0.032	3.45 ± 0.022
April	15.2 ± 0.43	33 ± 0.52	7 ± 0.02	0.9 ± 0.034	0.24 ± 0.021	0.56 ± 0.01	136.9 ± 6.94	30.01 ± 3.02	105 ± 2.06	20.15 ± 0.34	0.73 ± 0.02	2.03 ± 0.021	0.49 ± 0.02	4.53 ± 0.02

Table A.13: Physicochemical analysis of edaphic factors during 2020 - 21 at Jowar field, Rohtak

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
April	15.9 ±	39 ±	6.8 ±	0.91 ±	0.59 ±	1.01 ±	508.6 ±	9.8 ±	133 ±	36.41 ±	0.75 ±	1.09 ±	0.6 ±	2.45 ±
	0.29	0.09	0.04	0.03	0.03	0.03	7.34	0.99	2.01	1.21	0.02	0.03	0.02	0.03
May	18.5 ±	40 ±	6.9 ±	1.3 ±	0.44 ±	0.95 ±	479.3 ±	13.9 ±	155 ±	32.1 ±	0.65 ±	0.99 ±	0.6 ±	2.9 ±
	0.23	0.13	0.03	0.04	0.02	0.029	8.09	1.02	1.99	0.99	0.03	0.04	0.03	0.04
June	16.4 ±	42 ±	7.1 ±	1.5 ±	0.45 ±	0.94 ±	525.8 ±	7.6 ±	110 ±	30.06 ±	0.95 ±	1.49 ±	0.3 ±	2.9 ±
	0.33	0.2	0.02	0.039	0.01	0.02	8.5	2.09	1.62	0.98	0.04	0.03	0.04	0.03
July	16 ±	40 ±	7 ±	1.2 ±	0.48 ±	0.84 ±	513.7 ±	15.01 ±	99 ±	31.01 ±	0.81 ±	1.51 ±	0.44 ±	2.65 ±
	0.43	0.15	0.03	0.04	0.02	0.019	7.99	1.02	1.42	1.02	0.03	0.02	0.03	0.02

Table A.14: Physicochemical analysis of edaphic factors during 2021 - 22 at Jowar field, Rohtak

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
April	16.2 ± 0.35	37 ± 0.07	6.9 ± 0.02	0.81 ± 0.04	0.69 ± 0.03	1.11 ± 0.03	408.6 ± 7.22	9.8 ± 0.97	123 ± 0.79	28.41 ± 1.02	0.65 ± 0.03	1.2 ± 0.02	0.5 ± 0.03	2.4 ± 0.02
May	17.5 ± 0.32	39 ± 0.17	7 ± 0.03	1.3 ± 0.036	0.54 ± 0.02	0.95 ± 0.02	379.3 ± 8.02	13.9 ± 0.98	145 ± 0.92	26.1 ± 1.21	0.65 ± 0.04	0.99 ± 0.03	0.6 ± 0.04	2.8 ± 0.03
June	15.4 ± 0.42	40 ± 0.2	7.2 ± 0.03	1.6 ± 0.03	0.51 ± 0.02	0.84 ± 0.01	425.8 ± 8.61	7.6 ± 1.03	120 ± 1.02	25.06 ± 0.98	0.75 ± 0.03	1.39 ± 0.04	0.4 ± 0.03	2.7 ± 0.04
July	15.1 ± 0.21	39 ± 0.09	7.1 ± 0.02	1.4 ± 0.03	0.48 ± 0.03	0.82 ± 0.02	413.7 ± 8.61	15.01 ± 1.01	109 ± 1.12	26.01 ± 0.98	0.71 ± 0.02	1.41 ± 0.03	0.44 ± 0.02	2.5 ± 0.03

Table A.15: Physicochemical analysis of edaphic factors during 2020 - 21 at Forest land, Panipat

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
November	10.97 ± 0.49	20 ± 0.99	7.5 ± 0.01	1.09 ± 0.012	0.12 ± 0.02	0.21 ± 0.013	103.45 ± 4.01	5.7 ± 1.43	98 ± 4.12	10.9 ± 4.01	1.91 ± 0.32	4.4 ± 0.11	0.43 ± 0.11	2.9 ± 0.32
December	10.09 ± 0.33	14 ± 1.02	7.4 ± 0.012	1.1 ± 0.011	0.14 ± 0.017	0.24 ± 0.015	120.69 ± 3.99	6.3 ± 4.01	102 ± 3.98	9.08 ± 3.99	1.99 ± 0.4	6.9 ± 0.21	0.45 ± 0.21	2.3 ± 0.4
January	11.2 ± 0.32	13 ± 1.03	7.4 ± 0.015	1.13 ± 0.011	0.2 ± 0.015	0.34 ± 0.014	112.41 ± 4.02	8.2 ± 4.31	104 ± 2.99	13.9 ± 4.02	2.15 ± 0.23	6.8 ± 0.19	0.55 ± 0.19	3.5 ± 0.23
February	9.12 ± 0.34	20 ± 0.92	7.6 ± 0.01	1.12 ± 0.01	0.25 ± 0.019	0.43 ± 0.013	115.51 ± 4.03	12.8 ± 3.07	129 ± 3.91	10.4 ± 4.03	1.74 ± 0.31	3.57 ± 0.23	0.8 ± 0.23	3.6 ± 0.31

March	9.05 ± 0.43	24 ± 0.94	7.6 ± 0.01	1.13 ± 0.013	0.1 ± 0.021	0.17 ± 0.016	106.2 ± 4.01	7.1 ± 3.97	96 ± 4.11	12.3 ± 4.01	1.95 ± 0.34	3.15 ± 0.21	0.55 ± 0.21	2.6 ± 0.34
April	8.09 ± 0.34	26 ± 1.03	7.6 ± 0.011	1.1 ± 0.011	0.14 ± 0.018	0.24 ± 0.017	120.69 ± 3.89	10 ± 3.45	90 ± 4.91	10.2 ± 3.89	1.92 ± 0.23	5.1 ± 0.18	0.85 ± 0.18	2.9 ± 0.23
May	8.01 ± 0.25	29 ± 1.03	7.6 ± 0.013	1 ± 0.013	0.28 ± 0.016	0.48 ± 0.016	141.4 ± 3.88	14.7 ± 4.01	143 ± 3.09	8.4 ± 3.88	2.1 ± 0.27	5.4 ± 0.31	0.75 ± 0.31	5.4 ± 0.27
June	7.08 ± 0.36	34 ± 1.02	7.5 ± 0.002	1 ± 0.012	0.27 ± 0.014	0.46 ± 0.013	132.76 ± 4.02	12.5 ± 3.08	150 ± 2.09	9.8 ± 4.02	2.01 ± 0.22	4.5 ± 0.21	0.76 ± 0.21	4.6 ± 0.22
July	7.99 ± 0.19	30 ± 1.04	7.5 ± 0.012	1.13 ± 0.011	0.1 ± 0.019	0.17 ± 0.015	116.2 ± 3.96	12.9 ± 4.1	146 ± 4	8.5 ± 3.96	2.3 ± 0.21	3.5 ± 0.3	0.69 ± 0.3	3.5 ± 0.21

August	7.86 ± 0.42	30 ± 1.02	7.6 ± 0.012	1.13 ± 0.011	0.23 ± 0.016	0.39 ± 0.013	118.27 ± 3.78	10 ± 3.44	130 ± 3.98	8.8 ± 3.78	1.89 ± 0.19	1.19 ± 0.23	0.66 ± 0.23	3.1 ± 0.19
September	8.7 ± 0.45	28 ± 0.89	7.6 ± 0.011	1.09 ± 0.008	0.2 ± 0.014	0.34 ± 0.013	122.41 ± 3.98	9.9 ± 2.09	110 ± 3.09	9.8 ± 3.98	1.92 ± 0.2	1.99 ± 0.23	0.52 ± 0.23	2.9 ± 0.2
October	9.11 ± 0.4	22 ± 0.85	7.5 ± 0.01	1.1 ± 0.009	0.15 ± 0.014	0.26 ± 0.012	129.31 ± 4	9.8 ± 3.09	100 ± 2.99	10.2 ± 4	1.95 ± 0.19	2.72 ± 0.3	0.49 ± 0.3	2.7 ± 0.19

Table: A.16 Physicochemical analysis of edaphic factors during 2021 - 22 at Forest land, Panipat

Months	Soil Moisture (%)	Soil Temperature (°C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	N (ppm)	P (kg/ac)	K (kg/ac)	S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
November	11.97 ±	23 ±	7.6 ±	1.01 ±	0.11 ±	0.19 ±	105.45 ±	6.7 ±	108 ±	11.9 ±	1.81 ±	5.4 ±	0.45 ±	3.9 ±
	0.39	1.03	0.01	0.012	0.013	0.02	4.01	4.12	3.99	4.01	0.11	0.11	0.11	0.32
December	9.99 ±	19 ±	7.5 ±	1.11 ±	0.15 ±	0.22 ±	125.69 ±	6.3 ±	92 ±	19.08 ±	1.89 ±	6.9 ±	0.48 ±	2.3 ±
	0.36	1.03	0.012	0.011	0.015	0.017	3.99	3.98	4.01	3.99	0.21	0.21	0.21	0.4
January	11.02 ±	15 ±	7.5 ±	1.14 ±	0.22 ±	0.24 ±	122.41 ±	7.2 ±	104 ±	15.9 ±	1.85 ±	6.8 ±	0.55 ±	3.15 ±
	0.42	1.02	0.015	0.011	0.014	0.015	4.02	2.99	4.31	4.02	0.19	0.19	0.19	0.23
February	10.12 ±	20 ±	7.5 ±	1.12 ±	0.24 ±	0.33 ±	125.51 ±	10.8 ±	109 ±	13.4 ±	1.74 ±	4.57 ±	0.58 ±	3.06 ±
	0.44	1.04	0.01	0.01	0.013	0.019	4.03	3.91	3.07	4.03	0.23	0.23	0.23	0.31
March	9.05 ±	26 ±	7.6 ±	1.1 ±	0.19 ±	0.27 ±	116.2 ±	8.1 ±	96 ±	12.3 ±	1.95 ±	3.15 ±	0.55 ±	2.76 ±
	0.33	1.02	0.01	0.013	0.016	0.021	4.01	4.11	3.97	4.01	0.21	0.21	0.21	0.34

April	8.09 ± 0.24	27 ± 0.89	7.6 ± 0.011	1.01 ± 0.011	0.15 ± 0.017	0.24 ± 0.018	129.09 ± 3.89	10.1 ± 4.91	92 ± 3.45	10.2 ± 3.89	1.92 ± 0.18	5.1 ± 0.18	0.8 ± 0.18	3.9 ± 0.23
May	8.01 ± 0.29	29 ± 0.85	7.6 ± 0.013	1.02 ± 0.013	0.26 ± 0.016	0.38 ± 0.016	141.74 ± 3.88	13.7 ± 3.09	133 ± 4.01	9.4 ± 3.88	2.11 ± 0.31	5.4 ± 0.31	0.75 ± 0.31	4.4 ± 0.27
June	7.38 ± 0.26	36 ± 0.99	7.4 ± 0.002	1.11 ± 0.012	0.25 ± 0.013	0.36 ± 0.014	132.76 ± 4.02	12.5 ± 2.09	140 ± 3.08	9.1 ± 4.02	2.01 ± 0.21	4.5 ± 0.21	0.66 ± 0.21	4.6 ± 0.22
July	7.99 ± 0.29	32 ± 1.02	7.4 ± 0.012	1.14 ± 0.011	0.15 ± 0.015	0.17 ± 0.019	126.2 ± 3.96	12.9 ± 4	136 ± 4.1	8.5 ± 3.96	2.03 ± 0.3	3.5 ± 0.3	0.69 ± 0.3	3.5 ± 0.21
August	7.86 ± 0.32	28 ± 1.03	7.5 ± 0.012	1.12 ± 0.011	0.18 ± 0.013	0.29 ± 0.016	128.27 ± 3.78	10.03 ± 3.98	120 ± 3.44	8.8 ± 3.78	1.9 ± 0.23	2.19 ± 0.23	0.66 ± 0.23	3.1 ± 0.19
September	8.07 ± 0.35	31 ± 0.92	7.5 ± 0.011	1.09 ± 0.008	0.21 ± 0.013	0.24 ± 0.014	121.52 ± 3.98	10.9 ± 3.09	100 ± 2.09	9.08 ± 3.98	1.92 ± 0.23	2.99 ± 0.23	0.62 ± 0.23	2.9 ± 0.2

October	8.11 ± 0.24	27 ± 0.94	7.5 ± 0.01	1.01 ± 0.009	0.15 ± 0.012	0.26 ± 0.014	130.30 1 ± 4	10.8 ± 2.99	90 ± 3.09	9.2 ± 4	1.85 ± 0.3	2.72 ± 0.3	0.59 ± 0.3	3.7 ± 0.19
----------------	----------------	--------------	---------------	-----------------	-----------------	-----------------	--------------------	----------------	--------------	------------	---------------	---------------	---------------	---------------

Table: A.17 Physicochemical analysis of edaphic factors during 2020 - 21 at outskirts of Industrial land, Panipat

Months	Soil Moisture (%)	Soil Temperature (degree C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	Available N (ppm)	P (kg/ac)	K (kg/ac)	Available S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
November	17.5 ±	16 ±	7.5 ±	1.09 ±	0.12 ±	0.21 ±	123.45 ±	5.7 ±	88 ±	109 ±	1.91 ±	4.4 ±	0.63 ±	3.9 ±
	1.01	0.99	0.01	0.012	0.02	0.02	4.01	1.43	4.12	4.01	0.32	0.11	0.11	0.32
December	18.5 ±	14 ±	7.4 ±	1.1 ±	0.14 ±	0.24 ±	130.69 ±	6.3 ±	92 ±	99.08 ±	1.99 ±	4.9 ±	0.65 ±	3.3 ±
	0.99	0.89	0.012	0.011	0.01	0.02	3.99	4.01	3.98	3.99	0.4	0.21	0.21	0.4
January	18.9 ±	13 ±	7.4 ±	1.13 ±	0.2 ±	0.34 ±	152.41 ±	8.2 ±	94 ±	109 ±	1.65 ±	4.8 ±	0.75 ±	3.5 ±
	0.79	0.79	0.015	0.011	0.02	0.03	4.02	4.31	2.99	4.02	0.23	0.19	0.19	0.23
February	5.1 ±	30 ±	7.6 ±	1.12 ±	0.25 ±	0.43 ±	200.51 ±	12.8 ±	109 ±	104 ±	1.74 ±	3.57 ±	0.98 ±	2.7 ±
	0.65	0.78	0.01	0.01	0.02	0.03	4.03	3.07	3.91	4.03	0.31	0.23	0.23	0.31
March	8.5 ±	24 ±	7.6 ±	1.13 ±	0.1 ±	0.17 ±	176.2 ±	7.1 ±	96 ±	123 ±	1.95 ±	3.55 ±	0.75 ±	2.9 ±
	0.72	0.77	0.01	0.013	0.01	0.02	4.01	3.97	4.11	4.01	0.34	0.21	0.21	0.34

April	9.7 ± 0.72	26 ± 0.92	7.6 ± 0.011	1.1 ± 0.011	0.14 ± 0.02	0.24 ± 0.02	130.69 ± 3.89	10 ± 3.45	90 ± 4.91	102 ± 3.89	1.72 ± 0.23	4.1 ± 0.18	0.95 ± 0.18	2.9 ± 0.23
May	15.3 ± 0.69	27 ± 0.76	7.6 ± 0.013	1 ± 0.013	0.28 ± 0.02	0.48 ± 0.02	170.4 ± 3.88	11.7 ± 4.01	103 ± 3.09	88.4 ± 3.88	1.61 ± 0.27	4.4 ± 0.31	0.95 ± 0.31	3.4 ± 0.27
June	16.2 ± 0.65	34 ± 0.83	7.5 ± 0.002	1 ± 0.012	0.27 ± 0.01	0.46 ± 0.015	190.76 ± 4.02	14.5 ± 3.08	116 ± 2.09	78 ± 4.02	1.51 ± 0.22	4.5 ± 0.21	0.96 ± 0.21	3.6 ± 0.22
July	14.2 ± 0.71	30 ± 0.23	7.5 ± 0.012	1.13 ± 0.011	0.1 ± 0.01	0.17 ± 0.014	156.2 ± 3.96	12.9 ± 4.1	106 ± 4	85 ± 3.96	1.43 ± 0.21	3.5 ± 0.3	0.89 ± 0.3	3.5 ± 0.21
August	13.6 ± 0.81	30 ± 0.21	7.6 ± 0.012	1.13 ± 0.011	0.23 ± 0.01	0.39 ± 0.012	190.27 ± 3.78	13 ± 3.44	120 ± 3.98	88 ± 3.78	1.89 ± 0.19	3.19 ± 0.23	0.86 ± 0.23	3.1 ± 0.19
September	9.1 ± 0.91	28 ± 0.31	7.6 ± 0.011	1.09 ± 0.008	0.2 ± 0.01	0.34 ± 0.016	172.41 ± 3.98	9.9 ± 2.09	110 ± 3.09	98 ± 3.98	1.92 ± 0.2	2.99 ± 0.23	0.72 ± 0.23	2.9 ± 0.2

October	8.5 ±	27 ±	7.5 ±	1.1 ±	0.15 ±	0.26 ±	129.31 ±	9.8 ±	100 ±	102 ±	1.95 ±	2.72 ±	0.69 ±	2.7 ±
	0.92	0.51	0.01	0.009	0.01	0.012	4	3.09	2.99	4	0.19	0.3	0.3	0.19

Table: A.18 Physicochemical analysis of edaphic factors during 2021 - 22 at Outskirts of Textile land, Panipat

