Synecology of edaphic Arthropoda in Iowa agroecosystems

Milgar Camargos Loureiro

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Syneiology of edaphic Arthropoda in Iowa agroecosystems

by

Milgar Camargos Loureiro

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of DOCTOR OF PHILOSOPHY

Major: Entomology

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1976
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>ix</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>4</td>
</tr>
<tr>
<td>The Soil Environment</td>
<td>4</td>
</tr>
<tr>
<td>Hydrogen-ion concentration</td>
<td>5</td>
</tr>
<tr>
<td>Temperature</td>
<td>8</td>
</tr>
<tr>
<td>Moisture</td>
<td>12</td>
</tr>
<tr>
<td>Texture</td>
<td>14</td>
</tr>
<tr>
<td>Agricultural practices</td>
<td>15</td>
</tr>
<tr>
<td>Pesticides</td>
<td>17</td>
</tr>
<tr>
<td>Tilled-Soil Fauna</td>
<td>20</td>
</tr>
<tr>
<td>Iowa situation</td>
<td>20</td>
</tr>
<tr>
<td>Analytical Methods</td>
<td>23</td>
</tr>
<tr>
<td>Ordination</td>
<td>23</td>
</tr>
<tr>
<td>MATERIALS AND METHODS</td>
<td>25</td>
</tr>
<tr>
<td>Sampling Program</td>
<td>25</td>
</tr>
<tr>
<td>Sample site and field history</td>
<td>25</td>
</tr>
<tr>
<td>Collection of samples: 1972</td>
<td>28</td>
</tr>
<tr>
<td>Collection of samples: 1973-1974</td>
<td>29</td>
</tr>
<tr>
<td>Arthropoda Extraction Method</td>
<td>33</td>
</tr>
<tr>
<td>Identification and Storage</td>
<td>36</td>
</tr>
</tbody>
</table>
Ordination

RESULTS AND DISCUSSION

Arthropoda Extraction Method

Sampling Program 1972

Microarthropod fauna

The soil environment 1972

Hydrogen-ion concentration

Temperature

Moisture

Texture

Agricultural practices

Sampling Program 1973-1974

Microarthropod fauna

The soil environment 1973-1974

Hydrogen-ion concentration

Temperature

Moisture

Pore space

Texture

Agricultural practices

Pesticides

Ordination

Ordination of agroecosystems: 1972

Ordination of agroecosystems: 1973

Ordination of agroecosystems: 1974
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMARY AND CONCLUSION</td>
<td>112</td>
</tr>
<tr>
<td>LITERATURE CITED</td>
<td>120</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>130</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1. Total prominence values of edaphic Arthropoda in 5 soybean agroecosystems. Iowa, June to August 1972 42

Table 2. Population density in hundreds/m² (T), percentage (%), average (X), and standard error (SE) of edaphic Arthropoda in 5 soybean agroecosystems. Iowa, June to August 1972 51

Table 3. Measurements of abiotic soil components in 5 soybean agroecosystems. Iowa, June to August 1972 56

Table 4 Total prominence values of edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1973 61

Table 5. Total prominence values of edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1974 70

Table 6. Total number of families (F) and genera (G) of edaphic Arthropoda collected in Iowa agroecosystems 1972-1974 79

Table 7. Population density (hundreds/m²) of edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation
Table 8. Population density (hundreds/m²) of edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1973

Table 9. Percentage of the total PV of the most prominent edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1973

Table 10. Percentage of the total PV of the most prominent edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1974

Table 11. Measurements of abiotic soil components in 4 continuous corn agroecosystems. Ames, June to October 1973

Table 12. Measurements of abiotic soil components in 4 continuous soybean agroecosystems. Ames, June to October 1973

Table 13. Measurements of abiotic soil components in 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1973

Table 14. Measurements of abiotic soil components in 4
continuous corn agroecosystems. Ames, June to October 1974

Table 15. Measurements of abiotic soil components in 4 continuous soybean agroecosystems. Ames, June to October 1974

Table 16. Measurements of abiotic soil components in 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1974

Table 17. Duncan's Multiple Range Test of averages of soil moisture content for 4 continuous corn (1973) and 4 continuous soybean (1974) agroecosystems in Ames

Table 18. Duncan's Multiple Range Test of averages of total percentage of soil pore space for 4 continuous corn agroecosystems. Ames, 1974

Table 19. Ratio of decline between 1973 and 1974 Mesostigmata PV in 4 continuous corn, 4 continuous soybean, and oats-soybean-corn rotation agroecosystems in Ames
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Iowa cities nearest sampling sites</td>
<td>26</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Detachment of the corer from the soil sampler</td>
<td>31</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Soil sample in the corer being inverted intact on the sieve</td>
<td>31</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Introduction of the corer into the soil by standing on the ends of the rods</td>
<td>32</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Battery of modified Tullgren funnels</td>
<td>34</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Ordination of 5 soybean agroecosystems: 1972</td>
<td>102</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Ordination of 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems: 1973</td>
<td>104</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Ordination of 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems: 1974</td>
<td>108</td>
</tr>
</tbody>
</table>
DEDICATION

I would like to dedicate this thesis to my wife Maria Martha P. Loureiro, whose love, understanding, encouragement of my work greatly aided in the completion of this research.
INTRODUCTION

Given the widest interpretation, the group "edaphic Arthropoda" could include almost all terrestrial arthropods. In fact, 95% of all Insecta inhabit the soil at some time during their life cycle (Buckle, 1923), and insect species comprise approximately 80% of all animal species (Ross, 1965). Because these arthropods do not have equal degrees of association with the soil, it is difficult to determine what exactly constitutes a true edaphic arthropod. Thus, several criteria have been used in defining the various soil dwellers such as: body size, presence, habitat preference, and activity (Bachelier, 1968; Kevan, 1968; Kühnelt, 1961; and Wallwork, 1970).

Another criterion is based on the soil definition. The crust of the earth is derived primarily from minerals from the magma, which contain all the chemical elements obtained by the plants, except nitrogen. Soil nitrogen is stored in organic matter, the organic matter resulting from fragmentation of litter and cadavers. Thompson (1957) defines soils as "mixtures of mineral and organic matter that are capable of supporting plant life". Organic matter is considered herein as all material which is in the process of decomposition. Consequently, edaphic arthropods are those that spend the majority of their lives in the soil or in the associated litter (Kühnelt, 1961).

The scientific study of edaphic invertebrates is more than 130 years old, dating back to 1837 when Charles Darwin read his paper "On the formation of mould" to the Geological Society of London (Darwin, 1840). Because of the authoritativeness of Darwin's classic book "The Formation
of Vegetable Mould through the Action of Worms", it was accepted that the last word was said about the role of the earthworms in the soil formation. Thus, other edaphic invertebrates were relegated to a secondary position for decades, except termites, which Drummond (1887) considered "the tropical analogue of the earthworm".

Berlese (1905) revolutionized the extraction of edaphic arthropods with his extraction funnel and, since then, the systematics of geobionts increased slowly but without interruption. But, it was Jacot (1940) who was the first biologist to recognize the edaphic fauna as an entity. The emergence of soil zoology as a discipline started simultaneously, in 1950, with Kühnelt's classical book "Bodenbiologie mit besonderer Berucksichtigung der Tierwelt" and with the creation of the section of Soil Zoology at the 4th International Congress of the International Society of Soil Science, at Amsterdam.

The last two decades have witnessed the publication of several important books which synthesized much of what was known about the soil microcommunities. Books by authors such as Bachelier (1968), Burges and Raw (1967), Delamare-Deboutteville (1951), Doeksen and Drift (1963), Graff and Satchel (1967), Kevan (1955, 1968), Lawrence (1953), Murphy (1962), Pesson (1970), Phillipson (1970, 1971), Schaller (1968), and Wallwork (1970) have made significant contributions. In the early 1960's the emergence of periodicals such as Pedobiologia and Revue d'Ecologie et Biologie du Sol also testify to the expanding literature abroad. In temperate zones, most microcommunity studies have been conducted in forests or grasslands, but little is known of most other ecosystems.
In the U.S.A., studies of the interrelationship of microcommunities and their environments are only beginning. With the exception of a few scattered works of previous decades, the meetings of the Conference of Soil Microcommunities, held in Syracuse, New York, in 1971, 1972, and 1973 were the first significant events that brought together soil zoologists. The ultimate goal of the conference was to "develop a total appreciation for the ecology of microcommunities within soil horizon" (Dindal, 1973). Much of the type of pioneering work already done in Europe is still lacking, but the most urgent need is the development of usable keys for various taxa of edaphic arthropods.

With current emphasis on environmental quality, some pesticides face possible exclusion from agricultural use. It seems obvious that little progress can be made in developing new systems of soil-arthropod control until the identity, behavior, community structure, vertical and small horizontal distribution, and host range of important microarthropods have been ascertained.

This study will attempt to define the Arthropoda communities associated with typical Iowa agroecosystems and to assess the effects of some physical factors of the environment on composition and structure of these communities. The objectives covered by this research are:

1. To define the Arthropoda communities both qualitatively and quantitatively,
2. To compare Arthropoda populations in those communities and draw conclusions about their similarities, and
3. To understand the effects of important soil physical factors and the impact of cultural practices on Arthropoda in those agroecosystems.
LITERATURE REVIEW

The Soil Environment

Soil environmental conditions greatly influence the type and behavior of edaphic microfauna in any given soil. Abiotic factors such as soil structure, texture, humidity, aeration, temperature, pH, etc., and also biotic factors such as natural enemies, food supply, vegetation, etc., vary from place to place and from time to time. It is also often difficult to dissociate the effects of one factor from those of the others, because all of them are interrelated.

Zoologists are aware that the microclimate in which edaphic microfauna lives is very different from that measured by meteorologists at a height of 1.5 m above the ground. Zoologists are also more interested in the microclimate as it affects living conditions, than in the mechanism of the production of the microclimate.

Communities of edaphic organisms and their effective environment form the soil ecosystem. This is an open system because there is a considerable overlap of epigeic, hemiedaphic, and euedaphic populations. For convenience, the soil ecosystem will be treated as a unit in this study. The soil ecosystem is extremely complex, and its study covers wide and diverse areas. Thus, great difference exists in the available literature, reflecting researcher interests and different approaches to studying the soil ecosystem.

Since the publication of Kevan's (1955) Soil Zoology book, considerable progress has been made in developing methods of sampling edaphic microarthropods, extracting them from soil, culturing them in the
laboratory, etc. The majority of the soil-microcommunity studies were
drawn by European researchers, and their basic works have been synthe­
sized in several books, some of them cited in the introduction of this
study. Most of the contributions to soil zoology contain much overlap
in the literature cited. In this literature review an attempt was made
to reduce this overlap, citing representative selections and, in
particular, those studies that provide special insight into the micro-
arthropods of tilled soils.

In the United States the early outstanding contributions to an un­
derstanding of edaphic microfauna were made by Jacot (1935, 1936a, 1936b,
1940). His (1940) soil-fauna review may be regarded as the first
contribution, made by a biologist, toward the recognition of the soil
fauna as an entity, "geenton" as he called it. Pearse's (1946) micro-
fauna study of forest soil was a landmark in the trend toward more com­
plex edaphic fauna studies in the following years. By far the largest
number of papers in edaphic microfauna are concerned with forest and
old-field litter populations, e.g. (Cole, 1946; Bellinger, 1954;

**Hydrogen-ion concentration**

Difference in soil pH is often indicative of different soil types.
Forest soils show two distinct main types of organic profile, viz.,
mor and mull. Mor humus is rather acid, whereas mull is neutral and
generally alkaline. Mor humus usually supports an abundance of:
(1) fungi, and in decreasing order of importance, (2) Acarina and Collem­
bola, (3) Insecta larvae and Myriapoda, (4) Annelida, and (5) Isopoda.
Comparable riches in mull humus are filled by: 1) bacteria, 2) Annelida and Isopoda, 3) Myriapoda and Insecta larvae, and 4) Acarina and Collembola (Wallwork, 1970).

The pH concentration has little affect on Collembola populations, e.g., Friesia mirabilis is common on acidic and basic soils (Hale, 1967). Eut, Gisin (1943, 1951) pointed out that Odontella armata, Onychiurus zschokkei, O. burmeisteri are typically basophil, whereas O. lamellifera, O. absoloni, Willemia anophthalma, and Arrhopalites principalis are acidophil.

In Ames, from June to August 1969, Clemen and Pedigo (1970) sampled collembo lan populations to 7.62 cm deep in an alfalfa field (pH 7.5), continuous corn field (pH 6.0), a permanent pasture (pH 7.4), and from unmanaged field borders. The latter sites had a pH value of 7.8, 7.4, and 7.8 respectively. An ordination analysis of these sites showed that corn was quite dissimilar from the others. The potentially causal factors of this dissimilarity was soil pH, percentage available moisture (< 16%), along with man-induced disruptions.

Raw (1956) mentioned that Protura distribution was affected by the conditions induced by liming. An Eosentomon sp. was correlated with exchangeable calcium, and Proturentomon minimum was strongly correlated with exchangeable calcium and pH.

From the Duke Forest soil (pH varying from 4.5-7.0), Pearse (1946) found that an average of 65% of the animals were recovered from the litter, 30% from a depth of 0-5.1 cm, and 5% from a depth of 5.1-12.7 cm. In order of abundance, characteristic arthropods in that soil were: Protura, Diplura (Japygidae), Symphyla, Pauropoda, and Coleoptera.
(Staphylinidae: *Mayetia* sp.). In his study, Pearse found that soil pH was less effective in controlling number of animals than was soil moisture.

Bornebush (1930) cited Chilopoda (Lithobiidae) and Diplopoda together with lumbricoid worms as characteristic of brown forest soil (mull profile) whereas Chilopoda (Geophilomorpha) together with Diptera and Coleoptera (Elateridae) larvae characterize the podzol soils (mor profile).

Blower (1955) considered that most Diplopoda are influenced by calcareous soils, and calcium may limit the epidermal permeability and restrict water endosmosis. This factor would be important to Chilopoda (Lithobiomorpha) and Diplopoda (Polydesmida, Platydesmida and Polyzoniidae).

Coleoptera and Diptera contain a greater diversity of soil-dwellers than any other insect order. An impressive number of families are represented by euedaphic larva of these order, too many to be considered individually. Predatory Carabidae and both carnivorous and saprophagous Staphylinidae are usually the most predominant euedaphic Coleoptera. In general, Nematocera are the well represented euedaphic Diptera, followed by Brachycera and Cychlorrapha. Soil pH concentration acts more directly on the primary producer, affecting their growth, and indirectly on most of the euedaphic Pterygota by affecting their food supply (Kevan, 1968).

Acarina species (Cryptostigmata) differ in their ability to tolerate different levels of physical factors of the environment. Karppinen (1955) determined which combinations of factors were limiting for the
distribution of Finnish Camisiidae. *Heminothrus thori* was restricted to wet soil, pH greater than 5 and high humus content. *Nothrus silvestris* showed wide-range tolerance to the amount of humus, soil moisture, and pH from 4 to higher than 5. *Platynothrus peltifer* tolerated a range of soil pH, but was limited to moist or wet humus.

**Temperature**

Soil temperature depends on the amount of solar radiation falling on the soil surface, soil moisture, soil texture, humus content, etc. The flux of the heat into and out of the soil is a process of conduction. The heat wave is dampened in the lower layers of the soil, consequently there is a time lag between temperature changes at the surface and litter, and changes in the deeper layers. Also, the temperature shows less daily variation in the soil than that in the air above.

Butcher et al. (1971) conducted a literature review dealing with the ecology of the edaphic Collembola and Acarina, as did Christiansen (1964) in relation to Collembola.

Collembola are cosmopolitan in distribution, and specimens of Entomobryidae, Isotomidae, and Onychiuridae often form large edaphic populations. Collembola resistance to high or low temperature varies with the species and ages of the individuals. Edaphic population peaks may occur at any time of the year, but most species are abundant in early summer and fall (Butcher et al., 1971).

At Ames, Aburto (1956) sampled, at weekly intervals, in the top 7.62 cm of birdsfoot trefoil and brome-alfalfa fields exposed to the normal climatic conditions. He also sampled at biweekly intervals in
birdsfoot trefoil covered with a 25.4 cm straw mulch and overlaid with a tarpaulin.

*Isotoma* sp. and *Isotomina thermophila* made up 54% of the total number of Collembola in uncovered trefoil. In general, the Collembola populations in brome-alfalfa meadow were lower than those in birdsfoot trefoil fields. The total number of Collembola did not show a general decline as the soil temperature dropped from 32.2 °C in August to -5.0 °C in December in uncovered birdsfoot trefoil; or from -1.1 °C in December 1955 to 6.9 °C in April 1966, in covered birdsfoot trefoil. Also, highest population peaks were recorded "late in the season".

Odetoyinbo conducted studies at Ames, from June to December 1957, in the top 7.62 cm of birdsfoot trefoil and brome-alfalfa fields, each exposed to the normal climatic conditions. He also studied 2 birdsfoot trefoil plots, one covered with canvas and the other with a 25.4 cm straw mulch and overlaid with a tarpaulin.

Odetoyinbo (1957) studied the vertical distribution of Collembola in birdsfoot trefoil fields, rich in organic matter, down to 121.9 cm, pH ranging from 5.8-6.95 except at 91.4-121.9 cm, where the pH was between 7.6 and 7.9. The texture classes of the 2 fields were loam and clay loam, respectively. His data showed that Collembola migrated to the deeper, warmer soil layer in the winter and reversed this migration to the upper layers in the spring. The downward migration of Collembola reached its peak on March 21. Based on his investigations, temperature was considered the most important single factor determining the time and extent of the seasonal vertical migrations.

In the birdsfoot trefoil and brome-alfalfa fields exposed to the
normal climatic conditions, and in the birdsfoot trefoil covered with canvas there was a positive correlation between the Collembola population and soil temperature. This did not happen for the straw-mulch covered field.

Odetoyinbo (1957) cited that Japyx sp (Diplura: Japygidae) were recovered in high number in birdsfoot trefoil (91.4-106.7 cm) in January, and this insect gradually returned to upper layers in April and May. Soil temperature was an important factor determining this seasonal vertical migration.

In the United States little ecological information is available on Pauropoda. Starling (1944) studied the ecological aspects of this microarthropod of the Duke Forest. He considered the optimum temperature, based on number of Pauropoda present in the soil samples, to be 17-23 °C. When Pauropoda were placed in constant temperature cabinets, the optimum range was 16-20 °C. A correlation appeared to exist between high incidence of Pauropoda populations and optimum temperature for mold growth, generally 10-30 °C. Mold fungi were the usual food of Pauroplus carolinensis.