Months	Soil Moisture (%)	Soil Temperature (degree C)	Soil pH	Soil EC (dS/m)	SOC (%)	SOM (%)	Available N (ppm)	P (kg/ac)	K (kg/ac)	Available S (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)	Mn (ppm)
November	18.5 ± 1.01	17 ± 0.99	7.6 ± 0.01	1.07 ± 0.012	0.13 ± 0.02	0.23 ± 0.02	113.45 ± 4.01	6.7 ± 4.12	90 ± 3.99	109 ± 4.01	1.91 ± 0.11	3.4 ± 0.11	0.63 ± 0.11	2.9 ± 0.32
December	17.9 ± 0.99	15 ± 0.89	7.5 ± 0.012	1.11 ± 0.011	0.14 ± 0.02	0.25 ± 0.01	120.69 ± 3.99	6.3 ± 3.98	92 ± 4.01	99.08 ± 3.99	1.99 ± 0.21	3.9 ± 0.21	0.65 ± 0.21	2.3 ± 0.4
January	17.89 ± 0.79	14 ± 0.79	7.5 ± 0.015	1.12 ± 0.011	0.22 ± 0.03	0.33 ± 0.02	152.41 ± 4.02	7.2 ± 2.99	100 ± 4.31	111 ± 4.02	2.15 ± 0.19	3.8 ± 0.19	0.75 ± 0.19	3.5 ± 0.23
February	12.1 ± 0.65	28 ± 0.78	7.5 ± 0.01	1.11 ± 0.01	0.27 ± 0.03	0.41 ± 0.02	210.51 ± 4.03	12.8 ± 3.91	117 ± 3.07	104 ± 4.03	1.74 ± 0.23	2.97 ± 0.23	0.98 ± 0.23	3.6 ± 0.31

March	7.5 ± 0.72	23 ± 0.77	7.4 ± 0.01	1.13 ± 0.013	0.17 ± 0.02	0.27 ± 0.01	156.2 ± 4.01	11.1 ± 4.11	106 ± 3.97	133 ± 4.01	1.95 ± 0.21	3.15 ± 0.21	0.75 ± 0.21	3.6 ± 0.34
April	7.7 ± 0.72	25 ± 0.92	7.4 ± 0.011	1.11 ± 0.011	0.14 ± 0.02	0.24 ± 0.02	130.69 ± 3.89	8.01 ± 4.91	93 ± 3.45	92 ± 3.89	2.2 ± 0.18	3.3 ± 0.18	0.95 ± 0.18	3.9 ± 0.23
May	14.3 ± 0.69	28 ± 0.76	7.4 ± 0.013	1.1 ± 0.013	0.18 ± 0.02	0.38 ± 0.02	198.4 ± 3.88	13.7 ± 3.09	113 ± 3.45	82.4 ± 3.88	2.1 ± 0.31	3.4 ± 0.31	0.95 ± 0.31	3.4 ± 0.27
June	15.2 ± 0.65	35 ± 0.83	7.5 ± 0.002	1.01 ± 0.012	0.24 ± 0.015	0.36 ± 0.01	216.76 ± 4.02	14.5 ± 2.09	130 ± 3.08	76 ± 4.02	2.01 ± 0.21	3.5 ± 0.21	0.96 ± 0.21	3.5 ± 0.22
July	14.2 ± 0.71	32 ± 0.23	7.5 ± 0.012	1.12 ± 0.011	0.13 ± 0.014	0.37 ± 0.01	166.2 ± 3.96	11.9 ± 4	116 ± 4.1	89 ± 3.96	2.3 ± 0.3	3.5 ± 0.3	0.89 ± 0.3	3.5 ± 0.21
August	13.6 ± 0.81	30 ± 0.21	7.6 ± 0.012	1.12 ± 0.011	0.2 ± 0.012	0.32 ± 0.01	198.27 ± 3.78	13 ± 3.98	130 ± 3.44	83 ± 3.78	1.89 ± 0.23	2.19 ± 0.23	0.86 ± 0.23	3.1 ± 0.19

September	10.1 ± 0.91	29 ± 0.31	7.6 ± 0.011	1.01 ± 0.008	0.21 ± 0.016	0.31 ± 0.01	182.41 ± 3.98	7.9 ± 3.09	120 ± 2.09	88 ± 3.98	1.92 ± 0.23	2.29 ± 0.23	0.72 ± 0.23	2.9 ± 0.2
October	10.5 ± 0.92	28 ± 0.51	7.5 ± 0.01	1.1 ± 0.009	0.17 ± 0.012	0.16 ± 0.01	126.31 ± 4	6.8 ± 2.99	101 ± 3.09	92 ± 4	1.95 ± 0.3	1.72 ± 0.3	0.69 ± 0.3	2.7 ± 0.19

REFERENCES

REFERENCES

- Abbas, M. J., & Parwez, H. (2012). Impact of edaphic factors on the diversity of soil microarthropods in an agricultural ecosystem at Aligarh. *Indian J. Fundam. Appl. Life Sci*, 2, 185-191.
- Abe, T., Bignell, D. E., & Higashi, M. (Eds.). (2000). *Termites: evolution, sociality, symbioses, ecology*. Springer Science and Business Media.
- Abrol, I. P., Yadav, J. S. P., & Massoud, F. I. (1988). *Salt-affected soils and their management* (Vol. 39). Food and Agriculture Org..
- Acharya, P., Samal, S., & Mishra, C. S. K. (2020). Microarthropod population dynamics in a subtropical deciduous forest of the Eastern-Ghat hill range in India in response to variation in edaphic factors. . *Research Square (Research Square)*.
- Acharya, S., & Basu, P. (2014). Diversity and richness of soil oribatid mites (Acarina: Arachnida: Arthropoda) in grape orchards, Nashik, Maharashtra. *International Journal of Research Studies in Biosciences*, 2(7), 23-27.
- Acharya, S., & Datta, T. K. (2019). Diversity of soil cryptostigmatid mites (Acari: Oribatida) of Himachal Pradesh, India, from an altitudinal perspective. *Journal of Asia-Pacific Biodiversity*, 12(3), 357-362.
- Aderoju, D. O., & Festus, A. G. (2013). Influence of salinity on soil chemical properties and surrounding vegetation of Awe salt mining site, Nasarawa State, Nigeria. *African Journal of Environmental Science and Technology*, 7(12), 1070-1075.
- Adviento-Borbe, M. A. A., Doran, J. W., Drijber, R. A., & Dobermann, A. (2006). Soil electrical conductivity and water content affect nitrous oxide and carbon dioxide emissions in intensively managed soils. *Journal of environmental quality*, 35(6), 1999-2010.

Agosti, D., Majer, J. D., Alonso, L. E., & Schultz, T. R. (2000). Standard methods for measuring and monitoring biodiversity. *Smithsonian Institution, Washington DC*, 9, 204-6.

Agrell, I. (1941). Zur Ökologie der Collembolen. Untersuchungen im schwedischen Lappland. *Opuscula Entomologica Suppl.*, 3, 236.

Ahrens, D., Hartmann, M., & Weipert, M. (2012). New species and a morphology-based phylogeny of the genus *Nepaloserica* (Coleoptera, Scarabaeidae). *Biodiversität und Naturausstattung im Himalaya IV. Verein der Freunde und Förderer des Naturkundemuseums Erfurt eV, Erfurt*, 305-316.

Aizat, A. M., Roslan, M. K., Sulaiman, W. N. A., & Karam, D. S. (2014). The relationship between soil pH and selected soil properties in 48 years logged-over forest. *International Journal of environmental sciences*, 4(6), 1129-1140.

Akkerhuis, G. J. O., De Ley, F., Zwetsloot, H., Ponge, J. F., & Brussaard, L. (1988). Soil microarthropods (Acari and Collembola) in two crop rotations on a heavy marine clay soil. *Revue d'Ecologie et de Biologie du Sol*, 25(2), 175-202.

Alexandrov, A. V., & Grotta, J. C. (2002). Arterial reocclusion in stroke patients treated with intravenous tissue plasminogen activator. *Neurology*, 59(6), 862-867.

Alexandrov, V., Eitzinger, J., & Oberforster, M. (2001). Adaptation of crop-weather models in Austria and Bulgaria. In *Proceedings of the 5th European Conference on Applications of Meteorology*.

Ali-Shtayeh, M. S., & Salahat, A. G. M. (2010). The impact of grazing on natural plant biodiversity in Al-Fara'a area. *Biodiversity and Environmental Sciences Studies Series*, 5(1), 1-17.

Alloway, B. J. (Ed.). (2008). *Micronutrient deficiencies in global crop production*. Springer Science and Business Media.

- Alvarez, T., Frampton, G. K., & Goulson, D. (1999). The effects of drought upon epigeal Collembola from arable soils. *Agricultural and Forest Entomology*, 1(4), 243-248.
- Amador, J. A., & Görres, J. H. (2007). Microbiological characterization of the structures built by earthworms and ants in an agricultural field. *Soil Biology and Biochemistry*, 39(8), 2070-2077.
- Amoli, K., & Cunnington, A. M. (1977). House dust mites in Iran. *Clinical and Experimental Allergy*, 7(1), 93-101.
- Anderson, J. M. (1988). Spatiotemporal effects of invertebrates on soil processes. *Biology and fertility of soils*, 6, 216-227.
- Andow, D. A. (1991). Yield loss to arthropods in vegetationally diverse agroecosystems. *Environmental Entomology*, 20(5), 1228-1235.
- André, H. M., Ducarme, X., & Lebrun, P. (2002). Soil biodiversity: myth, reality or conning?. *Oikos*, 96(1), 3-24.
- Annamalai, S., Santhanam, M., Selvaraj, S., Sundaram, M., Pandian, K., & Pazos, M. (2018). "Green technology": Bio-stimulation by an electric field for textile reactive dye contaminated agricultural soil. *Science of the total environment*, 624, 1649-1657.
- Anu, A., Sabu, T. K., & PJ, V. (2009). Seasonality of litter insects and relationship with rainfall in a wet evergreen forest in south Western Ghats. *Journal of insect science*, 9(1), 46.
- Aoki, J. I. (1965). Notes on the species of the genus *Epilohmannia* from the Hawaiian Islands (Acarina: Oribatei). *Pacific insects*, 7(2), 309-315.
- Aristotle, J. A., Smith, W. D., Ross, J. I., Beare, G. R. T., & Ross, H. H. (1978). The works of Aristotle.

Artemjeva, T. I., & Gatilova, F. G. (1975). Soil microfauna changes under the influence of various fertilizers. In *Progress in Soil Zoology: Proceedings of the 5 th International Colloquium on Soil Zoology Held in Prague September 17–22, 1973* (pp. 463-468). Springer Netherlands.

Asikidis, M. D. (1991). Spatial and temporal patterns of an oribatid mite community in an evergreen-sclerophyllous formation (Hortiales, Greece). *Pedobiologia*, 35, 53-63.

Ausmus, B. S., & Witkamp, M. (1974). *Litter and soil microbial dynamics in a deciduous forest stand* (No. EDFB-IBP-73-10). Oak Ridge National Lab.(ORNL), Oak Ridge, TN (United States).

Ausmus, B. S., Edwards, N., & Witkamp, M. (1976). Microbial immobilization of carbon, nitrogen, phosphorus and potassium: implications for forest ecosystem processes. In *Symposium of the British Ecological Society*.

Axelsen, J. A., & Kristensen, K. T. (2000). Collembola and mites in plots fertilised with different types of green manure. *Pedobiologia*, 44(5), 556-566.

Azam, N., & Haque, M. S. U. (2015). Agriculture Play Crucial Role in the Life of Indian Economy. *International Journal of scientific research and management (IJSRM)*, 3(3).

Baardsen, L. F., De Bruyn, L., Adriaensen, F., Elst, J., Strubbe, D., Heylen, D., & Matthysen, E. (2021). No overall effect of urbanization on nest-dwelling arthropods of great tits (*Parus major*). *Urban Ecosystems*, 1-14.

Baath, E., Berg, B., Lohm, U., Lundgren, B. O., Lundvist, H., Rosswall, T., ... & Wirén, A. (1980). Effects of experimental acidification and liming on soil organisms and decomposition in a Scots pine forest. *Pedobiologia;(German Democratic Republic)*, 20(2).

- Babenko, A. B. (1997). The taxonomy and distribution of the genus *Anurida* (Collembola: Neanuridae) in the northern Palaearctic. *European Journal of Entomology*, *94*, 511-536.
- Badawi, A. (1982). The role of termites in changing certain chemical characteristics of the soil (*Psammotermes hybostoma* Desneaux). *Sociobiology*, *7*, 135-143.
- Badejo, M. A. (1982). *The distribution and abundance of soil microarthropods in three different habitats at the University of Ife campus* (Doctoral dissertation, MSc thesis).
- Badejo, M. A., & Akinwale, P. O. (2006). Microenvironmental preferences of oribatid mite species on the floor of a tropical rainforest. *Experimental and applied acarology*, *40*, 145-156.
- Bagyaraj, D. J., Nethravathi, C. J., & Nitin, K. S. (2016). Soil biodiversity and arthropods: Role in soil fertility. *Economic and ecological significance of arthropods in diversified ecosystems: Sustaining regulatory mechanisms*, 17-51.
- Balogh, P., Gergócs, V., Farkas, E., Farkas, P., Hufnagel, L., & Kocsis, M. (2008). Oribatid assemblies of tropical high mountains on some points of the “Gondwana-Bridge”—a case study. *Applied Ecology and Environmental Research*, *6*(3), 127-158.
- Bandeira, A. G., & Torres, M. F. P. (1988). Considerações sobre densidade, abundância e variedade de invertebrados terrestres em áreas florestais de Carajás, Sudeste da Amazônia.
- Banerjee, J. M. (1967). 'History of FirojshahTughalaq.
- Barrios, E. (2007). Soil biota, ecosystem services and land productivity. *Ecological economics*, *64*(2), 269-285.
- Baweja, K. D. (1939). Studies of the soil fauna, with special reference to the recolonization of sterilized soil. *The Journal of Animal Ecology*, 120-161.

Bean, A., Gietzen, R., Montross, C., & Silbergeld, B. (1994). What's bugging the bugs? Effects of manipulated habitats on soil arthropod communities within the same soil type.

Beare, M. H., Coleman, D. C., Crossley, D. A., Hendrix, P. F., & Odum, E. P. (1995). A hierarchical approach to evaluating the significance of soil biodiversity to biogeochemical cycling. In *The significance and regulation of soil biodiversity: Proceedings of the international symposium on soil biodiversity, held at Michigan State University, East Lansing, May 3–6, 1993* (pp. 5-22). Springer Netherlands.

Behan-Pelletier, V. M. (1999). Oribatid mite biodiversity in agroecosystems: role for bioindication. *Agriculture, ecosystems and environment*, 74(1-3), 411-423.

Behan-Pelletier, V. M. (2003). Acari and Collembola biodiversity in Canadian agricultural soils. *Canadian Journal of Soil Science*, 83(Special Issue), 279-288.

Behan-Pelletier, V. M., & Kanashiro, D. (2010). Acari in grassland soils of Canada. *Arthropods of Canadian grasslands*, 1, 137-166.

Behera, S. K., & Shukla, A. K. (2013). Depth-wise distribution of zinc, copper, manganese and iron in acid soils of India and their relationship with some soil properties. *Journal of the Indian society of Soil Science*, 61(3), 244-252.

Belfield, W. (1970). The effect of shade on the arthropod population and nitrate content of a West African soil. *Proc. IVth Int. Coll. Soil, Zool*, 557-567.

Bellinger, P. F. (1954). Studies of soil fauna with special reference to the Collembola.

Bender, S. F., Wagg, C., & van der Heijden, M. G. (2016). An underground revolution: biodiversity and soil ecological engineering for agricultural sustainability. *Trends in ecology & evolution*, 31(6), 440-452.

Bennett, L. T., Mele, P. M., Annett, S., & Kasel, S. (2010). Examining links between soil management, soil health, and public benefits in agricultural landscapes: an Australian perspective. *Agriculture, Ecosystems and Environment*, 139(1-2), 1-12.

Bentley, B. L. (1984). Nitrogen fixation in termites: fate of newly fixed nitrogen. *Journal of Insect physiology*, 30(8), 653-655.

Berg, M. P. (2006). Arthropod collection and identification: laboratory and field techniques. [Review of: T.J. Gibb, C.Y. Oseto (2006) Arthropod collection and identification: laboratory and field techniques.]. *Entomologische Berichten*, 66.

Berlese, A. (1905). Acari nuovi. Manipulus IV (Acari di Giava). *Redia*, 2, 154-176.

Berthet, P. (1967). The metabolic activity of oribatid mites (Acarina) in different forest floors. *Secondary productivity of terrestrial ecosystems (principles and methods)*, 2, 709-725.

Bertolini, F., Rebulli, P., Riccardi, D., Cortellaro, M., Ranzi, M. L., & Sirchia, G. (1989). Evaluation of platelet concentrates prepared from buffy coats and stored in a glucose-free crystalloid medium. *Transfusion*, 29(7), 605-609.

Bestelmeyer, B. T., Agosti, D., Alonso, L. E., Silvestre, R., Brown Jr, W. L., & Delabie, J. H. (2000). Field techniques for the study of ground-dwelling ants: an overview, description and evaluation. *Ants: standard methods for measuring and monitoring biodiversity*.

Beutler, A. N., Centurion, J. F., Souza, Z. M., Andrioli, I., & Roque, C. G. (2002). Water retention in two oxisols under different uses. *Revista Brasileira de Ciência do Solo*, 26, 829-834.

Bhagawati, S., Bhattacharyya, B., Medhi, B. K., Bhattacharjee, S., & Mishra, H. (2020). Diversity and density of Collembola as influenced by soil physicochemical properties in fallow land ecosystem of Assam, India. *J. Environ. Biol*, 41, 1626-1631.

Bhagawati, S., Bhattacharyya, B., Medhi, B. K., Bhattacharjee, S., & Mishra, H. (2018). Impact of soil physicochemical properties on the density and diversity of Collembola in Majuli River Island, Assam, India. *Journal of Entomology and Zoology studies*, 6, 837-842.

Bhattacharya, T., & Chakraborti, P. (1995). Community structure of soil Oribatida of a young rubber plantation and an adjacent wasteland in Tripura (India). *Advances in Ecology and Environmental Sciences (Mishra, PC, Behera, N., Senapati, BK and Guru, BC Eds.)*, Ashish Publishing House, New Delhi, 65-77.

Bill, M. A., Fuchs, J. R., Li, C., Yui, J., Bakan, C., Benson, D. M., ... & Lesinski, G. B. (2010). The small molecule curcumin analog FLLL32 induces apoptosis in melanoma cells via STAT3 inhibition and retains the cellular response to cytokines with anti-tumor activity. *Molecular cancer*, 9, 1-12.