Edwards (1959a) found that Scutigerella immaculata populations reached a peak in May on the soil surface, followed by a rapid decline to minimum levels in July, and increased slightly again during the autumn. Edwards (1961) mentioned that Symphyla were relatively tolerant of wide temperature changes. High surface temperature during the summer months and the drying out of the top soil layers resulted in downward migration of S. immaculata and Symphylella vulgaris.

Cryptostigmata are more generally restricted to the soil than any
other Acarina groups, and there seems to be a definite tendency in these mites to choose a certain optimal temperature (Butcher et al., 1971).

Madge (1964a, 1964b, 1964c) mentioned that a tectostracum (water proof cuticular layer of wax) was present in epigeic or hemiedaphic species such as Belba geniculosa, Carabodes labyrinthicus, Platynothrus peltifer, etc and absent in the euedaphic Hypochthonius rufulus and Nanhermannia nana. Also, the tectostracum melting point was higher in Humerobates rostrolamellatus and C. labyrinthicus than in the hemiedaphon. The thermal death point for these two species was 43-44 °C and 41-42 °C, respectively, whereas that of the euedaphic H. rufulus and N. nana were 28-36.5 °C and 31-40 °C, respectively. These studies pointed out that epigeic and hemiedaphic Cryptostigmata are more tolerant to high temperature than euedaphic ones (Madge, 1965).

Aburto (1956) stated that Acarina populations did not show any clear-cut relationship with the normal fall in mean soil temperature from August (32.2 °C) to December (-5.0) 1955 in birdsfoot trefoil and brome-alfalfa ecosystems.

Odetoyinbo (1957) mentioned that the birdsfoot trefoil exposed to the normal climatic conditions showed a significant positive correlation between Acarina populations and soil temperature, whereas those in the brome alfalfa showed no apparent correlation at the same range of temperature, -1.7-27.8 °C. Both of the covered fields showed negative but nonsignificant correlation at the same range of temperature, -5.6-27.8 °C.

Odetoyinbo (1957) pointed out that Acarina migrate to deeper and warmer soil, 106.7-121.9 cm. More Acarina were sampled from these depths
than any other on April 6. The rise in soil temperature from April to
June was accompanied by a distinct upward migration of the mites.

**Moisture**

The liquid phase of the soil comprises gravitational water, capillary
water, and hygroscopic water. Gravitational water is that drained in the
soil by gravitational forces. It is instrumental in leaching nutrients
and, with waterlogged conditions, interferes with aeration. Hygroscopic
water is held as film on the surface of the soil particles or aggregates
with a tension of 4.5 pF or more. Thus, this water has little biological
importance. Capillary water is held in capillary space between soil
particles and aggregates, moving as a liquid in any direction in response
to capillary tension and may also move as vapor from one part of the
soil to another (Thompson, 1957). Therefore, the capillary water is
very important from an ecological point of view.

Wallwork (1970) considered the soil atmosphere saturated, to all
intents and purposes, if the moisture content of the soil remains above
4.5 pF (wilting coefficient). Bachelier (1971) mentioned that the
relative humidity (h) is related to the pF by the equation: pF = 6.5
+ \log_{10} (2 - \log_{10} h). Thus, at pF 4.5 the relative humidity is theo-
retically 98%, and even at pF 5.5 it is still 80%. Vannier (1967)
showed that in soil where the wilting point is seldom attained, the
variation in the amount of water and those of the relative humidity of
the soil atmosphere did not affect the behavior of the soil animals.

The effect of soil moisture on Collembola presents basic dis-
agreement among researchers. Some found that density and diversity of
Collembola are negatively correlated to soil moisture, others pointed
out positive correlations or no correlation at all (Christiansen, 1964).

Aburto (1956) mentioned a marked decrease in the collembolan density (millions/acre in the top 7.6 cm of the soil) in all birdsfoot trefoil and brome-alfalfa fields when the soil moisture content (Pw) increased.

Odetoyinbo (1957) found in every field investigated an apparent negative correlation between Collembola and Pw. Also, *Isotoma thermophila* preferred moist soil, while *Hypogastura* sp. and *Mesaphorura* sp. did best under dry conditions.

Kevan (1968) stated that delicate, poorly pigmented Diplura are among the most dependent arthropods on high humidity, and that "*Campodea* are fairly common whenever the soil maintains a fairly even humidity". These statements can be questioned on the basis of Vannier's (1967) work.

Protura favor high soil moisture (Wallwork, 1970), and their scarcity in agricultural soil and abundance in forest soil has been considered to be caused by their high moisture and organic-matter requirement. However, Raw (1956) found them very numerous in permanent pasture having lower moisture levels.

Blower (1955) considered Chilopoda and Diplopoda very sensitive to desiccation; the former are even more susceptible than the latter. Geophilomorpha did not show appreciably greater resistance to desiccation than Lithobiomorpha, and this was attributed to imperfect spiracular closing mechanisms. Curry (1974) found no spiracular closing devices," and indeed none are necessary as the cuticle seems to be permeable," in *Lithobius forficulatus*, *L. variegatus*, *Haplophilus subterraneus*, *Geophilus insculptus*. Consequently, Geophilomorpha and Lithobiomorpha are
found in most habitats.

Edwards (1961) stated that *Scutigerella immaculata* could not survive when the relative humidity of the soil atmosphere was less than 100%. He also demonstrated that *S. immaculata* reacts to a soil gradient having a peak Pw of 11.2%.

Starling (1944) mentioned that the greatest number of Pauropoda was collected from sandy soil with 11-20 Pw and from clay loam soil with 21-30 Pw.

Aburto (1956) stated that the Acarina population varied considerably during the observation period, and that there was no correlation with those figures and soil moisture content.

Odetoyinbo (1957) found a negative correlation between Acarina and Pw in birdsfoot trefoil and brome-alfalfa exposed to normal climatic conditions.

**Texture**

Soil texture refers to size of the soil particles, and these are classified according to 3 fractions: clay, sand, and silt. Under most conditions, a clay content of 20-25% of the soil particles provides desirable qualities of aeration, water-holding capacity and nutrient-holding capacity (Thompson, 1957).

In Pearse's (1946) study comparing arthropods in sandy and clay soils, Chilopoda, Diplopoda, Pauropoda, Diplura (Japygidae), Thysanoptera, other Pterygota (adults and larvae), and Pseudoscorpionida favored clay soil. Meanwhile, Acarina, Symphyla, Collembola and Araneida favored sandy soil. Protura appeared to show no preference.
Soil texture is important to nonburrowing microarthropods. Lithobiomorpha are unable to burrow and move through galleries and crevices in the soil. Geophilomorpha force their way through the soil by waves of muscular contractions and expansions rather like Oligochaeta, although they cannot ingest soil (Manton, 1952; Cole, 1946). One Pseudoscorpionida specimen, a non-burrowing microarthropod, was surprisingly recovered at 61-76.2 cm deep in an alfalfa field (Odetoyinbo, 1957).

The particle size of the soil affects the mean diameter of the pore space, which in turn, will limit the size of the individuals that thrive in it. Therefore, the total pore volume will limit the population size. These factors are more clearly noted when vertical distribution of species is considered. Odetoyinbo (1957) stated that below the 45.7 cm layer, Collembola were restricted to the smaller-sized Onychiurus sp., Hypogastrura sp., and occasionally Mesaphorura sp. Below the 22.9 cm layer, the predominant Acarina were immature specimens of Nanorchestidae (Astigmata).

Edwards and Lofty (1969) mentioned that Cryptostigmata populations, in each of 3 soil types, peat, clay-loam and sand-loam, were more numerous in woodlands, less so in pasture, and fewest in arable soil. Also, these authors noted the same tendency, in general, with regard to populations of other microarthropods in those 3 habitats.

Agricultural practices

In general, most microarthropods are found in the litter of woodland soils, whereas in pastures, most live within 5 cm of the surface. In tilled soils they are found more evenly distributed through the upper
15 cm. Epigeic, hemiedaphic, and euedaphic microarthropod taxa differ considerably in their vertical distributions, which in turn, affects their susceptibility to cultivation.

Cultivation affects edaphic microarthropods by destroying their habitat and mechanically damaging them. When uncultivated soil is tilled, Isopoda, many Diplopoda and Chilopoda, Collembola (Entomobryidae, Isotomidae, Sminthuridae), Cryptostigmata (Damaeidae, Galumnidae), etc. rapidly disappear. Therefore, only very small or elongated microarthropods such as Oppia spp. and similar minute Cryptostigmata, Onychiurus spp. and Tullbergia spp., are rather abundant in tilled soil (Ghilarov, 1975).

Edwards and Lofty (1969) mentioned that in a 300-year pasture, sampled immediately after being plowing and diskig and again 2 weeks later, populations of Prostigmata, Thysanoptera and Diptera increased. Populations of Mesostigmata, Symphyla, Diplopoda, Protura, Coleoptera, and Collembola (Sminthuridae) decreased less than 40%. In contrast, populations of Chilopoda, Pauropoda, and Collembola (Onychiuridae and Entomobryidae) decreased more than 50%.

Tischler (1955) considered that both the time and the type of plowing can affect the edaphic populations differently. Plowing in autumn caused a sudden strong decline in population curves of Acarina and Collembola, followed by a great recovery in spring. Plowing in spring especially reduced adult carabid hibernators, while the larval hibernators are less affected. Deep plowing favored burrowing soil-dwellers. Surface plowing favored Chilopoda, whereas Diplopoda, Acarina and Collembola were not influenced by depth of the plowing. He also considered that summer crops are characterized by an impoverished
edaphic fauna because of the disturbance of the field in the spring.

Within each soil type, the microarthropod populations are significantly higher in unmanaged plots than in adjacent cultivated fields. Ghilarov (1975) mentioned that population density of Cryptostigmata, per square meter in an unmanaged area adjacent to winter wheat and sugar beet fields, was 3.6 and 1.8 times higher than that in the field, respectively. The same trend is observed in Clemen and Pedigo's (1970) paper. There, the total collembolan population in unmanaged field borders of alfalfa, corn, and pasture were (in prominence values) 1.5, 3.5, and 1.5 times higher than those in the crop fields, respectively.

Tischler (1955) stated that fertilization with organic manure increased edaphic fauna more intensively and more rapidly than mineral fertilizer.

Edwards and Lofty (1975) stated that soil cultivation tended to decrease the number of most of edaphic species of Arthropoda, but cultivation tended to favor larger predatory Acarina and Diptera larvae. When cultivation ceased, populations of most microarthropods recovered within 6 months.

**Pesticides**

Edwards and Lofty (1969) studied the fumigants DD and Vapan. They found that these treatments usually kill more than 99% of the original microarthropod populations, and complete community recovery may take more than 2 years.

Herbicides affect edaphic fauna mostly indirectly by destroying weeds on which many soil macroarthropods feed. Herbicides have shown
no significant influence upon Collembola (Christiansen, 1964). But, Edwards and Lofty (1969) stated that only simazine and DNOC decreased microarthropod densities, but only slightly during the time the herbicide persisted in the soil, viz., 4-6 month for simazine. This herbicide decreased predatory Acarina numbers, hemiedaphic Collembola and, to a lesser extent, detritivorous Acarina.

Reeves (1973) stated that the influence of pesticides on Cryptostigmata has not been extensively studied, but they appear generally to be lesser affected than other edaphic microarthropods.

Dindal et al. (1975) studied the effect of a single DDT application on soil microarthropod communities. The application was made in June 1969, in a previously untreated silt-loam grass field. Oppiella nova was the most abundant Cryptostigmata on both untreated and treated fields. Its numbers were 2 times greater in the treated field during October and November of 1969 and 1970, than in the untreated one. In the treated samples, Collembola were initially suppressed (June to August) but had a twofold population increased in December. This population was gradually reduced to zero during June to August 1970. Laelapidae, Ascidae, Veigaiidae (all Mesostigmata) had their normal peak populations on untreated plots from June to August. By treatment, this peak was reduced 50%, whereas in 1970 Mesostigmata numbers on the treated plots doubled over those in the untreated plots. Combining the Collembola (prey) and Mesostigmata (predator) trends, the reduction of predators was followed by an increase of prey. When Mesostigmata population doubled, a corresponding reduction of Collembola occurred.

Edwards and Lofty (1969), however, stated that DDT applications
greatly reduced the number of Mesostigmata and had little effect on Collembola, thus DDT treatment invariably increased Collembola populations.

Aburto (1956) studied Collembola and Acarina populations following chlorinated hydrocarbon treatments in the top 7.6 cm of a peat soil, near Britt, Iowa. The field had been in pasture for many years before planting with corn in 1955. The granular insecticides, added to the soil in May 1955 were: heptachlor on Attaclay RMV-AA, and dieldrin, chlordane, and heptachlor on no. 4 Vermiculite. In later August, the decreases of Collembola populations, in millions/acre, were 40% in the dieldrin-treated plots, and 100% reduction in the remaining plots. The Acarina population, in millions/acre, was decreased 50% in heptachlor on Attaclay RVM-AA plots, was reduced 100% in both heptachlor and chlordane on Vermiculite plot, but appeared not to be affected by the dieldrin on Vermiculite treatment.

Aburto (1956) also studied chlorinated hydrocarbon insecticides applied to the soil of a continuous corn field (454 g/acre) near Burlington, Iowa in May 1953. In July 1955, the Collembola population (millions/acre) in this field showed a decrease of 100% in heptachlor-treated plots, was reduced 85.7% in both aldrin and BHC plots, and diminished 72% in endrin-treated plots. The Acarina population (millions/acre) decreased 50% in the aldrin-treated plots and was reduced 67% in the other treated plots.

Odetoynibo (1957) studied the vertical migration of Collembola and Acarina populations following phorate treatment in an "old" alfalfa field, at Ames. Phorate was sprayed, 227 g/acre, on July 24, 1956.
Samples taken 4 days later, in the top 7.6 cm soil layer, showed:

(1) a marked decrease of Collembola and Acarina populations, (2) a conspicuous absence of *Brachystomella*, *Isotomina*, *Isotoma*, and *Pseudarchutes*, (3) that the collembolan population consisted almost exclusively of *Hypogastrura*, *Onychiurus*, and *Mesaphorura*, and (4) sharp drops in Acarina populations. One week after spraying, the maximum concentration of Collembola was in the 7.6-30.5 cm layer. On August 21, the zone of maximum concentration of Collembola and Acarina was 30.5-45.7 cm and 15.2-61 cm, respectively. Collembola and Acarina populations in unsprayed plots did not show similar vertical migrations during the observed period.

Edwards and Lofty (1969) stated that none of the tested organophosphates (diazinon, parathion, menazon, disulfoton, phorate, thionazin, fenitrothion) or carbamates (carbaryl) affected arthropod numbers as much as did the chlorinated hydrocarbons.

**Tilled-Soil Fauna**

**Iowa situation**

It is beyond the scope of this study to make an extensive literature review of the microarthropods that thrive in all tilled soils. Instead, representative selections of studies dealing with Iowa edaphic microarthropods are cited, except Insecta (Pterygota) and Acarina other than Cryptostigmata.

Mills (1934) taxonomically treated Iowa Collembola. He included 132 species, 43 genera and recognized only 4 families. This, is by far, the most complete systematic treatment of Iowa Collembola.
Aburto (1956) and Odetoyinbo (1957) studied, quantitatively, Collembola and Acarina in birdsfoot fields, cornfields, brome-alfalfa fields and pastures. Aburto found 6 families and 8 genera as follows: Brachystomellidae (*Brachystomella*), Entomobryidae (*Lepidocyrtus*), Isotomidae (*Isotoma, Isotomina*), Onychiuridae (*Mesaphorura, Onychiurus*), Hypogastruridae (*Hypogastrura*), and Neanuridae (*Pseudochorutes*). Odetoyinbo (1957) found the same taxa mentioned by Aburto, with the addition of Sminthuridae (*Sminthurus*).

O'Neill and Pedigo (1969) studied Collembola communities in the Ledges State Park, Boone County. Soil cores were taken from woodlands, grasslands, cultivated fields, pastures, fencerows, marshlands and caves. Cluster analyses were used for comparing sample sites in grasslands and woodlands.

Clemen and Pedigo (1970) sampled collembolan populations near Ames. A two-dimensional ordination analysis was used to compare an alfalfa field, a continuous corn field, a permanent pasture, and unmanaged field borders.

Wonio (1970) applied methods of dissimilarity coefficients, cluster analyses, and community ordination for studying Collembola populations in the Iowa State University Arboretum.

Wonio and Pedigo (1973) described ecological observations of *Onychiurus similis*. The same authors (1974) reviewed the literature on 'ecomorphosis' in the genus *Isotoma*, and *Spinisotoma dispersa* was recorded for the first time in Iowa.

In the Iowa State University Collection (ISUC) there are two Campodeidae specimens and a Japygidae from Red Haw State Park, Decorah.
Ewing (1940), Tuxen (1964) and Womersley (1939) taxonomically treated Iowa Protura: *Eosentomon wheeleri* (Eosentomidae), and *Proturentomon iowaense* (Protentomidae). In the ISUC there are 2 proturans, one from Columbus Junction and other from the Ledges State Park, Boone.

Hilton (1934) described *Pauropus medianus* (Pauropoda: Pauropodidae) from Ames.

Waterhouse (1970) mentioned *Scutigerella immaculata* (Symphyla) from Story and Linn Counties in corn fields. In the ISUC there is also a specimen from Scott County.

Chamberlin (1912a) studied the systematics of Iowa Geophilomorpha: Geophilidae (*Geophilus rubens, Arenophilus bipuncticeps, Pachymerium ferrugineum*), Linoteniidae (*Linotenia fulva*), Soniphilidae (*Sonophilus embius* and *Poaphilus kewinus*).

Ewing (1917) taxonomically studied Ames' Cryptostigamata: Cepheidae (*Cepheus subniger*), Damaeidae (*Damaeus brevitarsus*), Haplozetidae (*Peloribates iowaensis*), Liacaridae (*Liacarus fusiformis*) and Oribatellidae (*Oribatella achipteroides australis*).

Aburto (1956) and Odetoyinbo (1957) studied, quantitatively, Acarina from Ames. The latter mentioned 11 families found in birds-foot trefoil and alfalfa fields: Acaridae and immature Nanorchestidae (Astigmata), Belbidae, Ceratozetidae, Epilohmanniidae, Eremaeidae, Galumnidae, Hypochthoniidae, Oribatulidae (Cryptostigmata), Laelapidae, and Pseudoparasitidae (Mesostigmata).
Analytical Methods

Ordination

The desirable order of ecological research in a given area is first synecological studies of the constituent species and their numerical relationship with the environment, and secondly, the autoecological studies if the latter are to have the maximum meaning (Curtis and McIntosh, 1951).

For several decades ecologists have been devising methods of describing, analyzing and synthesizing the complexity of communities. Significant contributions to quantitative ecological methodology were first made by botanists, and in the United States, the development of the Wisconsin comparative or polar ordination (Bray and Curtis, 1957), with its extensive applications, stimulated work in plant sociology. Statistical approaches to quantitative plant ecology were revised by several authors in a work edited by Whittaker (1973). This work critically reviews most of the literature on the use and development of several ordination methods.