Bini, D., dos Santos, C. A., do Carmo, K. B., Kishino, N., Andrade, G., Zangaro, W., & Nogueira, M. A. (2013). Effects of land use on soil organic carbon and microbial processes associated with soil health in southern Brazil. *European Journal of Soil Biology*, 55, 117-123.

Birch, L. C., & Clark, D. P. (1953). Forest soil as an ecological community with special reference to the fauna. *The Quarterly Review of Biology*, 28(1), 13-36.

Blackith, R. E. (1974, January). The Ecology of Collembola in Irish Blanket Bogs (Irish Contribution to International Biological Programme: No. 1). In *Proceedings of the Royal Irish Academy. Section B: Biological, Geological, and Chemical Science* (pp. 203-226). Royal Irish Academy.

Blake, I. H. (1931). Further studies on deciduous forest animal communities. *Ecology*, 12(3), 508-527.

Block, W. (1966). Some characteristics of the Macfadyen high gradient extractor for soil micro-arthropods. *Oikos*, 1-9.

Blower, J. G. (1955). Millipedes and centipedes as soil animals. *Soil zoology*, 138-151.

Blower, J. G. (1985). *Millipedes: Keys and Notes for the Identification of the Species* (Vol. 35). Brill Archive.

Bocock, K. L. (1963). The digestion and assimilation of food by *Glomeris*. *Soil organisms*, 85-91.

Boddy, L., & Jones, T. H. (2008, January). Interactions between basidiomycota and invertebrates. In *British Mycological Society Symposia Series* (Vol. 28, pp. 155-179). Academic Press.

Bonkowski, M., Griffiths, B. S., & Ritz, K. (2000). Food preferences of earthworms for soil fungi. *Pedobiologia*, 44(6), 666-676.

Bornebusch, C. H. (1930). The fauna of forest soil. *Det Forstlige Forsogsvaesen* *Danmark*, 11, 1-158.

Borner, C. (1906). Das System der Collembolen nebst Beschreibung neuer Collembolen des Hamburger Naturhistorischen Museums. *Mitteilungen aus dem Naturhistorischen Museum in Hamburg*, 23, 147-188.

Bosch-Serra, À. D., Yagüe, M. R., & Teira-Esmatges, M. R. (2014). Ammonia emissions from different fertilizing strategies in Mediterranean rainfed winter cereals. *Atmospheric Environment*, 84, 204-212.

Brahmam, P., Sravanthy, C. H., Laxman, P., Samatha, C. H., & Sammaiah, C. H. (2010). Biodiversity of soil arthropods in Bt-cotton fields of Warangal, Andhra Pradesh, India. *Bioscan*, 5(1), 159-160.

Bray, R. H., & Kurtz, L. T. (1945). Determination of total, organic, and available forms of phosphorus in soils. *Soil science*, 59(1), 39-46.

Bremner, G. (1990). A Berlese funnel for the rapid extraction of grassland surface macro-arthropods. *New Zealand Entomologist*, 13(1), 76-80.

Brown, J. M. (1932). A New Species of *Proisotoma* (Order Collembola) from India.

Brown, V. K. (1995). Grassland Invertebrates: Ecology, Influence on Soil Fertility and Effects on Plant Growth-by JP Curry Chapman & Hall, 1994. &50. 00 hbk (vii+ 437 pages) ISBN 0 412 16520 1. *Trends in Ecology and Evolution*, 10(1), 49-49.

Bruckner, M. Z. (2012). Water and soil characterization-pH and electrical conductivity, microbial life educational resources. *Montana State University Bozeman*.

Buck, W. (2019). *Mahabharata*. University of California Press.

Buckle, P. (1921). A preliminary survey of the soil fauna of agricultural land. *Ann. Appl. Biol*, 8, 135-145.

Burgess, N. D., Ponder, K. L., & Goddard, J. (1999). Surface and leaf-litter arthropods in the coastal forests of Tanzania. *African Journal of Ecology*, 37(3), 355-365.

Burns, R. G., & Martin, J. P. (1986). Biodegradation of organic residues in soil. *Microfloral and faunal interactions in natural and agro-ecosystems*, 137-202.

Butcher, J. W., Snider, R., & Snider, R. J. (1971). Bioecology of edaphic Collembola and Acarina. *Annual review of entomology*, 16(1), 249-288.

Buxton, R. D. (1981). Termites and the turnover of dead wood in an arid tropical environment. *Oecologia*, 51(3), 379-384.

Cakir, M., & Makineci, E. (2013). Humus characteristics and seasonal changes of soil arthropod communities in a natural sessile oak (*Quercus petraea* L.) stand and adjacent Austrian pine (*Pinus nigra* Arnold) plantation. *Environmental monitoring and assessment*, 185, 8943-8955.

Cancela Da Fonseca, L. (1995). Characterization of benthic communities of St. Andrew's pond. In *Proceedings of the 4th Congress of the Alentejo* (pp. 36-51).

Cannon, R. J. C., & Block, W. (1988). Cold tolerance of microarthropods. *Biological Reviews*, 63(1), 23-77.

Cantarella, H. (2007). Nitrogênio. *Fertilidade do solo*, 2, 375-470.

Cao, S., Sun, G., Zhang, Z., Chen, L., Feng, Q., Fu, B., ... & Wei, X. (2011). Greening china naturally. *Ambio*, 40, 828-831.

Causarano, H. (2005). Fundamentals of Soil Ecology. 2nd ed. *Vadose Zone Journal*, 4(2), 450-450.

Chakrabarti, S., & Sarkar, S. (2011). Three new species of eriophyoid mites (Acari: Eriophyoidea) infesting fruit yielding plants from India. *Zootaxa*, 2988(1), 28-36.

Chandra, K. (2011). Insect fauna of states and union territories in India. *ENVIS Bulletin: Wildlife & Protected Areas*, 14(1), 189-218.

Chaudhuri, D. K., & Roy, S. (1972). An ecological study on Collembola of West Bengal. *India. Ric. Indian Museum India*, 66(1-4), 81-101.

Chen, B., & Wise, D. H. (1999). Bottom-up limitation of predaceous arthropods in a detritus-based terrestrial food web. *Ecology*, 80(3), 761-772.

Chen, C., Singh, A. K., Yang, B., Wang, H., & Liu, W. (2023). Effect of termite mounds on soil microbial communities and microbial processes: Implications for soil carbon and nitrogen cycling. *Geoderma*, 431, 116368.

Chernova, N. M., Balabina, I. P., & Ponomareva, O. N. (1995). Changes in population growth of springtail [Collembola] under the influence of herbicides. *Polskie Pismo Entomologiczne*, 64(1-4).

Chodak, M., & Niklińska, M. (2010). Effect of texture and tree species on microbial properties of mine soils. *Applied Soil Ecology*, 46(2), 268-275.

- Choudhuri, D. K., & Banerjee, S. (1975). Qualitative and quantitative composition of Acari and Collembola in relation to soil organic matter-microbes complex. *Oriental insects*, 9(3), 313-316.
- Choudhuri, D. K., & Pande, T. (1982). ecological study of acarines from soil of Himalayan ecosystem. *Geobios new reports*.
- Choudhuri, D. K., & Roy, S. (1971). Seasonal fluctuation and vertical distribution of the genus *Lepidocyrtus* (Collembola: Insecta) in some uncultivated fields of gangetic West Bengal, India. *Rev Ecol Biol Sol*.
- Choudhuri, D. K., & Roy, S. (1971). The Collembolan (Insecta) of the uncultivated fields in Burdwan district (West Bengal) with remarks on correlation between monthly population and certain soil factors. In *Proc. Zool. Soc* (Vol. 24, pp. 33-39).
- Choudhury, S. R. (1972). The Nature of Nonspecific esterases a subunit concept. *Journal of Histochemistry & Cytochemistry*, 20(7), 507-517.
- Christiansen, K. (1970). Experimental studies on the aggregation and dispersion of Collembola. *Pedobiologia*, 10, 180-198.
- Christiansen, M. N. (1964). Influence of chilling upon subsequent growth and morphology of cotton seedlings. *Crop Science*, 4(6), 584-586.
- Ciarkowska, K., & Niemyska-Łukaszuk, J. (2002). Microstructure of humus horizons of gypsic soils from the Niecka Nidziańska area (South Poland). *Geoderma*, 106(3-4), 319-329.
- Clark, M. S., Horwath, W. R., Shennan, C., & Scow, K. M. (1998). Changes in soil chemical properties resulting from organic and low-input farming practices. *Agronomy Journal*, 90(5), 662-671.
- Clark, S., & Greenslade, P. (1996). Review of Tasmanian *Hanseniella* Bagnall (Symphyla: Scutigerellidae). *Invertebrate Systematics*, 10(1), 189-212.

- Coddington, J. A., Young, L. H., & Coyle, F. A. (1996). Estimating spider species richness in a southern Appalachian cove hardwood forest. *Journal of arachnology*, 111-128.
- Cole, P. M., Luby, J., & Sullivan, M. W. (2008). Emotions and the development of childhood depression: Bridging the gap. *Child Development Perspectives*, 2(3), 141-148.
- Coleman, D. C., & Whitman, W. B. (2005). Linking species richness, biodiversity and ecosystem function in soil systems. *Pedobiologia*, 49(6), 479-497.
- Coleman, D. C., Crossley Jr, D. A., & Hendrix, P. F. (2004). *Fundamentals of Soil Ecology*, Elsevier Academic Press. *San Diego, US*.
- Coleman, D. C., Crossley Jr, D. A., & Hendrix, P. F. (2004). *Fundamentals of soil ecology*, 2 edn Elsevier Academic Press. *Burlington, USA*.
- Collins, N. M. (1981). The role of termites in the decomposition of wood and leaf litter in the southern Guinea savanna of Nigeria. *Oecologia*, 51, 389-399.
- Collins, N. M. (1983). The utilization of nitrogen resources by termites(Isoptera). In *SYMP. BR. ECOL. SOC. 1983..*
- Cornaby, B. W., Gist, C. S., & Crossley, D. A. (1975). Resource partitioning in leaf-litter faunas from hardwood and hardwood-converted-to-pine forests.
- Cornwell, W. K., Cornelissen, J. H., Allison, S. D., Bauhus, J., Eggleton, P., Preston, C. M., ... & Zanne, A. E. (2009). Plant traits and wood fates across the globe: rotted, burned, or consumed?. *Global Change Biology*, 15(10), 2431-2449.
- Coulibaly, S. F., Coudrain, V., Hedde, M., Brunet, N., Mary, B., Recous, S., & Chauvat, M. (2017). Effect of different crop management practices on soil Collembola assemblages: A 4-year follow-up. *Applied Soil Ecology*, 119, 354-366.

Coulson, S. J., Hodkinson, I. D., Wooley, C., Webb, N. R., Block, W., Worland, M. R., ... & Strathdee, A. T. (1996). Effects of experimental temperature elevation on high-arctic soil microarthropod populations. *Polar Biology*, *16*, 147-153.

Cragg, J. B. (1961). Some aspects of the ecology of moorland animals. *The Journal of Ecology*, *49*(3), 477.

Crossley Jr, D. A. (1977). The roles of terrestrial saprophagous arthropods in forest soils: current status of concepts. In *The role of arthropods in forest ecosystems* (pp. 49-56). Berlin, Heidelberg: Springer Berlin Heidelberg.

Crossley Jr, D. A., Mueller, B. R., & Perdue, J. C. (1992). Biodiversity of microarthropods in agricultural soils: relations to processes. *Agriculture, Ecosystems and Environment*, *40*(1-4), 37-46.

Culliney, T. (2013). Role of arthropods in maintaining soil fertility. *Agriculture*, *3*(4), 629–659.

Curry, J. P. (1993). *Grassland invertebrates: ecology, influence on soil fertility and effects on plant growth*. Springer Science and Business Media.

Dahiya, S. Soil Health Card. *INDIAN FARMER*, 819.

Darlong, V. T., & JRB, A. (1982). Differences in arthropod population structure in soils of forest and Jhum sites of North-East India. *Pedobiologia*, *23*(2), 112–119.

Davis, B. N. K. (1963). A study of micro-arthropod communities in mineral soils near Corby, Northants. *The Journal of Animal Ecology*, 49-71.

Davis, R. K. (1963). Recreation planning as an economic problem. *Nat. Resources J.*, *3*, 239.

de Boer, T. E., Holmstrup, M., van Straalen, N. M., & Roelofs, D. (2010). The effect of soil pH and temperature on *Folsomia candida* transcriptional regulation. *Journal of insect physiology*, *56*(4), 350-355.

De Graaf, R. A. (2019). *In vivo NMR spectroscopy: principles and techniques*. John Wiley and Sons.

Decaëns, T., Jiménez, J. J., Gioia, C., Measey, G. J., & Lavelle, P. (2006). The values of soil animals for conservation biology. *European Journal of Soil Biology*, 42(1), S23–S38.

Degens, B. P., Schipper, L. A., Sparling, G. P., & Vojvodic-Vukovic, M. (2000). Decreases in organic C reserves in soils can reduce the catabolic diversity of soil microbial communities. *Soil Biology and Biochemistry*, 32(2), 189-196.

Dehar, P. S., Paray, M. Y., & Dhingra, S. (2019). A study on the mite species composition reported from the flour mills in Kashmir (India). *Research Guru*, 4, 630-641.

Dermody, O., Weltzin, J. F., Engel, E. C., Allen, P., & Norby, R. J. (2007). How do elevated [CO₂], warming, and reduced precipitation interact to affect soil moisture and LAI in an old field ecosystem?. *Plant and Soil*, 301, 255-266.

Dexter, A. R. (2004). Soil physical quality: Part I. Theory, effects of soil texture, density, and organic matter, and effects on root growth. *Geoderma*, 120(3-4), 201-214.

Dheeba, B., & Sampathkumar, P. (2012). A comparative study on the phytoextraction of five common plants against chromium toxicity. *Oriental Journal of Chemistry*, 28(2), 867.

Dhooria, M. S. (2016). *Fundamentals of applied acarology*. Springer.

Diaz, A., Okabe, K., Eckenrode, C. J., Villani, M. G., & Oconnor, B. M. (2000). Biology, ecology, and management of the bulb mites of the genus *Rhizoglyphus* (Acari: Acaridae). *Experimental and applied acarology*, 24, 85-113.

Dickinson, C. H., & Pugh, G. J. F. (Eds.). (1974). *Biology of Plant Litter Decomposition: 2 Vol.* Academic Press. A subsidiary of Harcourt Brace Jovanovich.

- Dindal, D. L. (1990). *Soil Biology Guide*—Wiley and Sons. *New York*.
- Doran, J. W., & Safley, M. (1997). Defining and assessing soil health and sustainable productivity. Biological indicators of soil health. New York: CAB International.
- Dowdy, W. W. (1944). The influence of temperature on vertical migration of invertebrates inhabiting different soil types. *Ecology*, 25(4), 449-460.
- Drift, J. V. D. (1950). *Analysis of the animal community in a beech forest floor* (Doctoral dissertation, Leyden.).
- Drinkwater, L. E., Letourneau, D. K., Workneh, F. A. H. C., Van Bruggen, A. H. C., & Shennan, C. (1995). Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological applications*, 5(4), 1098-1112.
- DS, M. (1965). Leaf fall and litter disappearance in a tropical forest. *Pedobiologia*, 5, 237-288.
- Dunger, W. (1958). Über die Veränderung des Falllaubes im Darm von Bodentieren. *Zeitschrift Für Pflanzenernährung, Düngung, Bodenkunde*, 82(2-3), 174–193.
- Eaton, T. H. (1943). Biology of a mull-forming millipede, *Apheloria coriacea* (Koch). *The American Midland Naturalist*, 29(3), 713-723.
- Eberhard, S., & Spate, A. (1995). *Cave invertebrate survey: toward an atlas of New South Wales cave fauna*. Department of Urban Affairs and Planning and the Australian Heritage Commission.
- Edward, C. A., & Lofty, J. R. (1973). The influence of cultivation on soil animal population. Progress in Soil Zoology. *Proe. 5th Int. Collq. on Soil Zoology*, 399-407.
- Edwards, C. A. (1990). Symphyla. *Soil Biology Guide*.
- Edwards, C. A., & Lofty, J. R. (1974). Ttte invertebrate fauna of the Park Grass Plots. I. Soil fauna. *Roth. Fjcp. Stat. Rep. 1974. Part, 2*, 133-154.

Eisenbeis, G., & Wichard, W. (2012). *Atlas on the biology of soil arthropods*. Springer Science and Business Media.

Elkins, N. Z., Sabol, G. V., Ward, T. J., & Whitford, W. G. (1986). The influence of subterranean termites on the hydrological characteristics of a Chihuahuan desert ecosystem. *Oecologia*, 68(4), 521–528.

Elmquist, D. C., Kahl, K. B., Johnson-Maynard, J. L., & Eigenbrode, S. D. (2023). Linking agricultural diversification practices, soil arthropod communities and soil health. *Journal of Applied Ecology*, 60(9), 1952-1963.

Endlweber, K., & Scheu, S. (2006). Effects of Collembola on root properties of two competing ruderal plant species. *Soil Biology and Biochemistry*, 38(8), 2025-2031.

Endlweber, K., & Scheu, S. (2007). Interactions between mycorrhizal fungi and Collembola: effects on root structure of competing plant species. *Biology and fertility of Soils*, 43, 741-749.

Engels, F., & Untermann, E. (2021). The origin of the family, private property and the state. In *Politics and Kinship* (pp. 217-223). Routledge.

Envi Stats India. (2019). Environment Accounts. (II) 16.

Epstein, E. (1965). Typical concentrations sufficient for plant growth. *Plant Biochemistry*, 438-466.

Ermilov, S. G., & Anichkin, A. E. (2014). Taxonomic study of oribatid mites (Acari, Oribatida) of Bi Dup-Nui Ba National Park (southern Vietnam). *Zootaxa*, 3834(1), 1-86.

Erwin, T. L. (1982). Tropical forests: their richness in Coleoptera and other arthropod species. *The Coleopterists Bulletin*.