Although various methods of ordination have been used by plant ecologists, little application has been made in animal community study. One of the earliest attempts was made in Beals' (1960) two-dimensional ordination of forest bird communities. Ordinations have been used in some invertebrate studies, but thus far its use has been limited to benthic invertebrate communities (Burlington, 1962; Dean and Burlington, 1963; Erman and Helm, 1971; and Pearson et al., 1967), soil nematodes (Ferris et al., 1971; and Johnson et al., 1973), Plecoptera (Fenni,

Reviews of ordination comparative techniques by Beals (1973), Gauch and Whittaker (1972) and Whittaker and Gauch (1973) have concluded that the polar ordination is relatively simple and still gives the most easily understood ecological information. Consequently, these reviews offer a basic background for analyses used in this study.
MATERIALS AND METHODS

Sampling Program

Sample site and field history

A preliminary sampling survey of edaphic arthropods was made in crops in 5 counties (Fig. 1) during the cropping season of 1972. In Sutherland (NW) the field was located at Siles Steel's farm with corn adjacent to the field on the north, and a gravel road on the other sides. In Independence (NE) the field was located about 1,600 km. south of the Iowa State University (ISU) Clariton Clyde farm, with an adjacent cornfield on the north and west, soybean on the east and by the State Highway 150 on the south. In Shenandoah (SW) the field was located 1 mile south and 1 mile west of the city limits and was adjacent to the airport road on the north. A cornfield bordered the east side of the field and fallow areas bordered west and south. In Bloomfield (SE) the field was located at Adler Chandler's farm and was adjacent to grassland. In Ames (central region of the state) the field was located at ISU Woodruff farm, in a radius of 2 miles from the city. The field had a gravel road on the south and soybean fields on the other sides. None had received soil insecticide treatment in 1972.

A more intensive sampling program was carried out during the cropping season of 1973 and 1974. Agroecosystems for these studies were continuous corn, which had at least 3 years of continuously grown corn prior the beginning of the study; continuous soybean, with at least 3 years prior planting of soybean; and rotation, which had at least 2 complete rotations of oats-soybean-corn in the field prior to
Figure 1. Iowa cities nearest sampling sites

SUTHERLAND

SHENANDOAH

AMES

INDEPENDENCE

BLOOMFIELD
the beginning of the study. Rotation and soybean fields had not received soil insecticide treatment for at least 4 years prior to the study. This was true also for 2 cornfields (C.1, C.4), but 2 others received carbofuran treatment (1.12 kg actual ingredient/ha) in 1974.

Soybean field 1 was located near the Ames Municipal Airport, with adjacent grassland on the south, soybeans on the west and east, and a concrete runway on the north. Soybean field 2 was located to the south of the Curtiss farm (ca. 1 mi south of the Ames city limits), with an adjacent gravel road on the west, and soybean fields on the other sides. Soybean field 3 was located on the northwest portion of the Curtiss farm, with a gravel road adjacent on the south and soybean fields on the other sides. Soybean field 4 was located at ISU Agronomy farm, with grassland on the north, cornfields on the east and south, and soybeans on the west.

Cornfield 1 was located along State Avenue (just south of the Ames city limits), with adjacent cornfields on the north and west, grass strip on the east, and US Highway 30 to the south. The remaining cornfields were located along the Mortenson Road southwest of Ames; fields 2 and 3 lay on the south of this gravel road, with field 4 on the north. Field 2 had cornfields adjacent on the north and west, and a gravel road on the east. Field 3 was bordered by corn on the north, east, and west. Cornfield 4 was adjacent to cornfields on the east, south, and west.

Rotation fields were located along the west side of South Dakota Avenue. Field 1 was bordered by grassland and fields 2, 3, and 4 were bordered by soybean in 1973 and corn in 1974.
Collection of samples: 1972

A sampling area of 0.06 ha was established in each field on uniform topography and was divided into 4 equal-sized plots. Each soil sample was taken with a metal cylindrical corer, 6-cm diameter X 6-cm deep. Ten cores were taken randomly in each plot in the plant row and as close as possible to the plant stalks.

All soil cores were placed in labeled plastic bags, and these, in turn, were placed in cylindrical containers of 0.473 l capacity. In the laboratory, an aliquot sample was taken from 7 roughly mixed soil cores. About 300 gm of this soil, from each sample area, was sent to the Soil Testing Laboratory (ISU) for pH analysis, within 12 hours after they were taken, and 40 gm were used for soil texture analysis (Bouyoucos, 1951).

Two cores per plot were used for extraction of edaphic arthropods. One core plot was used for a soil moisture content analysis, based on percentage oven-dry weight of the soil.

In each plot, at each sample time, the soil temperature was taken, using a Bi-Metal Dial thermometer reading at a depth of 9-10 cm. The thermometer was located as close as possible to the plant stalks, and mean temperatures were determined from 10 measurements in each plot.

The sample times for the soybean agroecosystem in 1972 were:
Ames June 15, June 30 and August 11; Bloomfield and Shenandoah July 14 and August 29; and Independence and Sutherland July 21 and August 30.
Collection of samples: 1973-1974

In the intensive sample program, each sample area was the same as in 1972. Each soil sample consisted of a metal cylinder, with the same dimensions as that used in 1972. Two cores taken randomly in each plot, as close as possible to the plant stalks.

The corer (Figs. 2 and 3) used in these studies was threaded on the top, and the bottom was beveled to a cutting edge. About 2 cm from the base of the basal cylinder, 1.2 cm holes were drilled through its diameter. A steel rod, 1.2 cm diameter × 25 cm long was centered through those holes. By standing on the ends of that rod (Fig. 4), this facilitates the introduction of the corer into the soil.

All soil cores were brought to the laboratory as in 1972. One soil core per plot was used for extraction of edaphic arthropods. One soil core per plot was used for soil relative-humidity analysis, based on percentage oven-dry weight of soil, as well as for determining percentage pore space, based on bulk density of this soil.

On the first sample date, 1 extra core was taken per plot. In the laboratory, 4 soil cores per sample area were mixed thoroughly. About 300 g of this soil were sent to the Soil Testing Laboratory (ISU) for pH analysis, within 12 hours after they were taken, and 40 gm were used for soil texture analysis, as it was done in 1972.

During the first sample date in 1974, a second, additional, core was taken randomly per plot. In the laboratory, 4 soil-cores per sample area were mixed thoroughly, and an aliquot sample was taken from each. These 12 aliquot samples were sent to the Ames Laboratory (ISU) for determination of insecticide residue.
Figure 2. Detachment of the corer from the soil sampler

Figure 3. Soil sample in the corer being inverted intact on the sieve
Figure 4. Introduction of the corer into the soil by standing on the ends of the rods
This determination was made because of the prevalent use of soil pesticides in Iowa, where approximately 5 million acres of farmland have been treated with about 3 million kilograms of soil insecticides.

The determination of both carbofuran and chlorinated hydrocarbon residues in soil were made using the Holden's (1973) method and the Nash et al.'s (1973) method, respectively.

In each plot, at each sample time, the soil temperature was taken as in 1972, but mean temperatures were determined from 4 measurements in sampled area.

The sample times for all agroecosystems in 1973 were June 21, July 25, August 18, October 13, and for 1974 were June 25, July 30, August 21, and October 3.

Arthropoda Extraction Method

Soil arthropods were extracted with modified Tullgren funnels. The extraction apparatus (Fig. 5) consisted of a battery of 12 anodized-aluminum funnels, mounted on 12 plywood boards. The boards were set in an angle-iron framework, one above the other, with 16 funnels/board. A cylindrical shroud was mounted above each funnel and housed the heating element, a 60 w light bulb. The bulb was located 24 cm above the surface of the soil sample, and all bulbs in battery were wired in parallel and were controlled by a variable rheostat.

The soil samples from the preliminary survey in 1972 were set, intact, upright directly on a no. 8-mesh galvanized sieve. Those of the intensive sampling program of 1973 and 1974, were not removed from the removable cutting attachment and were inverted intact on the sieve
Figure 5. Battery of modified Tullgren funnels
The purpose of the sieve was to retain large debris and some soil dwellers such as oligochaetes.

The funnels were operated in a room where the temperature was thermostatically maintained at 21 ± 1 °C. Arthropods were extracted over a 7-day period with the soil nearest the bulb at 25 °C during the first 2 days, 30 °C for the next 3 days, and 35 °C for the last 2 days. Arthropods extracted were collected into vials containing 95% ethyl alcohol.

A rigid recommendation of a single flotation method for all groups of edaphic arthropods is impractical, because facilities, agroecosystems and researcher techniques differ. Therefore, preliminary comparisons of effectiveness of saturated solutions of magnesium sulphate, xylene-water interphase, and saturated cold-sugar solution were made for this study. These comparisons indicated that the saturated cold-sugar solution was the most preferable.

The following flotation method was used to extract arthropods from samples and rid them of debris:

1. The fluid phase of each vial and the suspended microarthropods were poured into a 0.045-mm mesh sieve, 7.62 cm in diameter.
2. Material retained by the sieve was washed with distilled water.
3. The sieve was set, upside down, over a Syracuse dish. The microarthropods from the sieve were flushed with 95% ethyl alcohol into the dish. The contents of the dish were examined with a stereoscopic microscope.
4. The extraction vials, with remaining sediments, were filled with saturated cold (about 1 °C) sugar solution and were
shaken until all material was suspended; then the soil particles were left to settle.