Eschenbrenner, V. (1986). Contribution des termites à la micro-agrégation des sols tropicaux. *Cahiers ORSTOM, série Pédologie*, 22(4), 397-408.

Escherich, K. (1903). Beitrage zur kenntnis der thysanuren.

Esenowo, I., Udoidung, N., Akpan, A., Archibong, D., & Umoh, I. (2017). Evaluating the Abundance of Soil Macro-Invertebrates in Idoro Community, Akwa Ibom State, Nigeria. *Asian Journal of Environment and Ecology*, 3(4), 1-8.

Evans, T. A., Dawes, T. Z., Ward, P. R., & Lo, N. (2011). Ants and termites increase crop yield in a dry climate. *Nature Communications*, 2(1).

Ferguson, S. H., & Joly, D. O. (2002). Dynamics of springtail and mite populations: the role of density dependence, predation, and weather. *Ecological Entomology*, 27(5), 565-573.

Ferguson, S. H., & Joly, D. O. (2002). Dynamics of springtail and mite populations: the role of density dependence, predation, and weather. *Ecological Entomology*, 27(5), 565-573.

Filser, J. (2002). The role of Collembola in carbon and nitrogen cycling in soil. *Pedobiologia*, 46(3-4), 234–245.

Filser, J., Faber, J. H., Tiunov, A. V., Brussaard, L., Frouz, J., De Deyn, G., Uvarov, A. V., Berg, M. P., Lavelle, P., Loreau, M., Wall, D. H., Querner, P., Eijsackers, H., & Jiménez, J. J. (2016). Soil fauna: key to new carbon models. *SOIL*, 2(4), 565–582.

Filser, J., Fromm, H., Nagel, R. F., & Winter, K. (1995). Effects of previous intensive agricultural management on microorganisms and the biodiversity of soil fauna. *Plant and Soil*, 170, 123-129.

Fischer, E., Farkas, S., Hornung, E., & Past, T. (1997). Sublethal effects of an organophosphorous insecticide, dimethoate, on the isopod *Porcellio scaber* Latr. *Comparative Biochemistry and Physiology Part C: Pharmacology, Toxicology and Endocrinology*, 116(2), 161-166.

Fisher, B. L. (1999). Improving inventory efficiency: a case study of leaf-litter ant diversity in Madagascar. *Ecological Applications*, 9(2), 714-731.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., ... & Snyder, P. K. (2005). Global consequences of land use. *science*, 309(5734), 570-574.

Ford, J. (1937). Fluctuations in natural populations of Collembola and Acarina. *The Journal of Animal Ecology*, 98-111.

Forey, E., Coulibaly, S. F., & Chauvat, M. (2015). Flowering phenology of a herbaceous species (*Poa annua*) is regulated by soil Collembola. *Soil Biology and Biochemistry*, 90, 30-33.

Fрати, F., Carapelli, A., Fanciulli, P. P., & Dallai, R. (1995). The genus *Isotomurus*: where molecular markers help to evaluate the importance of morphological characters for the diagnosis of species. *Polskie Pismo Entomologiczne*, 64(1-4).

Frenzel, G. (1936). Untersuchungen über die Tierwelt des Wiesenbodens. (*No Title*).

Frouz, J. (1999). Use of soil dwelling Diptera (Insecta, Diptera) as bioindicators: a review of ecological requirements and response to disturbance. *Agriculture, ecosystems and environment*, 74(1-3), 167-186.

Frouz, J., & Jilková, V. (2008). The effect of ants on soil properties and processes (Hymenoptera: Formicidae). *Myrmecological News*, 11(11), 191-199.

Fujikawa, T. (1970). Distribution of soil animals in three forests of northern Hokkaido: Ii. Horizontal and vertical distribution of Oribatid mites (Acarina: Cryptostigmata). *Applied entomology and zoology*, 5(4), 208-212.

Fujikawa, T. (1972). Oribatid Fauna in Several Different Vegetations along the Ishikari Sea Shore. *Applied Entomology and Zoology*, 7(3), 173-176.

Fusaro, S., Gavinelli, F., Lazzarini, F., & Paoletti, M. G. (2018). Soil Biological Quality Index based on earthworms (QBS-e). A new way to use earthworms as bioindicators in agroecosystems. *Ecological Indicators*, 93, 1276-1292.

Futuyma, D. J. (1973). Ecology. The Experimental Analysis of Distribution and Abundance. Charles J. Krebs. *The Quarterly Review of Biology*, 48(1, Part 1), 47–48.

Gadaily, D., Ningthoujam, K., Thangjam, R., Pathak, M., & Rajesh, T. (2020). Soil arthropods diversity in agricultural and horticultural ecosystem of mid hills of Meghalaya.

Gallego-Zamorano, J., de Jonge, M. M., Runge, K., Huls, S. H., Wang, J., Huijbregts, M. A., & Schipper, A. M. (2023). Context-dependent responses of terrestrial invertebrates to anthropogenic nitrogen enrichment: A meta-analysis. *Global Change Biology*, 29(14), 4161-4173.

Galvan, P., Ponge, J. F., Chersich, S., & Zanella, A. (2008). Humus components and soil biogenic structures in Norway spruce ecosystems. *Soil Science Society of America Journal*, 72(2), 548-557.

Gama, L. T., Dickerson, G. E., Young, L. D., & Leymaster, K. A. (1991). Effects of breed, heterosis, age of dam, litter size, and birth weight on lamb mortality. *Journal of animal science*, 69(7), 2727-2743.

Gama, S., Vergassola, M., & Frisch, U. (1994). Negative eddy viscosity in isotropically forced two-dimensional flow: linear and nonlinear dynamics. *Journal of fluid mechanics*, 260, 95-126.

Garnier-Sillam, E., & Harry, M. (1995). Distribution of humic compounds in mounds of some soil-feeding termite species of tropical rainforests: its influence on soil structure stability. *Insectes Sociaux*, 42(2), 167–185.

Geisen, S., Wall, D. H., & van der Putten, W. H. (2019). Challenges and opportunities for soil biodiversity in the anthropocene. *Current Biology*, 29(19), R1036-R1044.

Geisseler, D., Horwath, W. R., & Scow, K. M. (2011). Soil moisture and plant residue addition interact in their effect on extracellular enzyme activity. *Pedobiologia*, 54(2), 71-78.

- Gere, G. (1963). Über einige faktoren des Streuabbaues. *Soil organisms*, 67-75.
- Gergócs, V., & Hufnagel, L. (2009). Application of oribatid mites as indicators. *Applied ecology and environmental research*, 7(1), 79-98.
- Gergócs, V., Garamvölgyi, Á., & Hufnagel, L. (2010). Indication strength of coenological similarity patterns based on genus-level taxon lists and prevalence distribution. *Applied Ecology and Environmental Research*, 8(1), 63-76.
- Ghatak, N. R., Hadfield, M. G., & Rosenblum, W. I. (1978). Association of central pontine myelinolysis and Marchiafava-Bignami disease. *Neurology*, 28(12), 1295-1295.
- Ghilarov, M. S. (1965). Some practical problems of soil zoology. *Pedobiologia*, 5, 189-204.
- Ghilarov, M. S. (1975). General trends of changes in soil animal population of arable land. In *Progress in Soil Zoology: Proceedings of the 5th International Colloquium on Soil Zoology Held in Prague September 17–22, 1973* (pp. 31-39). Dordrecht: Springer Netherlands.
- Ghosh, S. N., Chattopodhyay, A., & Bhattacharya, D. K. (1999). Population abundance, seasonal fluctuation of ants (Hymenoptera: Formicidae) in automobile exhaust fed road side soil of Calcutta. *Records of the Zoological Survey of India*, 97(2), 139-148.
- Ghosh, T. C. (2018). Impact of macro vegetation and edaphic variables on the distribution and diversity of Oribatida (Acari) in Northern Tripura, India. *Biologia*, 73, 1229-1236.
- Ghosh, T. C., & Mandal, S. (2017). Distribution and seasonal abundance of acarine community (Arachnida: Acari) in a zoological park of Darjeeling Himalayas, West Bengal, India. *Persian Journal of Acarology*, 6(1).

Gibb, T. J., & Oseto, C. Y. (2006). *Arthropod collection and identification: laboratory and field techniques*. Academic press.

Gill, N. K., & Kaur, H. A. R. W. I. N. D. E. R. (2014). A study on the occurrence, prevalence and species composition of mite fauna in human dwellings of Patiala city, Punjab (India). *Indian Journal of Scientific Research*, 8(1), 91-97.

Gill, R. W. (1969). Soil microarthropod abundance following old-field litter manipulation. *Ecology*, 50(5), 805-816.

Gillott, C. (2005). *Entomology*. Springer Science and Business Media.

Gimeno-García, E., Andreu, V., & Boluda, R. (1996). Heavy metals incidence in the application of inorganic fertilizers and pesticides to rice farming soils. *Environmental pollution*, 92(1), 19-25.

Gisin, H. (1943). Okologie und lebensgemeinschaften der collembolen im schweizerischen exkursionsgebiet basels. *Revue suisse de Zoologie*, 50, 131-224.

Glasgow, J. P. (1939). A population study of subterranean soil Collembola. *The Journal of Animal Ecology*, 323-353.

Golovatch, S. I., & Wesener, T. (2016). A species checklist of the millipedes (Myriapoda, Diplopoda) of India. *Zootaxa*, 4129(1), 1-75.

Government of Haryana (2011). Statistical Abstract of Haryana, Department of Economic and Statistical Analysis, Chandigarh.

Government of Haryana (2018-19). Statistical Abstract of Haryana. Department of Economic and Statistical Analysis, Haryana 2020. Section-II, Basic Statistics, 9-14.

Government of India, Ministry of Agriculture, Department of Agriculture and cooperation; Mechanisation and Technology Division (<http://farmech.dac.gov.in/FarmerGuide/HR/index1.html>)

- Grassi, B. (1887). *Progenitori dei miriapodi e degli insetti: altre ricerche sui tisanuri*.
- Greenslade, P. J. M. (1985). Pterygote insects and the soil: their diversity, their effects on soils and the problem of species identification.
- Greig-Smith, P., & Margalef, R. (1971). Perspectives in ecological theory. *The Journal of Ecology*, 59(1), 308.
- Greig-Smith, P., & Williams, C. B. (1966). Patterns in the balance of nature and related problems in quantitative ecology. *The Journal of Ecology*, 54(2), 549.
- Gressitt, J. L. (1961). Problems in the zoogeography of Pacific and Antarctic insects. *Pacific Insects Monograph*, 2, 1-94.
- Griffiths, D. A., Wilkin, D. R., Southgate, B. J., & Lynch, S. M. (1976). survey of mites in bulk grain stored on farms in England and Wales. *Annals of applied biology*.
- Guru, B. C., Panda, S., & Mahapatra, P. (1988). Species composition, vertical distribution and seasonal variation of Collembola in cultivated and uncultivated sites of Eastern Orissa. *J. Soil. Biol. Ecol*, 8(2), 104-116.
- Haarløv, N. (1947). A new modification of the Tullgren apparatus. *The Journal of Animal Ecology*, 115-121.
- Haarlo, N. (1960). Microarthropods from Danish soils. Ecology, phenology. *Oikos*, (3 (suppl.)).
- Haase, J., Brandl, R., Scheu, S., & Schädler, M. (2008). Above-and belowground interactions are mediated by nutrient availability. *Ecology*, 89(11), 3072-3081.
- Hågvar, S. (1995). Instability in small, isolated microarthropod communities. *Polskie Pismo Entomologiczne*, 64(1-4).
- Hågvar, S., & Abrahamsen, G. (1980). Colonisation by Enchytraeidae, Collembola and Acari in sterile soil samples with adjusted pH levels. *Oikos*, 245-258.

- Hågvar, S., & Abrahamsen, G. (1990). Microarthropoda and Enchytraeidae (Oligochaeta) in naturally lead-contaminated soil: a gradient study. *Environmental Entomology*, 19(5), 1263-1277.
- Haj Sghaier, A., Tarnawa, Á., Khaeim, H., Kovács, G. P., Gyuricza, C., & Kende, Z. (2022). The effects of temperature and water on the seed germination and seedling development of rapeseed (*Brassica napus* L.). *Plants*, 11(21), 2819.
- Hale, K. L. (1966). Kinship reflections in syntax: Some Australian languages. *Word*, 22(1-3), 318-324.
- Hale, W. G. (1966). A population study of moorland Collembola. *Pedobiologia*, 6, 65-99.
- Hale, W. G., Burges, A., & Raw, F. (1967). Collembola in soil biology.
- Hammer, M. (1944). Studies on the oribatids and collemboles of Greenland. (*No Title*).
- Handa, S. H. O. B. H. A., & Vats, L. K. (1990). Soil litter Coleoptera in a deciduous forest stand at Kurukshetra. *Uttar Pradesh Journal of Zoology*, 10(1), 88-90.
- Handschin, E. (1929). *Beiträge zur Collembolenfauna von Süd-Indien*.
- Hardie, M., & Doyle, R. (2012). Measuring soil salinity. *Plant salt tolerance: methods and protocols*, 415-425.
- Harris, D. R., & Fuller, D. Q. (2014). Agriculture: definition and overview. *Encyclopedia of global archaeology*, 104-113.
- Haryana, W. M. C. I. (2016). Trend and consequences of rice wheat mono-cropping in Haryana, India.
- Hasegawa, M. (1997). Changes in Collembola and Cryptostigmata communities during the decomposition of pine needles. *Pedobiologia*, 41, 225-241.

- Hassall, M. (1977). Consumption of leaf litter by the terrestrial isopod *Philoscia muscorum* in relation to food availability in a dune grassland ecosystem. *Ecological Bulletins*, 550-553.
- Hassall, M., Turner, J. G., & Rands, M. R. W. (1987). Effects of terrestrial isopods on the decomposition of woodland leaf litter. *Oecologia*, 72(4), 597–604.
- Hattar, S. J. S., Alfred, J. R. B., & Darlon, V. T. (1993). Soil acarina and collembola in forest and cultivated land of Khasi Hills, Meghalaya. *Records of the Zoological Survey of India*, 116(1-4), 89-97.
- Hazra, A. K., & Choudhuri, D. K. (1983). A study of Collembola communities in cultivated and uncultivated sites of West Bengal in relation to three major soil factors. *Revue d'écologie et de biologie du sol*, 20(3), 385-401.
- Hazra, A. K., & Choudhuri, D. K. (1990). Ecology of subterrenean macro and micro arthropod fauna in different degraded and polluted soil environment of West Bengal, India. (*No Title*).
- Hazra, A. K., Dey, M. K., & Mandal, G. P. (2005). Diversity and distribution of arthropod fauna in relation to mangrove vegetation on a newly emerged island on the river Hooghly, West Bengal. *Records of the Zoological Survey of India*, 104(3-4), 99-102.
- Hazra, A. K., Mandal, G. P., & Suman, K. K. (2004). On a collection of Collembola insects from Jammu and Kashmir. *Bionotes*, 6(1).
- Hebert, P. D., Cywinska, A., Ball, S. L., & DeWaard, J. R. (2003). Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 270(1512), 313-321.
- Hijii, N. (1987). Seasonal changes in abundance and spatial distribution of the soil arthropods in a Japanese cedar (*Cryptomeria japonica* D. Don) plantation, with special reference to Collembola and Acarina. *Ecological Research*, 2, 159-173.

- Holland, J. H. (2000). *Emergence: From chaos to order*. OUP Oxford.
- Holmgren, N. (1906). *Studien über südamerikanische Termiten* (Doctoral dissertation, Fischer).
- Holmgren, N. (1910). Das system der termiten. *Zoologischer Anzeiger*, 35(9-10), 284-286.
- Holmgren, N. (1912). Termite studies 3. Systematic der Termiten die familie Metatermitidae. *K. Svenska vetensk. Akad. Handl*, 48(4), 166.
- Hooke, R. (2003). *Micrographia: or some physiological descriptions of minute bodies made by magnifying glasses, with observations and inquiries thereupon*. Courier Corporation.
- Hopkin, S. P. (1997). *Biology of the springtails:(Insecta: Collembola)*. OUP Oxford.
- Hopkin, S. P., & Read, H. J. (1993). The biology of millipedes. *Choice Reviews Online*, 30(08), 30-438330-4383.
- Hopkin, S. P., Jones, D. T., & Dietrich, D. (1993). The isopod *Porcellio scaber* as a monitor of the bioavailability of metals in terrestrial ecosystems: towards a global “woodlouse watch” scheme. *Science of the Total Environment*, 134, 357-365.
- Hopkins, R. (1997). *Educating Black males: Critical lessons in schooling, community, and power*. State University of New York Press.
- Hossam ElShafie, M., Adel Morsey, H., & Emad Eid, Y. (2001). Ipsilateral fracture of the femoral neck and shaft, treatment by reconstruction interlocking nail. *Archives of orthopaedic and trauma surgery*, 121, 71-74.
- Howard, A., Howard, G. L., & Khan, A. R. (1910). The economic significance of natural cross-fertilization in India. (*No Title*).

Hoy, M. A. (2008). Soil mites (Acari: Oribatida and others). *Encyclopedia of entomology*, 3463-3466.

Huether, W. (1983). Human influence on collembolan populations in Brazilian rainforests. *Pedobiologia.*, 25(5).

Hufnagel, L., Gergócs, V., Garamvölgyi, Á., & Homoródi, R. (2011). Seasonal change of oribatid mite communities (Acari, Oribatida) in three different types of microhabitats in an oak forest. *Applied Ecology and Environmental Research*, 9(2), 181-195.

Huhta, V., & Mikkonen, M. (1982). Population structure of Entomobryidae (Collembola) in a mature spruce stand and in clear-cut reforested areas in Finland.

Huhta, V., Persson, T., & Setälä, H. (1998). Functional implications of soil fauna diversity in boreal forests. *Applied Soil Ecology*, 10(3), 277-288.

Ilyas, M., & Parwez, H. (2012). Studies of the soil pterygote insects in relation to certain ecological factors in agricultural field at Aligarh, Uttar Pradesh, India. *Journal of Entomological Research*, 36(3), 273-280.

Imms A.D. and Herdman W.A. (1906). *Memoirs on Typical British Marine Plants and Animals XIII*. Anurid. pp.1-99.