5. Steps 1 to 4 were repeated 3 times.

6. Any soil material remaining in the vial was washed with 95% ethyl alcohol into a Syracuse dish and checked for any micro-arthropods trapped in soil particles or air bubbles.

Identification and Storage

In the laboratory, edaphic arthropods were identified under the stereomicroscope, and specimen numbers were recorded. Prior to the identification, some specimens were cleared in a preparation dish containing 10% KOH solution. This preparation dish was set on a slide warmer table at 40 °C.

The small size of some microarthropods required that they be observed under the compound microscope at high magnifications. Therefore, some specimens were placed temporarily or permanently on microscope slides. For temporary preparations, a single cavity slide was filled with glycerine. Permanent mounting fluid used was Clark and Morishita's (1950) methocellulose medium.

Important keys used in the identification of microarthropods were those: Arnett (1968), Balogh (1972), Chamberlin (1912a, 1912b), Chamberlin (1931), Chapman (1930), Curran (1934), DeLong (1948), Edwards (1959b), Froeschner (1944, 1949), Medler and Ghosh (1969), Paclt (1957), Ross et al. (1971), Salmon (1964), Stannard (1968), Tuxen (1964), and Verhoeff (1934). Books by Borror and DeLong (1971) and Peterson (1948, 1951) were used in general identification of adults and larvae of insect
families, respectively.

After identification and counting, some specimens were placed in 1/4 dram vials, which were filled with 95% ethyl alcohol, and capped with a small wad of cotton. These small vials were, in turn, placed in 17 X 60 mm vials filled with 95% ethyl alcohol. The vials, with appropriate labels, were then capped with neoprene stoppers and placed in storage racks. Voucher specimens from this study were deposited in the Iowa State University Insect Collection, Ames, Iowa.

Ordination

The two-dimensional ordination, used by Beals (1960), was the method of analysis in this investigation. In studying forest bird communities, Beals developed the concept of prominence value (PV) an index calculated by multiplying density of a population by the square root of the frequency of occurrence of that population. In this study the, PV = density \( \sqrt{\text{frequency}} \), where density and frequency are defined as follows:

\[
\text{Density} = \frac{\text{Total individuals of a taxon collected}}{\text{Total samples taken}}
\]

\[
\text{Frequency} = \frac{\text{Total cores in which a taxon occurred}}{\text{Total samples taken}}
\]

The rationale for the use of this index is that the density is the most important measurement, while the frequency (a measure of the distribution through space) is used to modify the density. Beals arbitrarily established the square root of the frequency in order to obtain
randomness ("... one bird observed at one point is half as "prominent" as one bird observed at four points.").

In order to use the two-dimensional ordination scheme, a coefficient of similarity was calculated as: \( C = 2 \frac{w}{a + b} \)

- **C** = coefficient of similarity
- **a** = the sum of PV of all species in community a
- **b** = the sum of PV of all species in community b
- **w** = the sum of the smallest P.V. of the species that the two communities have in common.

This coefficient was calculated for each community compared with all others, and a matrix of similarity was constructed. Since distance between communities in ordination represents degree of difference rather than similarity, the C values were converted to dissimilarity values \( 1.00 - C \). The dissimilarity values were totaled for each community-pair combination, and the community with the highest sum was designated "a" and assigned a location of zero on the X-axis of the ordination. The other end of this axis was the community having the least in common with the first one, and designated "b". Thus, the X-axis corresponded to the dissimilarity value for communities "a" and "b". The distance \( x \) of each of the remaining communities from community "a" along the X-axis is then obtained by the formula:

\[
x = \frac{L^2 + Da^2 + Db^2}{2L}
\]

- **L** = dissimilarity value between communities "a" and "b"
- **Da** = dissimilarity values between plotted community "a" and the community in question
Db = dissimilarity value between plotted community "b" and the community in question

The Y-axis was constructed to separate communities which fall close together on the X-axis, but which are dissimilar. To do this, the communities with the poorest values "e" on the X-axis were determined by the formula \( e = \sqrt{D_{a}^2 - x^2} \). The community with the highest e value, which had not been used previously as a reference community, was designated "a" and assigned a location of zero on the Y-axis. The community most dissimilar to "a", and located within 0.10 L of "a" on the X-axis, was designated "b" and placed at the opposite end of the Y-axis. The location of the remaining communities along the Y-axis were calculated as for the X-axis.

This method was used with data obtained from 5 communities in 1972 (Table 1) and 12 ones in 1973 and 1974 (Tables 4 and 5). A computer program was written in Fortran IV to calculate this two-dimensional ordination. Coefficients of dissimilarity were used to draw a two-dimensional diagram of the dissimilarity relationship of the communities.
RESULTS AND DISCUSSION

Arthropoda Extraction Method

Absolute numbers of microarthropods in a soil sample are not known, and no present method developed successfully extracts all those geobionts from a sample. But, it has been widely accepted that the best general method for extracting edaphic microarthropods is a Tullgren funnel producing a gradient of temperature and moisture through the sample (Edwards and Fletcher, 1971; Macfadyen, 1955, 1962).

The modified Tullgren funnel extractor, with light and heat source controlled by rheostat, was chosen because it was easy to operate and specimens were collected undamaged and identifiable. The controlled gradient of temperature and moisture in this funnel seems to increase the extraction efficiency by preventing desiccation of most microarthropods.

The cores were inverted intact on the sieve because many microarthropods live near the surface, thus they had a shorter distance to travel from an inverted than from an upright core. Ethyl alcohol was used as a collecting fluid because of its killing effect. It preserved microarthropods from putrefaction, as well as prevented predators from consuming prey in the receptacle. Additionally, the method used is one of the recommended methods of extraction for microarthropods from arable, clay or loam soil (Edwards and Fletcher, 1971).

The specific gravity of most microarthropods lies between 1.0 and 1.1 (Edwards, 1967). Therefore, many of these float from soil shaken in a container with solution having a specific gravity of 1.2 or more.
A flotation method was used to extract microarthropods from the collecting vials and rid them of the debris that usually fell into these containers. The cold-sugar solution had the advantage of providing more undamaged and identifiable microarthropods. Membranous wings, appendages, and setae adhering to the arthropod body during step 4 of the flotation method were easily washed from the viscose solution during the repeated step 2. Also, the cold-sugar solution did not form small soil clumps where microarthropods might be trapped. The stock cold-sugar solution was maintained about 1 °C to avoid sucrose crystal precipitation. The xylene-water interphase had the disadvantage of adhering membranous wings, appendages, and setae to the arthropod body. The adhering structures were not easily washable, and processing usually damaged the arthropods. The magnesium sulphate technique had the disadvantage of forming small soil clumps during step 6 of the flotation method. Also, these clumps adhered to the inside of the collecting vials, trapping many animals among the soil particles.

Sampling Program 1972

**Microarthropod fauna**

In the 1972 sampling program, 2501 microarthropod specimens, distributed in 16 orders, 82 families, and 121 genera were collected. A completed list of these microarthropod is presented in Table 1.

Acarina was the most diverse taxon with 31 families and 36 genera. Oppiella, Ceratozetes, and Xylobates were the most abundant Cryptostigmata, while Rhodacaridae specimens were the most numerous predatory Mesostigmata (Table 1). Acarina always presented the highest population
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densities, average, and total percentage in all fields (Table 2). In the majority of the locations, Acarina densities were about double those of the Collembola.

Collembola always presented the second highest total population density, average, and total percentage in all sample sites (Table 2). Collembola was the third most diverse taxon, with 7 families and 19 genera. Epigeic and hemiedaphic Collembola (Sminthuridae, Tomoceridae, Hypogastruridae) were more abundant in the weed-infested field at Bloomfield. The lack of occurrence and the low PV of genera of those taxa in nonweedy fields (Table 1) indicated a possible deleterious effect of cultural practices.

Collembola density (hundreds/m²) was higher in August than in July at all sample sites. In July and August these densities were: Bloomfield 3.17-8.16, Independence 4.34-11.76, Shenandoah 1.25-3.23, Sutherland 1.62-8.67, respectively. In Ames the population average was 4.61 in June and 5.44 in August.

Most often, Acarina density showed a reverse trend compared with that of Collembola, i.e., density was highest in July and was lower in August. These densities were: Bloomfield 16.02-6.98, Independence 15.80-14.85, Shenandoah 8.29-2.28, respectively. In Ames the population average in June was 5.73 and in August 4.26.

Of the remaining Apterygota taxa, predaceous Diplura were represented by 2 families and 2 genera, and Protura had 1 family and 1 genus. Protura density was the fourth greatest of the taxa collected at Shenandoah (Table 2).
Table 2. Population density in hundreds/m² (T), percentage (%), average (X), and standard error (SE) of edaphic Arthropoda in 5 soybean agroecosystems. Iowa, June to August 1972

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</tr>
<tr>
<td>Coleoptera</td>
<td>0.81</td>
<td>2.08</td>
<td>1.25</td>
<td>2.68</td>
<td>0.15</td>
<td>0.87</td>
</tr>
<tr>
<td>Diptera</td>
<td>1.98</td>
<td>5.09</td>
<td>0.29</td>
<td>0.62</td>
<td>0.15</td>
<td>0.30</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>0.15</td>
<td>0.39</td>
<td>0.14</td>
<td>0.30</td>
<td>0.14</td>
<td>0.81</td>
</tr>
<tr>
<td>Homoptera</td>
<td>0.07</td>
<td>0.18</td>
<td>0.15</td>
<td>0.32</td>
<td>0.15</td>
<td>0.87</td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>0.44</td>
<td>1.13</td>
<td>0.07</td>
<td>0.15</td>
<td>0.15</td>
<td>0.87</td>
</tr>
<tr>
<td>Psocoptera</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Thysanoptera</td>
<td>0.15</td>
<td>0.39</td>
<td>0.22</td>
<td>0.47</td>
<td>0.37</td>
<td>2.14</td>
</tr>
<tr>
<td>TOTAL</td>
<td>38.90</td>
<td>100.0</td>
<td>46.58</td>
<td>100.0</td>
<td>17.26</td>
<td>100.0</td>
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</table>
Coleoptera was the second most diverse taxon, with 14 families and 25 genera. Coleoptera had the third highest total density, but varied between the third and fourth position among the fields sampled (Table 2). Coleoptera sampled were characterized by few individuals of many genera. They were absent in Shenandoah, except for Aphodius (Table 1). Ptinella, the most abundant coleopteran genus, feeds on decaying plant tissue. Highest populations were sampled in August, but no correlation was found between Ptinella and the abiotic soil components studied.

Diptera was the fourth most diverse taxon, with 8 families and 14 genera. Diptera density was the third highest in Bloomfield and varied between fourth and fifth among other locations. However, its average was the fourth highest overall (Table 2). Phytophagous larvae of both Sciaridae and Cecidomyiidae (Nematocera) were the most abundant Diptera, having their highest populations in Sutherland and Bloomfield. Similar to Coleoptera, Diptera collections were made up of very few specimens scattered among many genera. Diptera were absent in Shenandoah (Tables 1 and 2).

Hymenoptera density was the fifth highest in Bloomfield, whereas Thysanoptera density was the third highest in Shenandoah. But, in general, density of each pterygotan order (excepting Coleoptera and Diptera) was less than 1% in every location (Table 2).

Each Myriapoda order was represented by 1 family and 1 genus. By far, the most abundant was Symphyla, which shared with Coleoptera the third highest density at Independence. Symphyla had the fifth highest population average (Table 2).
Populations with the highest PV generally possessed greater success in terms of density, distribution and tolerance to the limiting factors both extrinsic and intrinsic to these populations. Similarly, sites with highest PV sums indicated more favorable habitat for the edaphic micro-arthropods studied. Of the total number of populations in a community, a relatively small percentage was usually abundant (high PV), and a larger percentage was rare (low PV). It was the large percentage of rare populations that greatly determined community diversity in this study.

The Ames location had the largest total PV followed by Independence, Bloomfield, Sutherland, and Shenandoah, in that order. In Ames, Proisotoma (Collembola) comprised 64.2% and Rhysotritia (Acarina) 11.3% of the total PV. In Independence, the Collembola Tullbergia (19.5%), the Acarina Oppiella and Ceratozetes (17.4% and 15.1%, respectively) comprised 52% of the total PV. In Bloomfield, the Collembola Hypogastrura (14.2%), Onychiurus (7.1%), Katianinna (4.7%), Tullbergia (4.2%), the Acarina Ceratozetes (12.5%) and Oppiella (9.9%) comprised 52.6% of the total PV. In Sutherland, the Collembola Onychiurus (17.1%), Isotoma (10.1%), Tullbergia (9.1%) and the Acarina Oppiela (17%) comprised 53.3% of the total PV. In Shenandoah the Collembola Proisotoma (21.2%), Tullbergia (15.9%) and Sinella (12.8%) totaled 49.9% of the total PV (Table 1).

The Independence location had the largest microarthropod density followed by Bloomfield, Sutherland, Ames, and Shenandoah, in that order (Table 2). However the population diversity (Table 1) expressed by numbers of genera was highest in Bloomfield (59), followed by Independence (51), Ames (44), Sutherland (38), and Shenandoah (23).
From the foregoing data on population density, diversity and PV, it is evident that: (1) Acarina and Collembola comprised 89.3% of the microarthropod population, (2) 6 or less genera in each sample field comprised ca. 50% or more of the total PV, (3) the genera that constituted ca. 50% of the total PV belonged to the Collembola and Acarina, (4) Acarina and Collembola together represented 45.5% of the total number of the genera, (5) Coleoptera and Diptera characterized by few individuals of many genera. In the remaining Pterygota, the density of each order usually was less than 1% in every location, and (6) Symphyla was the most abundant Myriapoda, and Lithobiomorpha the most important sampled predator. Consequently, the effect of the abiotic soil components on the edaphic microarthropod population will be analyzed emphasizing the most important orders.

The soil environment 1972

Hydrogen-ion concentration Measurements of the soil pH in soybean fields, from June to August are presented in Table 3. The pH concentration was slightly acid (pH 6.15-6.20) in Independence and Shenandoah, very slightly acid (pH 6.60-6.70) in Sutherland and Bloomfield, and slightly alkaline (pH 7.18) in Ames.

In general, others have found that Acarina and Collembola populations are little affected by pH concentration. But, in Ames, the only alkaline site, the ratio between Acarina and Collembola densities was 1.07, whereas in the acidic sites ranged from 1.61-2.61 (Table 2). Thus, pH cannot be dismissed as a potentially causal factor of dissimilarity of the Ames site.
Protura specimens have been found to be affected by pH concentration (Raw, 1956). *Protentomon* specimens in this study were acidophil, with the highest number collected from the slightly acid Shenandoah site (Tables 2 and 3).

Hydrogen-ion concentration seemed not to be correlated with the number of *Parajapyx* (Diplura), but *Campodea* was found only in acidic soil. The *Campodea* number found, however, was too small to permit conclusions about interactions between pH and the specimens found (Tables 1 and 3).

*Symphylella* (Symphyla) seemed not to be affected by the pH range 6.15-7.18. The only two *Pauropodidae* (Pauropoda) found were in slightly to very slightly acidic sampling sites (Tables 2 and 3). In general, these data regarding Symphyla, Diplura, and Pauropoda substantiate Pearse's (1946) findings.

**Temperature** In the soybean agroecosystems studied, soil temperature in the row is more stable than between the rows. This was caused by the soybean canopy. Actually, no significant difference in soil temperature was found among soybean fields, as indicated by a low F ratio (1.26, P > 0.05) from the analysis of variance based on Table 3 data.

The temperature range favorable to most edaphic microarthropods has been shown to be 10-30 °C (Vannier, 1971). The range of the soil temperature recorded in this study was 18-26 °C (Table 3), falling within this favorable range. It can be hypothesized, therefore that temperature was not a limiting factor to microarthropod populations. Additionally, there were no stenothermal genera collected.
Table 3. Measurements of abiotic soil components in 5 soybean agroecosystems. Iowa, June to August 1972

<table>
<thead>
<tr>
<th>Date</th>
<th>Field</th>
<th>pH</th>
<th>Temperature °C</th>
<th>Moisture Content %</th>
<th>% Clay</th>
<th>% Sand</th>
<th>% Silt</th>
<th>Soil Texture</th>
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<tr>
<td>Jul 14</td>
<td>Bloomfield</td>
<td>6.70</td>
<td>26.1</td>
<td>10.7</td>
<td>18.75</td>
<td>50.87</td>
<td>30.38</td>
<td>Loam</td>
</tr>
<tr>
<td>Aug 29</td>
<td></td>
<td>20.9</td>
<td></td>
<td></td>
<td>10.9</td>
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<td>Aug 29</td>
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<td>23.5±3.68</td>
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<td>10.8±0.14</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug 30</td>
<td>Independence</td>
<td>6.15</td>
<td>25.3</td>
<td>16.0</td>
<td>15.00</td>
<td>61.25</td>
<td>23.75</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Aug 30</td>
<td></td>
<td>21.0</td>
<td></td>
<td></td>
<td>8.5</td>
<td></td>
<td></td>
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<tr>
<td>Aug 30</td>
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<td>23.2±3.04</td>
<td></td>
<td>12.3±5.30</td>
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</tr>
<tr>
<td>Aug 30</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jul 14</td>
<td>Shenandoah</td>
<td>6.20</td>
<td>25.5</td>
<td>16.0</td>
<td>20.00</td>
<td>51.88</td>
<td>28.12</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Aug 29</td>
<td></td>
<td>20.00</td>
<td></td>
<td></td>
<td>22.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug 29</td>
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<td>22.8±3.89</td>
<td></td>
<td>19.2±4.53</td>
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<tr>
<td>Jul 21</td>
<td>Sutherland</td>
<td>6.60</td>
<td>20.5</td>
<td>25.0</td>
<td>20.00</td>
<td>58.13</td>
<td>21.87</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Aug 30</td>
<td></td>
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<td>11.6</td>
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<td>Aug 30</td>
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<td>19.3±1.77</td>
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<td>18.3±9.48</td>
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</tr>
<tr>
<td>Aug 30</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jun 16</td>
<td>Ames</td>
<td>7.18</td>
<td>18.2</td>
<td>29.2</td>
<td>17.50</td>
<td>63.88</td>
<td>18.92</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Jun 30</td>
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<td>20.2</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Jun 30</td>
<td></td>
<td>19.0</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Aug 11</td>
<td></td>
<td>20.5</td>
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<td></td>
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<tr>
<td>Aug 11</td>
<td></td>
<td>19.6±1.25</td>
<td></td>
<td>24.4±5.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aug 11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(a\) Average of 2 aliquot samples.

\(b\) Average of 40 samples.