Imran, M., Shaharoon, B., Crowley, D. E., Khalid, A., Hussain, S., & Arshad, M. (2015). The stability of textile azo dyes in soil and their impact on microbial phospholipid fatty acid profiles. *Ecotoxicology and Environmental Safety*, 120, 163-168.

Ineson, P., Leonard, M. A., & Anderson, J. M. (1982). Effect of collembolan grazing upon nitrogen and cation leaching from decomposing leaf litter. *Soil Biology and Biochemistry*, 14(6), 601-605.

Jackson, M. L. (1965). Free oxides, hydroxides, and amorphous aluminosilicates. *Methods of Soil Analysis: Part 1 Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling*, 9, 578-603.

Jacot, A. P. (1939). Reduction of spruce and fir litter by minute animals. *Journal of forestry*, 37(11), 858-860.

Jacot, A. P. (1940). The fauna of the soil. *The Quarterly Review of Biology*, 15(1), 28-58.

Janssen, M. A., Schoon, M. L., Ke, W., & Börner, K. (2006). Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. *Global environmental change*, 16(3), 240-252.

Janssens, F. (2007). Checklist of the Collembola of the world. *Recuperado de <http://www.collembola.org>*.

Jeleva, M. (1970). The influence of different methods of cultivation of the soil combined with enlarged doses of natural and mineral fertilizers on the soil oribatei. *Godishnik na Sofiŭskiia universitet, Biologicheski fakultet: Annuaire de l'Université de Sofia, Faculté de biologie. Zoologiia, fiziologiia i biokhimiia na zivotnite. Zoologie, physiologie et biochimie des animaux*, 65, 35.

Jenny, H. (1980). Ecological studies analysis and synthesis vol. 37. The soil resource origin and behavior, Jenny, H. Ecological Studies: Analysis and synthesis. *The soil resource: Origin and behavior*, 37, 377.

Jenny, H. (1981). The soil resource—origin and behavior. Ecological studies 37. *Soil Science*, 132(5), 380.

Jernigan, A., Kao-Kniffin, J., Pethybridge, S., & Wickings, K. (2023). Soil microarthropod effects on plant growth and development. *Plant and Soil*, 483(1), 27-45.

- Johnston, T. H., & Tiegs, C. W. (1921). New and little-known sarcophagid flies from south-eastern Queensland. In *Proceedings of the Royal Society of Queensland* (Vol. 33, No. 4, pp. 46-90). Brisbane.
- Jones, C. G., Lawton, J. H., & Shachak, M. (1994). Organisms as ecosystem engineers. *Oikos*, 69(3), 373–386.
- Joosse, E. N., & Groen, J. B. (1970). Relationship between saturation deficit and the survival and locomotory activity of surface dwelling Collembola. *Entomologia experimentalis et applicata*, 13(3), 229-235.
- Jordana, M., Newhouse, M. T., & Gauldie, J. (1987). Alveolar macrophage/peripheral blood monocyte-derived factors modulate proliferation of primary lines of human lung fibroblasts. *Journal of leukocyte biology*, 42(1), 51-60.
- Joshi, A., Kaur, S., Taneja, S. K., & Mandal, R. (2024). Review Article on Molecular Mechanism of Regulation of Hypertension by Macro-elements (Na, K, Ca and Mg), Micro-elements/Trace Metals (Zn and Cu) and Toxic Elements (Pb and As). *Biological Trace Element Research*, 202(4), 1477-1502.
- Joy, V. C., & Bhattacharya, T. (1981). A Comparative Assessment of the Effect of Some Herbicides on the Microarthropods of Cultivated Soils. ., 299-304.
- Joy, V. C., & Chakravorty, P. P. (1991). Impact of insecticides on nontarget microarthropod fauna in agricultural soil. *Ecotoxicology and Environmental Safety*, 22(1), 8-16.
- JW, D. (1996). Soil health and sustainability. *Advances in Agron.*, 56, 1-54.
- Kamill1, B. W., Steinberger2, Y., & Whitford3, W. G. (1985). Soil microarthropods from the Chihuahuan desert of New Mexico. *Journal of Zoology*, 205(2), 273-286.
- Kaur, N., & Dhingra, S. (2018). Seasonal abundance and diversity of astigmatic mites in storage facilities of Punjab, India. *Agricultural Science Digest-A Research Journal*, 38(1), 32-35.

Kautz, G., & Topp, W. (2000). Acquisition of microbial communities and enhanced availability of soil nutrients by the isopod *Porcellio scaber* (Latr.) (Isopoda: Oniscidea). *Biology and Fertility of Soils*, 31(2), 102–107.

Kautz, T., López-Fando, C., & Ellmer, F. (2006). Abundance and biodiversity of soil microarthropods as influenced by different types of organic manure in a long-term field experiment in Central Spain. *Applied Soil Ecology*, 33(3), 278-285.

Kelly, B., Allan, C., & Wilson, B. P. (2009). Corrigendum to: Soil indicators and their use by farmers in the Billabong Catchment, southern New South Wales. *Soil Research*, 47(3), 340-340.

Kevan, D. K. (1962). Soil animals. *Soil animals*.

Khalil, M. A., Janssens, T. K., Berg, M. P., & van Straalen, N. M. (2009). Identification of metal-responsive oribatid mites in a comparative survey of polluted soils. *Pedobiologia*, 52(3), 207-221.

Kibblewhite, M. G., Jones, R. J., Montanarella, L., Baritz, R., Huber, S., Arrouays, D., ... & Stephens, M. (2008). Environmental assessment of soil for monitoring volume VI: Soil monitoring system for Europe. *Eur*, 23490, 72.

Killham, K. (1994). *Soil ecology*. Cambridge University Press.

Klausman, L. (2006, April). Decomposition and microarthropod abundance in litter and soil in a Southern Appalachian wetlands complex. In *Proceedings of the National Conference on Undergraduate Research (NCUR)*. The University of North Carolina at Asheville (pp. 6-8).

Kolekar, Y. M., Pawar, S. P., Gawai, K. R., Lokhande, P. D., Shouche, Y. S., & Kodam, K. M. (2008). Decolorization and degradation of Disperse Blue 79 and Acid Orange 10, by *Bacillus fusiformis* KMK5 isolated from the textile dye contaminated soil. *Bioresource technology*, 99(18), 8999-9003.

Kováč, L. U., L'uptáček, P., Miklisová, D., & Mati, R. (2001). Soil Oribatida and Collembola communities across a land depression in an arable field. *European Journal of Soil Biology*, 37(4), 285-289.

Krebs, C. J. (1985). Ecology the experimental analysis of distribution and abundance.

Krebs, C. J. (1989). Ecological methodology. (*No Title*).

Krell, F. T., Chung, A. Y., DeBoise, E., Eggleton, P., Giusti, A., Inward, K., & Krell-Westerwalbesloh, S. (2005). Quantitative extraction of macro-invertebrates from temperate and tropical leaf litter and soil: efficiency and time-dependent taxonomic biases of the Winkler extraction. *Pedobiologia*, 49(2), 175-186.

Kromp, B. (1999). Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems and Environment*, 74(1-3), 187–228.

Kubiena, W. L. (1955). Animal activity in soils as a decisive factor in establishment of humus forms. *Soil zoology*, 2, 73-82.

Kuhnelt, W. (1976). *Soil biology with special reference to the animal kingdom* (No. 2nd Ed.(revised and enlarged)). Faber and Faber..

Kumar, A., & Singh, N. (2019). Physicochemical characterization and correlative study of soil parameters of selected states agricultural land.

Kumar, U., & Singh, R. (2016). Soil Fauna: A retrospection with reference to Indian soil. *International Journal of Research Studies in Zoology*, 2(3), 1-22.

Kumar, V. (2017). Study to evaluate success of diversification of agricultural Crops in Haryana. *Centre for Research in Rural and Industrial Development (CRRID)*.

Lagerlöf, R. K., & Tone, J. N. (1985). The effect of gossypol acetic acid on female reproduction. *Drug and chemical Toxicology*, 8(6), 469-482.

Lakly, M. B., & Crossley, D. A. (2000). Tullgren extraction of soil mites (Acarina): Effect of refrigeration time on extraction efficiency. *Experimental and Applied Acarology*, 24(2), 135-140.

Lakshmi, G., Okafor, B. N., & Visconti, D. (2020). Soil microarthropods and nutrient cycling. *Environment, climate, plant and vegetation growth*, 453-472.

Lavelle, P. (1997). Faunal activities and soil processes: adaptive strategies that determine ecosystem function. In *Advances in ecological research* (Vol. 27, pp. 93-132). Academic Press.

Lavelle, P., Lattaud, C., Trigo, D., & Barois, I. (1995). Mutualism and biodiversity in soils. In *The Significance and Regulation of Soil Biodiversity: Proceedings of the International Symposium on Soil Biodiversity, held at Michigan State University, East Lansing, May 3–6, 1993* (pp. 23-33). Springer Netherlands.

Layton, M. B., Stewart, S. D., Williams, M. R., & Long, J. L. (1999). Performance of Bt cotton in Mississippi, 1998. In *1999 Proceedings Beltwide Cotton Conferences, Orlando, Florida, USA, 3-7 January, 1999: Volume 2*. (pp. 942-945). National Cotton Council.

Lee, K. E. (1983). The influence of earthworms and termites on soil nitrogen cycling. In *International colloquium of soil zoology*. 8 (pp. 35-48).

Lee, K. E., & Wood, T. G. (1971). *Termites and soils*. London, UK, Academic Press.

Léonard, J., & Rajot, J. L. (2001). Influence of termites on runoff and infiltration: quantification and analysis. *Geoderma*, 104(1-2), 17–40.

Lepage, M., Morel, G., & C. Resplendino. (1974). Découverte de galeries de termites atteignant la nappe phréatique profonde dans le Nord du Sénégal. *Comptes Rendus de l'Académie Des Sciences.Série D : Sciences Naturelles*, 278, 1855–1858.

Lin, X., Stur, E., & Ekrem, T. (2015). Exploring genetic divergence in a species-rich insect genus using 2790 DNA barcodes. *PloS one*, 10(9), e0138993.

Lindberg, N., & Bengtsson, J. (2005). Population responses of oribatid mites and collembolans after drought. *Applied Soil Ecology*, 28(2), 163-174.

Lindberg, N., Engtsson, J. B., & Persson, T. (2002). Effects of experimental irrigation and drought on the composition and diversity of soil fauna in a coniferous stand. *Journal of Applied Ecology*, 924-936.

Linden, D. R., Hendrix, P. F., Coleman, D. C., & van Vliet, P. C. (1994). Faunal indicators of soil quality. *Defining soil quality for a sustainable environment*, 35, 91-106.

Lindo, Z., & N. Winchester, N. (2008). Scale dependent diversity patterns in arboreal and terrestrial oribatid mite (Acari: Oribatida) communities. *Ecography*, 31(1), 53-60.

Linnaeus, C. (1789). *Systema Naturae per regna tria naturae, secundum classes, ordines, genera, species; cum characteribus, differentiis, synonymis, locis* (Vol. 1). apud JB Delamolliere.

Liu, B., Tu, C., Hu, S., Gumpertz, M., & Ristaino, J. B. (2007). Effect of organic, sustainable, and conventional management strategies in grower fields on soil physical, chemical, and biological factors and the incidence of Southern blight. *Applied Soil Ecology*, 37(3), 202-214.

Liu, R., Chai, Y., & Zhu, F. (2013). Effect of long-term cultivation on soil arthropod community in sandy farmland. *Journal of Agricultural Science and Technology (Beijing)*, 15(1), 144-151.

Longino, J. T., Coddington, J., & Colwell, R. K. (2002). The ant fauna of a tropical rain forest: estimating species richness three different ways. *Ecology*, 83(3), 689-702.

Loranger, G., Bandyopadhyaya, I., Razaka, B., & Ponge, J. F. (2001). Does soil acidity explain altitudinal sequences in collembolan communities?. *Soil Biology and Biochemistry*, 33(3), 381-393.

Loranger, G., Ponge, J. F., & Lavelle, P. (2003). Humus forms in two secondary semi-evergreen tropical forests. *European Journal of Soil Science*, 54(1), 17–24.

Loring, J., Glimelius, B., Erickson, C., & Weston, J. A. (1981). Analysis of developmentally homogeneous neural crest cell populations in vitro: I. Formation, morphology and differentiative behavior. *Developmental Biology*, 82(1), 86-94.

Lou, X., Zhao, J., Lou, X., Xia, X., Feng, Y., & Li, H. (2022). The biodegradation of soil organic matter in soil-dwelling humivorous fauna. *Frontiers in Bioengineering and Biotechnology*, 9, 808075.

Louhar, G., Yadav, R., Pawar, A. B., Rekwar, R. K., Verma, A. K., & Yadav, D. K. (2020). Heavy metals distribution and their correlation with physicochemical properties of different soil series of northwestern India. *The Indian Journal of Agricultural Sciences*, 90(9), 1742–1746.

Luff, M. L. (1996). Use of carabids as environmental indicators in grasslands and cereals. *Annales Zoologici Fennici*, 33.

Lupardus, R. C., Battigelli, J. P., Janz, A., & Lumley, L. M. (2021). Can soil invertebrates indicate soil biological quality on well pads reclaimed back to cultivated lands?. *Soil and Tillage Research*, 213, 105082.

Mac Lagan, D. S. (1932). The effect of population density upon rate of reproduction with special reference to insects. *Proceedings of the Royal Society of London. Series B, Containing Papers of a Biological Character*, 111(773), 437-454.

Macfadyen, A. (1953). Notes on methods for the extraction of small soil arthropods. *The Journal of Animal Ecology*, 65-77.

Macfadyen, A. (1955). A comparison of methods for extracting soil arthropods. *Soil Zoology.–London (Butterworths)*, 315-332.

Macfadyen, A. (1961). Improved funnel-type extractors for soil arthropods. *The Journal of Animal Ecology*, 171-184.

- Macfadyen, A. (1962). Soil arthropod sampling. In *Advances in ecological research* (Vol. 1, pp. 1-34). Academic Press.
- Maclagan, D. S. (1932). An ecological Study of the “Lucerne Flea”(Smynturus viridis, Linn.)—I. *Bulletin of Entomological Research*, 23(1), 101-145.
- Madge, D. S. (1965). Leaf fall and litter disappearance in a tropical forest. *Pedobiologia*, 5, 273–288.
- Majer, J., Walker, T. C., & Berlandier, F. (1987). The role of ants in degraded soils within Dryandra state forest.
- Majer, J., Walker, T., & Françoise Berlandier. (1987). The role of ants in degraded soils within Dryandra State Forest. *Mulga Res. Cent. J.* , 9, 15–16.
- Malik, R. A., Hussain, A., Song, T. K., Kim, W. J., Ahmed, R., Sung, Y. S., & Kim, M. H. (2017). Enhanced electromechanical properties of (1-x) BiFeO₃–BaTiO₃–xLiNbO₃ ceramics by quenching process. *Ceramics International*, 43, S198-S203.
- Malik, R., Yadav, H., Yadava, N., Yadav, R., & Sangwan, P. S. (2017). Background levels of zinc, iron, manganese and copper in soil series of Haryana and their relationship with soil properties. *Indian Journal of Agricultural Sciences*, 87(8), 1094-8.
- Mandal, A., Das, S., & Ghosh, T. C. (2019). Abundance and diversity of soil Oribatid Mites (Acari: Oribatida) from North-East India-A review. *Asian Journal of Conservation Biology*, 8(2), 199-207.
- Mandal, G. P. (2010). Checklist of Indian Collembola (Insecta: Apterygota).
- Mandal, G. P. (2013). Two additional new records of Collembola from Arunachal Pradesh, India. *Bionotes*, 15(3), 85.

- Mandal, G. P. (2014, July). New Records of Collembola (Hexapoda) from Hazaribagh National Park, Jharkhand, India. In *Biological Forum* (Vol. 6, No. 2, p. 197). Research Trend.
- Mandal, G. P. (2018). Collembola of India-an updated checklist. *Halteres*, 9, 116-130.
- Mandal, G. P., & Hazra, A. K. (2002). Collembola Insects from Sri Sai Venkateswara National Park, Tirupati, Andhra Pradesh. *Bionotes*, 4(4), 89.
- Mandal, G. P., & Hazra, A. K. (2009). The diversity of Collembola (Hexapoda) from east and north-east India with some notes on their ecology. *Occasional Paper-Records of the Zoological Survey of India*, (298).
- Mandal, G. P., & Suman, K. K. (2014). Studies on diversity and distribution of soil micro-arthropods fauna with special reference to collembola in sajnekhali wild life sanctuary, south 24 pgs, West Bengal. *Records of the Zoological Survey of India*, 114(4), 623-636.
- Mandal, G. P., Suman, K. K., & Bhattacharya, K. K. (2016). Four New Species of Springtails (Hexapoda: Collembola) from Jharkhand, India. *Records of the Zoological Survey of India*, 116(1), 41-52.
- Mandal, G. P., Suman, K. K., & Bhattacharya, K. K. (2017). Five New Species of Collembola (Isotomidae) from Jharkhand, India. *Records of the Zoological Survey of India*, 117(2), 97-112.
- Mani, M. S. (1962). *Introduction to high altitude entomology: insect life above the timber-line in the North-West Himalaya* (Vol. 1, No. na). Methuen and Co. Ltd..
- Mani, M. S. (1968). *Ecology and biogeography of high altitude*. Junk.
- Mani, M. S. (1990). *Fundamentals of high altitude biology*. Oxford and IBH Publishing Company.

- Manu, M., Onete, M., Florescu, L., Bodescu, F., & Iordache, V. (2017). Influence of heavy metal pollution on soil mite communities (Acari) in Romanian grasslands. *North-Western Journal of Zoology*, 13(2).
- Manzoor, S. (2006). *Studies on chemical profiling of wastewater from Hattar Industrial Estate (NWFP), Pakistan* (Doctoral dissertation, Quaid-i-Azam University Islamabad, Pakistan).
- Maraun, M., Visser, S., & Scheu, S. (1998). Oribatid mites enhance the recovery of the microbial community after a strong disturbance. *Applied Soil Ecology*, 9(1-3), 175–181.
- Marcuzzi, G. I. O. R. G. I. O. (1970). Experimental observations on the role of *Glomeris* spp.(Myriapoda Diplopoda) in the process of humification of litter. *Pedobiologia*, 10(6), 401-6.
- Margalef. (1968). R. Perspective in Ecological Theory.
- Margam, V. M., Gachomo, E. W., Shukle, J. H., Ariyo, O. O., Seufferheld, M. J., & Kotchoni, S. O. (2010). A simplified arthropod genomic-DNA extraction protocol for polymerase chain reaction (PCR)-based specimen identification through barcoding. *Molecular biology reports*, 37, 3631-3635.
- Mayhew, P. J. (2007). Why are there so many insect species? Perspectives from fossils and phylogenies. *Biological Reviews*, 82(3), 425-454.
- McBrayer, J. F. (1973). Exploitation of deciduous leaf litter by *Apheloria montana* (Diplopoda: Eurydesriidae). *Pedobiologia*, 13(2), 90–98.
- McBrayer, J. F., Reichle, D. E., & Witkamp, M. (1974). *Energy flow and nutrient cycling in a cryptozoan food-web* (Vol. 73, No. 8). Oak Ridge National Laboratory.
- Mehta, C. R., Chandel, N. S., Senthilkumar, T., & Singh, K. K. (2014). Trends of agricultural mechanization in India. *CSAM policy brief*, 2(2), 1-13.

- Menta, C., & Remelli, S. (2020). Soil health and arthropods: From complex system to worthwhile investigation. *Insects*, *11*(1), 54.
- Meyer, E. (1996). Mesofauna. In *Methods in soil biology* (pp. 338-345). Berlin, Heidelberg: Springer Berlin Heidelberg.
- Meyer, M. C., Paschke, M. W., McLendon, T., & Price, D. (1998). *Decreases in soil microbial function and functional diversity in response to depleted uranium* (Vol. 27, No. 6, pp. 1306-1311). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.
- Migliorini, M., & Bernini, F. (1999). Oribatid mite coenoses in the Nebrodi Mountains (northern Sicily). *Pedobiologia*, *43*(4), 372-383.
- Migliorini, M., Pigino, G., Caruso, T., Fanciulli, P. P., Leonzio, C., & Bernini, F. (2005). Soil communities (Acari Oribatida; Hexapoda Collembola) in a clay pigeon shooting range. *Pedobiologia*, *49*(1), 1-13.
- Mikola, J., & Setälä, H. (1998). Productivity and trophic-level biomasses in a microbial-based soil food web. *Oikos*, 158-168.
- Misra, R. (1968). Ecology Work Book Oxford and IBH Publishing Company. *New Delhi*.
- Mitchell, M. J., David, M. B., & Morgan, C. R. (1983). Importance of organic sulfur constituents of forest soils and the role of the soil macro-fauna in affecting sulfur flux and transformation. In *International colloquium of soil zoology*. 8 (pp. 75-85).
- Mitchell, R. J., Campbell, C. D., Chapman, S. J., Osler, G. H., Vanbergen, A. J., Ross, L. C., ... & Cole, L. (2007). The cascading effects of birch on heather moorland: a test for the top-down control of an ecosystem engineer. *Journal of Ecology*, *95*(3), 540-554.
- Mitra, S. K., Dutta, A. L., Mandal, S. B., & Sengupta, D. (1983). Preliminary observations on the effects of rotation of crops and fertilizers on Collembola. In 8.

International Soil Zoology Colloquium, Louvain-la-Neuve (Belgium), 30 Aug-2 Sep 1982. UCL-Ecologie Animale.

Mittal, S. C. (1986). *Haryana, a Historical Perspective*. Atlantic Publishers and Distri.

Mola, I., Sabatini, M. A., Fratello, B., & Bertolani, R. (1987). Effects of atrazine on two species of Collembola (Onychiuridae) in laboratory tests. *Pedobiologia*, 30(3), 145-150.

Molero-Baltanás, R., & Choudhuri, D. K. (1983). A study of Collembola communities in cultivated and uncultivated sites of West Bengal in relation to three major soil factors. *Revue d'Écologie et de Biologie Du Sol*, 20(3), 385–401.

Moore, J. C., Snider, R. J., & Robertson, L. S. (1984). Effects of different management practices on Collembola and Acarina in corn production systems. I: The effects of no-tillage and atrazine. *Pedobiologia (Jena)*, 26(2), 143-152.

Moreira-Almeida, A., Lotufo Neto, F., & Koenig, H. G. (2006). Religiousness and mental health: a review. *Brazilian Journal of Psychiatry*, 28, 242-250.

Morris, H. M. (1922). The insect and other invertebrate fauna of arable land at Rothamsted 1. *Annals of Applied Biology*, 9(3-4), 282-305.

Mueller, L., Schindler, U., Mirschel, W., Shepherd, T. G., Ball, B. C., Helming, K., ... & Wiggering, H. (2011). Assessing the productivity function of soils. *Sustainable Agriculture Volume 2*, 743-760.

Mukharji, S. P., & Singh, J. (1970). Seasonal variations in the densities of soil arthropod population in a rose garden in Varanasi,(India). *Pedobiologia*, 10, 442-446.

Müller, O. F. (1776). *Zoologiae Danicae prodromus, seu, Animalium Daniae et Norvegiae indigenarum characteres, nomina, et synonyma imprimis popularium*. Impensis auctoris.

Murphy, P. W. (1962). Extraction methods for soil animals. I. Dynamic methods with particular reference to funnel processes. *Progress in soil zoology*. Butterworths, London, 75-114.

Nardi, J. B. (2019). *Life in the soil: a guide for naturalists and gardeners*. University of Chicago Press.

Ndiaye, D., Lepage, M., Sall, C. E., & Brauman, A. (2004). Nitrogen transformations associated with termite biogenic structures in a dry savanna ecosystem. *Plant and Soil*, 265(1-2), 189–196.

Niels Haarløv, Wilh Kuhnelt, Niels Haarløv, & Wilh Kuhnelt. (1961). Soil biology with special reference to the animal kingdom. *Oikos*.

Nielsen, M. N., Winding, A., Binnerup, S., & Hansen, B. M. (2002). Microorganisms as indicators of soil health.

Norarmi, N. F. B., Tajudin, N. H. B., Hadirah, N. S., Hafizo, B., Mohd, W. N. S. B. W., Luzi, N. A. B. M., ... & Musa, A. B. H. (2022). A Review on Textile and Clothing Industry Impacts on The Environment.

Noti, M. I., André, H. M., Ducarme, X., & Lebrun, P. (2003). Diversity of soil oribatid mites (Acari: Oribatida) from High Katanga (Democratic Republic of Congo): a multiscale and multifactor approach. *Biodiversity and Conservation*, 12, 767-785.

Oades, J. M. (1993). The role of biology in the formation, stabilization and degradation of soil structure. In *Soil structure/soil biota interrelationships* (pp. 377-400). Elsevier.

Oba, Y., Ôhira, H., Murase, Y., Moriyama, A., & Kumazawa, Y. (2015). DNA barcoding of Japanese click beetles (Coleoptera, Elateridae). *PLoS One*, 10(1), e0116612.

- Ogedegbe, O. B. A., & Egwuonwu, I. C. (2014). Biodiversity of soil arthropods in Nigerian Institute for oil palm research (NIFOR), Nigeria. *Journal of Applied Sciences and Environmental Management*, 18(3), 377-386.
- Ojha, R., Jalali, S. K., Ali, T. M., Venkatesan, T., Prosser, S. W., & Kumar, N. K. (2014). DNA barcoding of Indian ant species based on cox1 gene.
- Oliver, I. A. N., & Beattie, A. J. (1996). Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. *Ecological applications*, 6(2), 594-607.
- P.A.M. Van Amelsvoort, M. Van Dongen, & Der, V. (1988). The impact of collembola on humification and mineralization of soil organic matter. *Pedobiologia*, 31(1-2), 103–112.
- Pankhurst, C. E., Magarey, R. C., Stirling, G. R., Blair, B. L., Bell, M. J., Garside, A. L., & Venture, S. Y. D. J. (2003). Management practices to improve soil health and reduce the effects of detrimental soil biota associated with yield decline of sugarcane in Queensland, Australia. *Soil and Tillage Research*, 72(2), 125-137.
- Paoletti, M., Saupe, S. J., & Clavé, C. (2007). Genesis of a fungal non-self recognition repertoire. *PLoS ONE*, 2(3), e283.
- Parameswaran, M., Ghosh, S., Seenath, P., Mishra, U. S., Agarwal, M., Mallick, H., ... & Beena, P. L. (2018). Dimensions of India's economy as seen through the Economic Survey 2017-18 and the Union Budget 2018-19.
- Parker, L. W. (1984). Effects of simulated rainfall and litter quantities on desert soil biota: soil respiration, microflora and protozoa. *Pedobiologia*, 27, 185-195.
- Parveen, S., Bhatti, I. A., Ashar, A., Javed, T., Mohsin, M., Hussain, M. T., ... & Iqbal, M. (2020). Synthesis, characterization and photocatalytic performance of iron molybdate (Fe₂ (MoO₄)₃) for the degradation of endosulfan pesticide. *Materials Research Express*, 7(3), 035016.

- Pati, R., & Mukhopadhyay, D. (2011). Distribution of cationic micronutrients in some acid soils of West Bengal. *Journal of the Indian Society of Soil Science*, 59(2), 125-133.
- Paul, P., Sanyal, A. K., & Dey, D. (2011). Population Fluctuation of Soil Arthropods in Relation to Edaphic Factors in Cultivated and Non-Cultivated Plots at Khardah, North 24-Parganas, West Bengal-A Preliminary Study. *Records of the Zoological Survey of India*, 111(2), 7-21.
- Pawluk, S. (1987). Faunal micromorphological features in moder humus of some western canadian soils. *Geoderma*, 40(1-2), 3–16.
- Petal, J. O. A. N. N. A. (1978). role of ants in ecosystems. *International Biological Programme*.
- Petersen, H. (1994). A review of collembola ecology in ecosystem context. *Acta Zoologica Fannica*, 195, 118-128.
- Petersen, H., & Luxton, M. (1982). A comparative analysis of soil fauna populations and their role in decomposition processes. *Oikos*, 39(3), 288.
- Pielou, E. C. (1966). The measurement of diversity in different types of biological collections. *Journal of theoretical biology*, 13, 131-144.
- Pillai, K. S., & Singh, J. (1980). composition of soil microarthropods in a grassland ecosystem of Upper Gangetic Plain. In *Proceedings of the All India Symposium on Environmental Biology, December 27-29, 1977/sponsored by the University Grants Commission and the University of Kerala;*[editorial committee, KM Alexander... et al.]. Kariavattom, India: Dept. of Zoology, University of Kerala, 1980..
- Polis, G. A., & Strong, D. R. (1996). Food web complexity and community dynamics. *The American Naturalist*, 147(5), 813–846.

Pollierer, M. M., & Scheu, S. (2017). Driving factors and temporal fluctuation of Collembola communities and reproductive mode across forest types and regions. *Ecology and Evolution*, 7(12), 4390-4403.

Pollierer, M. M., Langel, R., Körner, C., Maraun, M., & Scheu, S. (2007). The underestimated importance of belowground carbon input for forest soil animal food webs. *Ecology Letters*, 10(8), 729-736.

Ponce, C., Bravo, C., de León, D. G., Magana, M., & Alonso, J. C. (2011). Effects of organic farming on plant and arthropod communities: A case study in Mediterranean dryland cereal. *Agriculture, Ecosystems and Environment*, 141(1-2), 193-201.

Poole, T. B. (1959, January). Studies on the food of Collembola in a Douglas fir plantation. In *Proceedings of the zoological Society of London* (Vol. 132, No. 1, pp. 71-82). Oxford, UK: Blackwell Publishing Ltd.

Poole, T. B. (2009). Studies on the food of collembola in a douglas fir plantation. *Proceedings of the Zoological Society of London*, 132(1), 71–82.

Potapov, A. M., Beaulieu, F., Birkhofer, K., Bluhm, S. L., Degtyarev, M. I., Devetter, M., ... & Scheu, S. (2022). Feeding habits and multifunctional classification of soil-associated consumers from protists to vertebrates. *Biological Reviews*, 97(3), 1057-1117.

Preston, S., Wirth, S., Ritz, K., Griffiths, B. S., & Young, I. M. (2001). The role played by microorganisms in the biogenesis of soil cracks: importance of substrate quantity and quality. *Soil biology and Biochemistry*, 33(12-13), 1851-1858.

Prestwich, G. D., Bentley, B. L., & Carpenter, E. J. (1980). Nitrogen sources for neotropical nasute termites: Fixation and selective foraging. *Oecologia*, 46(3), 397–401.

- Price, D. W., & Benham Jr, G. S. (1977). Vertical distribution of soil-inhabiting microarthropods in an agricultural habitat in California. *Environmental Entomology*, 6(4), 575-580.
- Prosi, F., & Dallinger, R. (1988). Heavy metals in the terrestrial isopod *Porcellio scaber* Latreille. I. Histochemical and ultrastructural characterization of metal-containing lysosomes. *Cell Biology and Toxicology*, 4(1), 81–96.
- Qin, S., Hu, C., He, X., Dong, W., Cui, J., & Wang, Y. (2010). Soil organic carbon, nutrients and relevant enzyme activities in particle-size fractions under conservational versus traditional agricultural management. *Applied Soil Ecology*, 45(3), 152-159.
- Raw, F. (1956). The abundance and distribution of Protura in grassland. *The Journal of Animal Ecology*, 15-21.
- Rebecchi, L., Sabatini, M. A., Cappi, C., Grazioso, P., Vicari, A., Dinelli, G., & Bertolani, R. (2000). Effects of a sulfonylurea herbicide on soil microarthropods. *Biology and Fertility of Soils*, 30, 312-317.
- Reddy, M. V., & Alfred, J. R. B. (1977). Seasonal fluctuations of soil arthropod populations in a pine forest ecosystem of North-Eastern India. In *All India Symp. on Environ. Biol., Trivandrum* (p. 21).
- Reddy, M. V., & Alfred, J. R. B. (1978). Some observations on the earthworm population and the biomass in a sub-tropical pine forest soil. *Soil Biology and Ecology in India, UAS Technical Series, Bangalore*, 78-82.
- Reganold, J. P., Elliott, L. F., & Unger, Y. L. (1987). Long-term effects of organic and conventional farming on soil erosion. *Nature*, 330(6146), 370-372.
- Reichle, D. E. (1977). The role of soil invertebrates in nutrient cycling. *Ecological Bulletins*, 145-156.
- Richards, P. J. (2009). Aphaenogaster ants as bioturbators: Impacts on soil and slope processes. *Earth-Science Reviews*, 96(1), 92–106.

Rickerl, D. H., Curl, E. A., & Touchton, J. T. (1989). Tillage and rotation effects on Collembola populations and Rhizoctonia infestation. *Soil and Tillage Research*, 15(1-2), 41-49.

Ricketts, T. G. (1986). Objectivity and objecthood: Frege's metaphysics of judgment. In *Frege synthesized: Essays on the philosophical and foundational work of Gottlob Frege* (pp. 65-95). Dordrecht: Springer Netherlands.

Robertson, B. A., Porter, C., Landis, D. A., & Schemske, D. W. (2012). Agroenergy crops influence the diversity, biomass, and guild structure of terrestrial arthropod communities. *BioEnergy Research*, 5, 179-188.

Robinson, J. B. D. (1958). Some chemical characteristics of "Termite soils" in Kenya Coffee fields. *Journal of Soil Science*, 9(1), 58-65.

Rogers, L. E. (1972). *The ecological effects of the western harvester ant (Pogonomyrmex occidentalis) in the shortgrass plains ecosystem*. University of Wyoming.

Rohitha, B. H. (1992). A simple sample separation system based on flotation for small samples of insects contaminated with soil. *New Zealand Entomologist*, 15(1), 81-83.

Rohrmann, G. F., & Rossman, A. Y. (1980). Nutrient strategies of *Macrotermes ukuzii* (Isoptera: Termitidae). *Pedobiologia*, 20(2), 61-73.

Romell, L. G. (1935). An example of myriapods as mull formers. *Ecology*, 16(1), 67-71.

Rosemary Gillman, L., K Jefferies, M., & Richards, G. (1972). Non-soil constituents of termite (*Coptotermes Acinaciformis*) mounds. *Australian Journal of Biological Sciences*, 25(5), 1005.

Rusek, J. (1975). Die bodenbildende Funktion von Collembolen und Acarina). *Pedobiologia*, 15(4-5), 299-308.

- Rusek, J. (1985). Soil microstructures - contributions on specific soil organisms. *Quaest. Entomol.*, 21(4), 497–514.
- Rusek, J. (1998). Biodiversity of Collembola and their functional role in the ecosystem. *Biodiversity and Conservation*, 7, 1207-1219.
- Rusek, J. (2002). Development and progress in Apterygota research in the territory of the former Czechoslovakia: Proceedings of the Xth international Colloquium on Apterygota, České Budějovice 2000: Apterygota at the Beginning of the Third Millennium. *Pedobiologia*, 46(3-4), 201-208.
- Ruzicka, V., & Bohac, J. (1994). The utilization of epigeic invertebrate communities as bioindicators of terrestrial environmental quality. *Biological Monitoring of the Environment: a manual of methods*. CAB International, 79-86.
- Sadaka-Laulan, N., Ponge, J. F., Roquebert, M. F., Bury, É., & Boumezzough, A. (1998). Feeding preferences of the collembolan *Onychiurus sinensis* for fungi colonizing holm oak litter (*Quercus rotundifolia* Lam.). *European Journal of Soil Biology*, 34(4), 179-188.
- Saha, A., Sekharan, S., & Manna, U. (2020). Superabsorbent hydrogel (SAH) as a soil amendment for drought management: A review. *Soil and Tillage Research*, 204, 104736.
- Sakine Serap Avgin, & Luff, M. L. (2010). Ground beetles (Coleoptera: Carabidae) as bioindicators of human impact. *Munis Entomology and Zoology*, 5(1), 209–215.
- Sall, S. N., Masse, D., Ndour, N. Y. B., & Chotte, J. L. (2006). Does cropping modify the decomposition function and the diversity of the soil microbial community of tropical fallow soil?. *Applied Soil Ecology*, 31(3), 211-219.
- Salmane, I. (2003). Investigations of Gamasina mites in natural and man-affected soils in Latvia (Acari: Mesostigmata). *13*, 129–137.

Salt, G., & Hollick, F. S. J. (1944). Studies of wireworm populations: I. A census of wireworms in pasture. *Annals of applied biology*, 31(1), 52-64.

Sanderan, R. (2021). TOSANGSEREKAN, A Theological Reflection on the Integrity of Creation in the Torajan Context.

Santhanam, R., & Velaycitham, P. Jegatheesam (1989). A manual of Fresh water Ecology.

Santiago, J., Dupeux, F., Round, A., Antoni, R., Park, S. Y., Jamin, M., ... & Márquez, J. A. (2009). The abscisic acid receptor PYR1 in complex with abscisic acid. *Nature*, 462(7273), 665-668.

Santos, P. F., DePree, E., & Whitford, W. G. (1978). Spatial distribution of litter and microarthropods in a Chihuahuan desert ecosystem. *Journal of Arid Environments*, 1(1), 41-48.

Sanyal, A. J., Freedman, A. M., Shiffman, M. L., Purdum III, P. P., Luketic, V. A., & Cheatham, A. K. (1994). Portosystemic encephalopathy after transjugular intrahepatic portosystemic shunt: results of a prospective controlled study. *Hepatology*, 20(1), 46-55.

Sanyal, A. K. (1982). Soil oribatid mites and their relation with soil factors in West Bengal. *Soil Biol, Ecol*, 2(1), 8-17.

Sanyal, A. K., & Bhaduri, A. K. (1986). Check list of oribatid mites (Acari) of India. *Rec. zool. Surv. India. Occ. Paper*, (83), 79.

Sanyal, A. K., & Sarkar, B. J. (1993). Ecology of soil oribatid mites in three contrasting sites at botanical garden, Howrah, West Bengal. *Environment and ecology. Kalyani*, 11(2), 427-434.

Sanyal, B. (1981). Organic compounds as corrosion inhibitors in different environments—a review. *Progress in Organic Coatings*, 9(2), 165-236.

Sarkar, S. (1990). Studies on microarthropod community in one undisturbed habitat of Tripura (India) with special reference to oribatid mites. *Revue d'Écologie et de Biologie du Sol*, 27(3), 307-329.

Sarkar, S., & Santos Subías, L. (1983). Some new Macropylines Oribates (Acarida) from India (Hypochthoniidae, Cosmoethonoidea and Epilohmanniidae).

Saxena, B., Rani, A., Sayyed, R. Z., & El-Enshasy, H. A. (2020). Analysis of nutrients, heavy metals and microbial content in organic and non-organic agriculture fields of Bareilly Region-Western Uttar Pradesh, India. *Biosciences Biotechnology Research Asia*, 17(2), 399-406.

Schaller, F. (1949). Die Collembolen in der Ökologie. *Naturwissenschaften*, 36(10), 296-299.

Schaller, F. (1950). *Biologische Beobachtungen an humusbildenden Bodentieren, insbesondere an Collembolen*.

Scheu, S., & Schulz, E. (1996). Secondary succession, soil formation and development of a diverse community of oribatids and saprophagous soil macro-invertebrates. *Biodiversity and Conservation*, 5, 235-250.

Scheunemann, L. P., Cunningham, T. V., Arnold, R. M., Buddadhumaruk, P., & White, D. B. (2015). How clinicians discuss critically ill patients' preferences and values with surrogates: an empirical analysis. *Critical care medicine*, 43(4), 757.

Schoenholtz, S. H., Van Miegroet, H., & Burger, J. A. (2000). A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. *Forest ecology and management*, 138(1-3), 335-356.

Schütz, K., Bonkowski, M., & Scheu, S. (2008). Effects of Collembola and fertilizers on plant performance (*Triticum aestivum*) and aphid reproduction (*Rhopalosiphum padi*). *Basic and Applied Ecology*, 9(2), 182-188.

- Schuurman, G. W. (2012). Ecosystem influences of fungus-growing termites in the dry paleotropics. *Soil ecology and ecosystem services*, 173-188.
- Seastedt, T. R. (1984). The role of microarthropods in decomposition and mineralization processes. *Annual review of entomology*, 29(1), 25-46.
- Seastedt, T. R., & Tate, C. M. (1981). Decomposition rates and nutrient contents of arthropod remains in forest litter. *Ecology*, 62(1), 13–19.
- Seniczak, A., Seniczak, S., Szczukowska, H., Graczyk, R., & Bukowski, G. (2016). Preliminary study of the impact of pig or goat manure fertilization of a meadow on oribatid mites. *Biological Letters*, 53(2), 55-66.
- Shaddy, J. H., & JW, B. (1977). The distribution of some soil arthropods in a manipulated ecosystem.
- Shakir, M. M., & Ahmed, S. (2015). Seasonal abundance of soil arthropods in relation to meteorological and edaphic factors in the agroecosystems of Faisalabad, Punjab, Pakistan. *International Journal of biometeorology*, 59, 605-616.
- Shannon, D., Sen, A. M., & Johnson, D. B. (2006). A comparative study of the microbiology of soils managed under organic and conventional regimes. *Soil Use and Management*, 18, 274-283.
- Sharma, S. K. (2006). *Haryana: Past and Present*. Mittal Publications
- Sharma, S. K., Ramesh, A., Sharma, M. P., Joshi, O. P., Govaerts, B., Steenwerth, K. L., & Karlen, D. L. (2011). Microbial community structure and diversity as indicators for evaluating soil quality. *Biodiversity, biofuels, agroforestry and conservation agriculture*, 317-358.
- Sheikh, A. A., Rehman, N., Bhat, T. A., Sofi, M. A., Bhat, M. A., Un Nabi, S., ... & Sofi, A. (2017). Vertical distribution of soil arthropods in apple ecosystem of Kashmir. *J. Entomol. Zool. Stud. JEZS*, 843, 843-846.

- Shelley, A., & Aditi, D. (2017). Diversity and distribution of oribatid mite fauna (Acari: Oribatida) in the forest floor of Satkosia Basipally Wild Life Sanctuary, Odisha, India. *Flora and Fauna (Jhansi)*, 23(1), 137-151.
- Sidde Gowda, D. K., & Rajagopal, D. (1990). Association of Termitomyces spp. with fungus growing termites. *Proceedings: Animal Sciences*, 99, 311-315.
- Sierwald, P., & Bond, J. E. (2007). Current status of the myriapod class Diplopoda (millipedes): taxonomic diversity and phylogeny. *Annu. Rev. Entomol.*, 52, 401-420.
- Sigler, W. V., & Turco, R. F. (2002). The impact of chlorothalonil application on soil bacterial and fungal populations as assessed by denaturing gradient gel electrophoresis. *Applied Soil Ecology*, 21(2), 107-118.
- Sihmar, R. (2014). Growth and instability in agricultural production in Haryana: A district level analysis. *International Journal of Scientific and Research Publications*, 4(7), 1-12.
- Silva, I. D., & Mendonça, E. D. S. (1997). Matéria orgânica do solo. *NOVAIS, RF; ALVAREZ V., VH; BARROS, NF; FONTES, RLF.*
- Simpson, E. H. (1949). Measurement of diversity. *nature*, 163(4148), 688-688.
- Singh, A., Srivastava, A., Saidulu, D., & Gupta, A. K. (2022). Advancements of sequencing batch reactor for industrial wastewater treatment: Major focus on modifications, critical operational parameters, and future perspectives. *Journal of Environmental Management*, 317, 115305.
- Singh, J. (1976). An agricultural geography of Haryana. *An agricultural geography of Haryana.*
- Singh, J., & KS, P. (1975). A study of soil micro-arthropod communities in some fields.

Singh, J., Raghvraman, M., Yadav, R. S., & Prasad, S. (2008). First report of diplurans (Insecta: Diplura) from Uttar Pradesh, India. *Indian Journal of Entomology*, 70(4), 337-340.

Singh, M. V., & Behra, S. K. (2011). *All India Coordinated Research Project of Micro-and Secondary-Nutrients and Pollutant Elements in Soil and Plant*. Indian Institute of Soil Science.

Singh, R., Glick, B. R., & Rathore, D. (2020). Role of textile effluent fertilization with biosurfactant to sustain soil quality and nutrient availability. *Journal of Environmental Management*, 268, 110664.

Singh, U. R. (1975). Effects of human impacts on the population density of soil mesofauna in tropical ecosystems around Varanasi, India. *Geobios*.

Sinha, P. B., Sen, N. S., & Jafri, H. A. (1988). On the seasonal population fluctuations of Collembola and Acarina in a deciduous forest at Ranchi. *Journal of Environmental Biology*, 9.

Sinha, S. K., Sirota, E. B., Garoff, A. S., & Stanley, H. B. (1988). X-ray and neutron scattering from rough surfaces. *Physical Review B*, 38(4), 2297.

Six, J., Bossuyt, H., Degryze, S., & Denef, K. (2004). A history of research on the link between (micro) aggregates, soil biota, and soil organic matter dynamics. *Soil and tillage research*, 79(1), 7-31.

Skubała, P., & Kafel, A. (2004). Oribatid mite communities and metal bioaccumulation in oribatid species (Acari, Oribatida) along the heavy metal gradient in forest ecosystems. *Environmental Pollution*, 132(1), 51-60.

Smith, J. L., & Doran, J. W. (1997). Measurement and use of pH and electrical conductivity for soil quality analysis. *Methods for assessing soil quality*, 49, 169-185.

Smith, V. A. (1999). *The early history of India*. Atlantic Publishers and Dist.

Soil Health portal of Ministry of Agriculture, Cooperation and Farmers Welfare (www.soilhealth.dac.gov)

Sojka, R. E., & Upchurch, D. R. (1999). Reservations regarding the soil quality concept. *Soil Science Society of America Journal*, 63, 1039-1054.

Sousa, D. D., Miranda, L. D., & Oliveira, S. D. (2007). Acidez do solo e sua correção. *Fertilidade do solo. Viçosa, MG: Sociedade Brasileira de Ciência do Solo*, 1, 205-275.

Southwood, T. R. E., & Henderson, P. A. (2009). *Ecological methods*. John Wiley and Sons.

Søvik, G., & Leinaas, H. P. (2002). Variation in extraction efficiency between juvenile and adult oribatid mites: *Ameronothrus lineatus* (Oribatida, Acari) in a Macfadyen high-gradient canister extractor. *Pedobiologia*, 46(1), 34-41.

Speight, M. R., & Lawton, J. H. (1976). The influence of weed-cover on the mortality imposed on artificial prey by predatory ground beetles in cereal fields. *Oecologia*, 23, 211-223.

Sriram, N., Reetha, D., & Saranraj, P. (2013). Biological degradation of reactive dyes by using bacteria isolated from dye effluent contaminated soil. *Middle East J Sci Res*, 17(12), 1695-1700.

Stach, J. (1947). The Apterygotan fauna of Poland in relation to the world-fauna of this group of insects. *Family: Isotomidae*.

Stål, C. (1875). Observations Orthoptérologiques. I. Sur une systématisation nouvelle des Phasmides. *Bihang till Kongliga Svenska Vetenskaps-akademiens Handlingar*, 3(14), 1-43.

Stål, C. (1878). Observationes orthoptérologiques 3. De genere Pezotettigis et nonnullis generibus affinibus. *Bihang till Kungliga Svenska Vetenskaps-Akademiens Handlingar*, 5, 1-20.

- Stål, C. A. R. L. (1866). Hemiptera Homoptera Latr. *Hemiptera africana*, 4(1), 276.
- Stebaeva, S. K. (1989). Role of Collembola in Organic Matter Decomposition in Technogenic Siberian Landscapes. In *3rd International Seminar on Apterygota* (pp. 299-306). University of Siena: Siena, Italy.
- Steinberger, Y., Freckman, D. W., Parker, L. W., & Whitford, W. G. (1984). Effects of simulated rainfall and litter quantities on desert soil biota: nematodes and microarthropods. *Pedobiologia (Jena)*, 26(4), 267-274.
- Steiner, R. A., McLaughlin, L., Faeth, P., & Janke, R. R. (1995). Incorporating externality costs into productivity measures: a case study using US agriculture. *Agricultural sustainability: economic, environmental and statistical considerations.*, 209-230.
- Stork, N. E. (2018). How many species of insects and other terrestrial arthropods are there on Earth?. *Annual review of entomology*, 63, 31-45.
- Stork, N. E., & Eggleton, P. (1992). Invertebrates as determinants and indicators of soil quality. *American Journal of Alternative Agriculture*, 7(1-2), 38-47.
- Strickland, A. H. (1947). The soil fauna of two contrasted plots of land in Trinidad, British West Indies. *The Journal of Animal Ecology*, 1-10.
- Striganova, B. R. (1971). Changes with age in the feeding activity of millipedes (Juloidea). *Zoologicheskii Zhurnal*, 50(10), 1472-1476.
- Strueder-Kypke, M. C., & Lynn, D. H. (2010). Comparative analysis of the mitochondrial cytochrome c oxidase subunit I (COI) gene in ciliates (Alveolata, Ciliophora) and evaluation of its suitability as a biodiversity marker. *Systematics and Biodiversity*, 8(1), 131-148.
- Sulkava, P., & Huhta, V. (2003). Effects of hard frost and freeze-thaw cycles on decomposer communities and N mineralisation in boreal forest soil. *Applied Soil Ecology*, 22(3), 225-239.

Sun, Y., Lei, C., Khan, E., Chen, S. S., Tsang, D. C., Ok, Y. S., ... & Li, X. D. (2017). Nanoscale zero-valent iron for metal/metalloid removal from model hydraulic fracturing wastewater. *Chemosphere*, *176*, 315-323.

Surya, P., & Saha Roy, T. K. (2015). Directory of Institutions and Resource Persons for Landslide Management in India, published by National Institute of Disaster Management. *Ministry of Home Affairs, Government of India, New Delhi-110*, *2*, 103.

Swift, M. J., Heal, O. W., Anderson, J. M., & Anderson, J. M. (1979). *Decomposition in terrestrial ecosystems* (Vol. 5). Univ of California Press.

Swift, M. J., Izac, A.-M. .N., & van Noordwijk, M. (2004). Biodiversity and ecosystem services in agricultural landscapes—are we asking the right questions? *Agriculture, Ecosystems and Environment*, *104*(1), 113–134.

Szabó, I. M., Jáger, K., Contreras, E., Márialigeti, K., Dzingov, A., & Barabas, G. Y. (1983). Composition and properties of the external and internal microflora of millipedes (Diplopoda). In *International colloquium of soil zoology*. *8* (pp. 197-206).

Szeptycki, A. (2007). Catalog of the world Protura. *Acta Zoologica Cracoviensia-Series B: Invertebrata*, *50*(1), 1-210.

Tabaglio, V., Gavazzi, C., & Menta, C. (2009). Physicochemical indicators and microarthropod communities as influenced by no-till, conventional tillage and nitrogen fertilisation after four years of continuous maize. *Soil and Tillage Research*, *105*(1), 135-142.

Takeda, H. (1984). A long term study of life cycle and population dynamics of *Folsomia octoculata* Handschin (Insecta: Collembola) in a pine forest soil. *Researches on Population Ecology*, *26*(1), 188–219.

Tamm, J. C. (1984). Surviving long submergence in the egg stage—a successful strategy of terrestrial arthropods living on flood plains (Collembola, Acari, Diptera). *Oecologia*, *61*(3), 417-419.

- Tamm, J. C. (1986). Temperature-controlled under-water egg dormancy and postflood hatching in *Isotoma viridis* (Collembola) as forms of adaptation to annual long-term flooding. *Oecologia*, 68, 241-245.
- Tejada, M., Garcia, C., Gonzalez, J. L., & Hernandez, M. T. (2006). Organic amendment based on fresh and composted beet vinasse: influence on soil properties and wheat yield. *Soil Science Society of America Journal*, 70(3), 900-908.
- Teuben, A., & Verhoef, H. A. (1992). Direct contribution by soil arthropods to nutrient availability through body and faecal nutrient content. *Biology and Fertility of Soils*, 14(2), 71–75.
- Thaler, R. H. (2008). Mental accounting and consumer choice. *Marketing Science*, 27(1), 15-25.
- Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, 418(6898), 671-677.
- Tilman, D., Fargione, J., Wolff, B., D'antonio, C., Dobson, A., Howarth, R., ... & Swackhamer, D. (2001). Forecasting agriculturally driven global environmental change. *science*, 292(5515), 281-284.
- Tobriya, S. K. (2014). Biological applications of Schiff Base and its metal complexes- A Review. *Int J Sci Res*, 3(9), 1254-1256.
- Tomlin, A. D., & Miller, J. J. (1987). Composition of the soil fauna in forested and grassy plots at Delhi, Ontario. *Canadian Journal of Zoology*, 65(12), 3048–3055.
- Trehan, K. N. (1945, April). Some observations on the soil fauna of cotton fields at Lyallpur. In *Proceedings/Indian Academy of Sciences* (Vol. 21, No. 4, pp. 191-201). New Delhi: Springer India.
- Tripathi, G., Kumari, R., & Sharma, B. M. (2007). Mesofaunal biodiversity and its importance in Thar desert. *Journal of Environmental Biology*, 28(2), 503.

Tripathy, M. B. (2021). Deterioration of Soil Health and its Management. *AGRICULTURE & FOOD: e-NEWSLETTER*, 9.

Trivedi, S., Aloufi, A. A., Ansari, A. A., & Ghosh, S. K. (2016). Role of DNA barcoding in marine biodiversity assessment and conservation: an update. *Saudi Journal of biological sciences*, 23(2), 161-171.

Tullberg, T. (1872). Forteckning ofver svenska Podurider. *Ofversigt of Kongliga Vetenskaps Akademiens-Forhandlingar, 1871*, 28, 143-155.

Tyokumbur, E. T. (2016). Evaluation of effects of heavy metals on abundance and diversity of soil mites in a tropical landfill. *International Journal of Pure and Applied Zoology*, 4(2), 155-160.

Urhan, R., Katılmış, Y., & Kahveci, A. Ö. (2008). Vertical distribution of soil mites (Acari) in Dalaman (Muğla prov.-Turkey). *Munis Entomology and Zoology*, 3(1), 333-341.

Usher, M. B. (1976). Aggregation responses of soil arthropods in relation to the soil environment. In *Symposium of the British Ecological Society*.

Usher, M. J., Burch, R. F., & Guralp, C. (1979). Wide-band feedback seismometers. *Physics of the Earth and Planetary Interiors*, 18(2), 38-50.

Usher, R. S. (1985). Beyond the anecdotal: Adult learning and the use of experience. *Studies in the Education of Adults*, 17(1), 59-74.

Uvarov, A. V. (2003). Effects of diurnal temperature fluctuations on population responses of forest floor mites. *Pedobiologia*, 47(4), 331-339.

Valdecasas, A. G., & Camacho, A. I. (2003). Conservation to the rescue of taxonomy. *Biodiversity and Conservation*, 12, 1113-1117.

Van Bruggen, A. H. C., & Grunwald, N. J. (1996). Tests for risk assessment of root infection by plant pathogens. *Methods for assessing soil quality.*, 293-310.

Van der Drift, J. (1963). The effects of animal activity in the litter layer. *Experimental pedology*, 227-235.

Van der Drift, J. (1975). The significance of the millipede *Glomeris marginata* (Villers) for oak-litter decomposition and an approach of its part in energy flow. In *Progress in Soil Zoology: Proceedings of the 5th International Colloquium on Soil Zoology Held in Prague September 17–22, 1973* (pp. 293-298). Dordrecht: Springer Netherlands.

van Straalen, N. M. (1998). Evaluation of bioindicator systems derived from soil arthropod communities. *Applied soil ecology*, 9(1-3), 429-437.

van. (1951). Analysis of the animal community in a beech forest floor. *Tijdschrift Voor Entomologie*, 94, 1–168.

Vannier, G. (1987). The porosphere as an ecological medium emphasized in Professor Ghilarov's work on soil animal adaptations. *Biology and Fertility of Soils*, 3(1-2), 39-44.

vanVliet, P. C., & Hendrix, P. F. (2007). Role of fauna in soil physical processes. In *Soil biological fertility: a key to sustainable land use in agriculture* (pp. 61-80). Dordrecht: Springer Netherlands.

Varm, A., Kolli, B. K., Paul, J., Saxena, S., & KÄ¶nig, H. (1994). Lignocellulose degradation by microorganisms from termite hills and termite guts: A survey on the present state of art. *FEMS Microbiology Reviews*, 15(1), 9–28.

Vats, L. K., & Handa, S. (1988). Soil litter arthropods in a deciduous forest stand at Kurukshetra. *Indian Journal of forestry*.

Verma, K. S., Pandey, R., & Ay, A. (2014). Nutritional assessment of different parts of *Acacia catechu* Willd. collected from central India. *International Journal of Pharmaceutical Sciences and Research (IJPSR)*, 5(7), 2980-2986.

- Verma, R. R., Singh, K. P., & Srivastva, T. K. (2014). Nutrient status in sugarcane growing soils of Haryana. *Current Advances in Agricultural Sciences (An International Journal)*, 6(1), 20-23.
- Vikram Reddy, M., & Venkataiah, B. (1990). Seasonal abundance of soil-surface arthropods in relation to some meteorological and edaphic variables of the grassland and tree-planted areas in a tropical semi-arid savanna. *International Journal of Biometeorology*, 34, 49-59.
- Vitousek, P. M., Naylor, R., Crews, T., David, M. B., Drinkwater, L. E., Holland, E., ... & Zhang, F. S. (2009). Nutrient imbalances in agricultural development. *Science*, 324(5934), 1519-1520.
- Vlug, H., & Borden, J. H. (1973). Soil Acari and Collembola populations affected by logging and slash burning in a coastal British Columbia coniferous forest. *Environmental Entomology*, 2(6), 1016-1023.
- Vreeken-Buijs, M. J., Hassink, J., & Brussaard, L. (1998). Relationships of soil microarthropod biomass with organic matter and pore size distribution in soils under different land use. *Soil Biology and Biochemistry*, 30(1), 97-106.
- Wagner, D. L. (2020). Insect declines in the Anthropocene. *Annual review of entomology*, 65, 457-480.
- Walakley, A., & Black, C. A. (1934). Estimation of organic carbon by chromic acid titration method. *Soil Science*, 37, 29-38.
- Wali, M. K., & Kanno, P. B. (1975). Prairie ant mound ecology: interrelationships of microclimate, soils and vegetation. *Prairie: A Multiple View*, 155-169.
- Walker, F. (1870). *Catalogue of the Specimens of Dermaptera Saltatoria in the Collection of the British Museum: III* (Vol. 3). Trustees of the British Museum.

- Walker, F. (1871). Catalogue of the specimens of Dermaptera Saltatoria in the collection of the British Museum, Supplement, Part V. *Catalogue of the specimens of Dermaptera Saltatoria in the collection of the British Museum, Supplement, Part V*, 49-89.
- Wallwork, J. A. (1959). The distribution and dynamics of some forest soil mites. *Ecology*, 40(4), 557-563.
- Wallwork, J. A. (1967). Acari. In "Soil Biology"(BURGES, A. and F. RAW, eds).
- Wallwork, J. A. (1970). Ecology of soil animals. *Ecology of soil animals*.
- Wallwork, J. A. (1970). Ecology of soil animals. *Ecology of soil animals*.
- Wallwork, J. A. (1982). *Desert soil fauna*. Praeger Publishers.
- Wallwork, J. A., Burges, A., & Raw, F. (1967). Acari. Soil Biology. *Academic Press, London and New York*, 363-395.
- Wallwork, J. A. (1982). Desert Soil Fauna. United States: Praeger.
- Walter, D. E., Kethley, J., & Moore, J. C. (1987). A heptane flotation method for recovering microarthropods from semiarid soils, with comparison to the Merchant-Crossley high-gradient extraction method and estimates of microarthropod biomass. *Pedobiologia*, 30(4), 221-232.
- Wardle, D. A. (1995). Impacts of disturbance on detritus food webs in agroecosystems of contrasting tillage and weed management practices. In *Advances in ecological research* (Vol. 26, pp. 105-185). Academic Press.
- Watanabe, H. (1968). On the vertical distribution of soil macro animals in three different forests. *Journal of the Japanese Forestry Society*, 50(7), 204-210.

Weetman, G. F., & Webber, B. (1972). The influence of wood harvesting on the nutrient status of two spruce stands. *Canadian Journal of Forest Research*, 2(3), 351–369.

Weigel, D. J., Martin, S. S., & Bennett, K. K. (2005). Ecological influences of the home and the child-care center on preschool-age children's literacy development. *Reading Research Quarterly*, 40(2), 204-233.

Weis-Fogh, I. (1948). Ecological investigations on mites and collemboles in the soil Nat, *Jutland*, 1, 137-270.

Whitford, W. G. (1989). Abiotic controls on the functional structure of soil food webs. *Biology and Fertility of Soils*, 8, 1-6.

Whitford, W. G. (1991). Subterranean termites and long-term productivity of desert rangelands. *Sociobiology*, 19(1), 235-244.

Whitford, W. G. (1992). Effects of climate change on soil biotic communities and soil processes. *Global warming and biological diversity*, 124-136.

Wichard, W. (1987). *Atlas on the Biology of Soil Arthropods*. Springer.

Wijaya, W., Suhaimi, Z., Chua, C. X. E., Sunil, R. S., Kolundžija, S., Bin Rohaizat, A. M., ... & Lauro, F. M. (2023). Frequent pulse disturbances shape resistance and resilience in tropical marine microbial communities. *ISME communications*, 3(1), 55.

Wilcocks, C. R., & Oliver, E. H. A. (1971). A rapid mechanical method for extracting soil arthropods. *New Zealand Journal of agricultural research*, 14(3), 725-734.

Williams, C. B. (1964). Patterns in the balance of nature and related problems of quantitative ecology. *Patterns in the balance of nature and related problems of quantitative ecology*.

Wilson, H. H. (1868). *The Vishnu Purana* (Vol. 9). Trübner.

- Winck, B. R., Chauvat, M., Coulibaly, S. F., Santonja, M., Saccol de Sá, E. L., & Forey, E. (2020). Functional collembolan assemblages induce different plant responses in *Lolium perenne*. *Plant and Soil*, 452, 347-358.
- Witkamp, M. (1971). Soils as components of ecosystems. *Annual Review of Ecology and Systematics*, 2(1), 85–110.
- Wolda, H. (1988). Insect seasonality: why?. *Annual review of ecology and systematics*, 19(1), 1-18.
- Wood, T. G. (1976). The role of termites (Isoptera) in decomposition processes. *The role of terrestrial and aquatic organisms in decomposition processes*.
- Writing Group Members, Rosamond, W., Flegal, K., Furie, K., Go, A., Greenlund, K., ... & Hong, Y. (2008). Heart disease and stroke statistics—2008 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation*, 117(4), e25-e146.
- Yadav, R. S. (2017). First records of Collembola and their diversity measurement from BAU, Ranchi, Jharkhand. *Journal of Entomology and Zoology Studies*, 5(5), 1724-1727.
- Yadav, R. S. (2017). Preliminary checklist of springtails (Arthropoda: Collembola) of Uttar Pradesh, India. *Journal of Threatened Taxa*, 9(12), 11054-11059.
- Yadav, R. S. (2018). A new world beneath the earth: Sign of good health. In *National Seminar on Transforming Agriculture to Doubling of Farmers Income at Babasaheb Bhimrao Ambedkar University, Lucknow on* (pp. 205-206).
- Yadav, R. S. (2018). First preliminary report of diplurans (Diplura: Insecta) from Jharkhand, India. *J Entomol Zool Stud*, 6(2), 2359-2362.
- Yadav, R. S., Kerketta, D., & Kumar, D. Biodiversity of Soil Arthropods: Symbol of Soil Health.

- Yadav, R. S., Kerketta, D., Kumar, D., & Prasad, S. (2018). Vertical Distribution of Collembola (Arthropoda: Collembola) at Varanasi, India. *International Journal of Current Microbiology and Applied Sciences*, 7(3), 609-613.
- Yadav, R. S., Prasad, S., & Kumar, D. (2017). Diversity of epigeic Collembola of Bibhutibhusan Wildlife Sanctuary, North 24 Parganas, West Bengal (India). *International Journal of Fauna and Biological Studies*. 5(2), 17–21.
- Yair, A., & Rutin, J. (1981). Some aspects of the regional variation in the amount of available sediment produced by isopods and porcupines, northern Negev, Israel. *Earth Surface Processes and Landforms*, 6(3-4), 221-234.
- Yang, X., & Tang, J. (2004). Soil arthropod communities in different successional tropical secondary forests in Xishuangbanna. *Ying Yong Sheng tai xue bao= The Journal of Applied Ecology*, 15(6), 988-994.
- Zaady, E., Groffman, P. M., Shachak, M., & Wilby, A. (2003). Consumption and release of nitrogen by the harvester termite *Anacanthotermes ubachi navas* in the northern Negev desert, Israel. *Soil Biology and Biochemistry*, 35(10), 1299–1303.
- Zhang, J., Yang, J., An, P., Ren, W., Pan, Z., Dong, Z., ... & Tian, H. (2017). Enhancing soil drought induced by climate change and agricultural practices: Observational and experimental evidence from the semiarid area of northern China. *Agricultural and Forest Meteorology*, 243, 74-83.
- Zhang, P., Li, L., Pan, G., & Ren, J. (2006). Soil quality changes in land degradation as indicated by soil chemical, biochemical and microbiological properties in a karst area of southwest Guizhou, China. *Environmental Geology*, 51, 609-619.
- Zheng, C., Ouyang, F., Liu, X., Ma, J., Zhao, F., Ouyang, Z., & Ge, F. (2019). Effect of coupled reduced irrigation and nitrogen fertilizer on soil mite community composition in a wheat field. *Ecology and Evolution*, 9(19), 11367-11378.

Zhimomi, V. A., Ao, M. A., & Chaturvedi, D. P. (2009). Seasonal abundance of major groups of and their correlation with abiotic factors in rice ecosystem. *International Journal of Agriculture Environment and Biotechnology*, 2(3), 289-293.

Zhu, X., & Zhu, B. (2015). Diversity and abundance of soil fauna as influenced by long-term fertilization in cropland of purple soil, China. *Soil and Tillage Research*, 146, 39-46.

Zinkler, D., & Platthaus, J. Ö. R. G. (1996). Tolerance of soil-dwelling Collembola to high carbon dioxide concentrations. *European Journal of Entomology*, 93, 443-450.

Zodinpuui, B., & Lalthanzara, H. (2019). Diversity of soil macroarthropods in shifting cultivation and forest ecosystem of Mizoram, Northeast India. *Journal of Applied and Natural Science*, 11(3), 601-611.

LIST OF PUBLICATIONS

1. Research paper “The relationship between soil arthropod abundance and edaphic factors in Haryana agricultural ecosystem” in Scopus indexed Journal “Journal of Entomological Research”, June 2023, 47(2) with impact factor 0.14.

LIST OF CONFERENCES

1. Oral presentation in International Conference at LPU dated 17 - 18/ 12/ 2021
“Relative abundance of soil arthropods in different farming lands of Haryana in relation to a blend of meteorological and edaphic factors”
2. Oral presentation in National Conference at Arya (P.G.) College, Panipat dated 19/ 2/ 2022 “ Relative abundance of soil arthropods in relation with edaphic factors at sugarcane fields in Karnal and Yamunanagar districts of Haryana in India.”
3. Poster presentation in International Conference at DCRUST, Murthal, Sonipat dated 17 - 18/ 1/ 2023 “A preliminary study of soil arthropods in relation with edaphic factors in a forest division, Assan Kalan Village near thermal, Panipat, Haryana, India.”
4. Poster presentation in National Conference at Arya (P.G.) College, Panipat dated 28/ 2/ 2023 “Impact of 15-year-old forest division’s edaphic factors upon soil dwelling insects.”

LIST OF WORKSHOPS

1. Short Term Course on Research and Review Paper Writing and Publication at LPU dated 6/2/2023 - 10/2/2023

The relationship between soil arthropod abundance and edaphic factors in Haryana agricultural ecosystem

Kavita Taneja* and Joydeep Dutta*

Department of Zoology, School of Bioengineering and Biosciences, Lovely Professional University,
Phagwara - 144 402, Punjab, India

ABSTRACT

Soil arthropods of different districts of Haryana were sampled monthly using the Berlese Tullgren method. Present findings indicated that soil arthropod abundance varied between months of sampling and between plants. Out of 500 soil arthropod samples collected, the presence of 40% collembolan, 30% acarina, 15% dipterans larvae, 10% araneae, and 5% thysanura was revealed. Soil organic matter and soil temperature both confirmed a significant-high-quality correlation with abundance, while soil moisture had a weak high-quality correlation. The pH of the soil had a negative correlation with total number of arthropods.

Key words : Acarina, collembolan, dipterans, Haryana, soil fauna.

INTRODUCTION

Soil arthropods have been found reacting react to a variety of edaphic and meteorological factors that have been well documented in natural ecosystems, but little research has been conducted in more fluctuating agroecosystems; wheat fields (Gill, 2013); sugarcane (Sajjad *et al.*, 2012) and rice (Zhang *et al.*, 2013). Collembolan (Gbarakoro *et al.*, 2010), acarina (Kaczmarek *et al.*, 2010), and araneae (Mukhtar *et al.*, 2012), have all shown seasonal variation in relative abundance. Thus, soil arthropod data can be used to precisely illustrate almost any characteristic of an ecosystem. In addition, the former is an important source of soil productivity in the agro-ecosystem, and without the presence of these soil-dwelling organisms, the soil would be a non-productive medium (Fox, 2003). No significant research has been conducted closer to arable soils in terms of soil microarthropod productivity and population dynamics from this location. Thus, present study focuses on soil arthropods of farming land of Haryana.

MATERIALS AND METHODS

Haryana's agricultural zones I (Karnal, Yamuna Nagar) and II (Sirsa, Rohtak) have been purposefully

chosen (Table 1) for farming land because they have better irrigation facilities, drastic agriculture options, and a higher percentage area coverage and crop type coverage. The present study was conducted from November 2020 to October 2021.

Sampling of soil : In the current study, sampling (Table 2) was done by making a "V" shaped cut into a depression of 15 cm depth at the sampling site and moving away a 1 cm to 2 cm soil layer with a spade. The collected sample was then placed on paper, where all the subsamples were thoroughly mixed, collected by the quarter method, and packed in labelled packets (Campos, 2017). The total weight of soil collected was 1.25 kg. The soil samples were taken at a rate of 5 independent replicates (500 g) per plot from three different fields of the same cropland. Collected soil samples were immediately stored in labelled airtight plastic polythenes with sample information (e.g., date, district, code, cropland, landowner, etc.) at 4°C in

Table 1. Selected crops in given districts.

S. No.	Crops	Highest production districts
1.	Sugarcane	Yamunanagar (YN)
2.	Wheat	Sirsa (SI)
3.	Rice	Karnal (KR)
4.	Jowar	Rohtak (RO)

*Corresponding authors' E-mail : joydeep.dutta@lpu.co.in

**Department of Zoology, Lala Desh Bandhu Gupta Government College, Sector - 18, Panipat - 132 103, Haryana, India

Plag Kavita Revised 3

ORIGINALITY REPORT

10%

SIMILARITY INDEX

7%

INTERNET SOURCES

8%

PUBLICATIONS

%

STUDENT PAPERS

PRIMARY SOURCES

1	permanent.access.gpo.gov Internet Source	2 %
2	docplayer.com.br Internet Source	1 %
3	mdpi.com Internet Source	1 %
4	www.researchgate.net Internet Source	<1 %
5	www.phytojournal.com Internet Source	<1 %
6	Mara Fernanda, Grizelle Gonzlez, Elvira Cuevas. "Chapter 14 Quantifying Variation of Soil Arthropods Using Different Sampling Protocols: Is Diversity Affected?", IntechOpen, 2012 Publication	<1 %
7	Veronika Gergócs, Norbert Flórián, Zsolt Tóth, Tibor Szili-Kovács, Márton Mucsi, Miklós Dombos. "Crop species and year affect soil-dwelling Collembola and Acari more strongly	<1 %