\(c\) Average of 4 samples.
The Myriapoda collected were not affected by the temperature recorded in this study. Specimens of Pauropodidae were found in the soil temperature range 18-20 °C, which Starling (1944) considered the optimum soil temperature for Pauropoda. Scutigerella was collected in soil temperature range 18-25 °C. But Symphyla are reported tolerant of a wide temperature range (Edwards, 1961). Therefore, this factor is considered not limiting for the specimens captured.

The highest soil temperature, 26.1 °C was recorded in Bloomfield during the sample period. At that temperature, Collembola (Brachystomella, Pseudosinella, Sinella, Hypogastrura, Folsomia, Onychyurus, Tullbergia) and Acarina (Belba, Platynothrus, Cepheus, Ceratozetes, Hypochthoniella, Epilohmannia, Galumna, Quadroppia, Oppiella, Xylobates, specimens of Phytoseiidae, Laelapidae and Rhodacaridae, Macrocheles and Scutacarus) seemed not to be affected.

In general, then, no correlation was found between temperature and density of Acarina and Collembola (Tables 2 and 3).

**Moisture** Texture, structure, and organic matter are the principal factors affecting the soil water-holding capacity. The finer textured the soil, the more water it holds.

In Iowa, a pH of 2.5 and 4.2 for a Clarion sandy loam correspond to values of 15.5 Pw and 7.2 Pw, respectively, for a Marshall silt loam 24.0 Pw and 12.7 Pw, respectively. Considering that the soil moisture recorded (Table 3) had values above the wilting point for the texture class, it is assumed that the soil atmospheres were saturated in those fields. Moreover, no significant difference in Pw was found among the soybeans fields, as indicated by a low F ratio (2.31, P > 0.05).
of an analysis of variance based on Table 3 data. Also, there was no correlation found between \( P_w \) and Collembola and Acarina densities. Consequently, the edaphic microarthropod behavior was not affected by an hydric deficit.

Edaphic microarthropods usually live in the larger soil capillaries, in which the atmosphere is an important part of their environment. The properties of the soil atmosphere are largely influenced by the soil moisture. Microarthropods are more responsive to an hydric excess than an hydric deficit, because water occupies soil capillaries and forces microarthropod migration. Consequently, it is the hydric excesses rather than the hydric deficits that should be considered as a potential causal factor affecting microarthropod communities in Ames (Tables 2 and 3).

In the 8.5-29.2\% range in soil moisture recorded (Table 3), there was no characterized stenohydric genus. *Lamycetes* (Chilopoda) was found in the high part of the range (16-29.2 \( P_w \)) a fact that may be explained by its sensitivity to the desiccation. However, euryhydric genera were found, such as Collembola (*Onychiurus*, *Tullbergia*, *Hypogastrura*, *Entomobrya*, *Isotoma*), Diplura (*Parajapyx*), Symphyla (*Symphylella*), and Acarina (*Rhysotritia*, *Oppiella*).

**Texture** The mean diameter of the soil pore space will limit the size of the microarthropods that thrive in it. The microarthropods' body size ranges from 0.20-10 mm, thus they must live in large soil pores. And, the finer textured the soil the smaller the pore spaces.

In the agroecosystems studied (Table 2), the greatest number of microarthropods was found at Independence. Also, the smallest amount of
clay was found at that site (Table 3), suggesting a potential relationship to microarthropod densities.

*Symphylella* (Symphyla) favored sandy loam soil with high content of sand particles, but *Parajapyx* (Diplura) seemed to be indifferent. Also, no correlation was found between soil texture class and the microarthropod densities (Tables 2 and 3).

**Agricultural practices** Agricultural practices interact with each other in their effects on microarthropods. Some of these act synergistically, and others act in opposition. Thus, they change the microarthropod population quantitatively and qualitatively.

The absence of Isopoda, Diplopoda, Cryptostigmata (Damaeidae), the presence of only 2 Chilopoda specimens, and a relatively small number of Collembola (Entomobryidae, Sminthuridae), indicated that those populations tended to quickly decrease after plowing and diskling. However, Collembola (*Onychiurus, Tullbergia*) and Cryptostigmata (*Oppiella*) were still abundant in the agroecosystems after tillage. These data agreed with Ghilarov's (1975) statements.

Surface plowing in autumn and diskling in the following spring were the general tillage practices in all fields studied. Acarina, Collembola, Diplura and other microarthropods reportedly migrate to deeper, warmer soil layers in the winter and reverse this migration to the upper layers in the spring (Odetoyinbo, 1957). Thus, the habitat and, subsequently, the density of edaphic microarthropods were disturbed at the end and at the beginning of each cropping season. In addition, monoculture tends to eliminate those microarthropods associated with other than the crop plant.
These factors are considered of great importance in explaining the low microarthropod densities in soybean fields (Table 2), compared with those of less disturbed woodland and pasture ecosystems. In the soybean agroecosystems, population densities were expressed by hundreds/m$^2$, whereas in woodland and pasture, they are usually cited in thousands/m$^2$ (Kevan, 1968; Phillipson, 1971).

Sampling Program 1973-1974

Microarthropod fauna

The same fields were sampled during the cropping seasons of 1973 and 1974. Thus, the data from those sampling programs will be presented and discussed together.

In the 1973 sampling program, 12,312 microarthropod specimens were collected, representing 19 orders, 92 families, and 162 genera. In 1974 the microarthropods sampled comprised 18,193 specimens, 17 orders, 90 families, and 141 genera. A complete list of these arthropods is presented in Tables 4 and 5.

Acarina was the most diverse order (Table 6), and in this taxon Cryptostigmata was the most abundant. For both cropping seasons, the most prominent Cryptostigmata were Cepheus (PV = 275.13), Tectocepheus (PV = 157.29), and Ceratozetes (PV = 100.53). The most numerous Cryptostigmata in corn (1973), soybean (1973-1974) and rotation (1974) agroecosystems were Cepheus, Tectocepheus and Ceratozetes. However, Oppiella was more numerous than Ceratozetes in rotation (1973) and in corn (1974) agroecosystems.
Table 4. Total prominence values of edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation\(^a\) agroecosystems. Ames, June to October 1973

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Corn Fields</th>
<th>Soybean Fields</th>
<th>Rotation Fields</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>C-1 C-2 C-3 C-4</td>
<td>S-1 S-2 S-3 S-4</td>
<td>R-1 R-2 R-3 R-4</td>
</tr>
<tr>
<td><strong>COLLEMBOLA</strong></td>
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<tr>
<td>Anurida</td>
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</tr>
<tr>
<td>Brachystomellida</td>
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<td></td>
</tr>
<tr>
<td><strong>Entomobryidae</strong></td>
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<td>1.13</td>
</tr>
<tr>
<td>Lepidocyrtus</td>
<td>3.46 19.16 1.91 36.82</td>
<td>15.01 0.25 0.25 3.78</td>
<td>8.56 0.39 0.38</td>
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<td>Orchesella</td>
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<td>2.51</td>
<td>1.21 0.26</td>
</tr>
<tr>
<td>Pseudosinella</td>
<td>1.50 7.63 3.15 0.13</td>
<td>7.75 23.99 5.77 11.43</td>
<td>0.71</td>
</tr>
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</tr>
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<td>0.26 0.91</td>
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<tr>
<td>Proisotoma</td>
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**TOTAL**  
38.21 140.50 26.50 115.44 142.45 87.13 34.63 121.68 32.69 43.44 96.30 72.83
Table 5. Total prominence values of edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation* agroecosystems. Ames, June to October 1974

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^aCorn in 1974.

^bImmature.
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<td>121</td>
<td>92</td>
<td>162</td>
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</tbody>
</table>

In 1973, the most numerous predatory Mesostigmata were Rhodacaridae specimens in corn and rotation agroecosystems, and Laelaptidae specimens in soybean fields. In 1974, Rhodacaridae were the most abundant Mesostigmata in the agroecosystems studies (Tables 4 and 5).

The most abundant Prostigmata (Tables 4 and 5) were **Scutacarus** in corn (1973-1974), and soybean (1974), and **Rhagidia** was the most numerous in soybean (1973) and rotation (1973-1974) agroecosystems.
Acarina always presented the highest population densities (Tables 7 and 8), averages, and total percentages in all fields studied. In 1973 and 1974, the Acarina density averages (hundreds/m²) ± standard errors were: corn 23.53±4.54 and 51.54±9.46, soybean 38.73±7.29 and 25.69±5.66, and rotation 26.21±3.90 and 64.20±7.22.

The acarid percentages of the total microarthropod population in 1973 and 1974 were: corn 73.08% and 83.04%, soybean 80.42% and 77.22%, and rotation 79.73% and 88.6%. Thus, from 1973 to 1974, both Acarina density and its percentage of the total population increased in corn and rotation and decreased in soybean agroecosystems. The ratio between Acarina and Collembola densities varied from 2.32-12.73 in 1973 and 2.57-40.82 in 1974 (Tables 7 and 8).

Collembola always presented the second highest density (Tables 7 and 8), and the most prominent Collembola for both cropping seasons were Lepidocyrtus (PV = 207.31), Proisotoma (PV = 180.39) and Pseudosinella (PV = 112.69).

The most numerous Collembola were: corn (1973) Lepidocyrtus, Proisotoma, Isotoma, and in 1974 Lepidocyrtus, Pseudosinella and Onychiurus; soybeans in 1973 and 1974 Pseudosinella, Folsomia, Lepidocyrtus, (the latter was replaced by Proisotoma in 1974); and rotation Proisotoma, Isotoma, Lepidocyrtus in 1973 and Proisotoma, Folsomides, Isotoma in 1974 (Tables 4 and 5).

Collembola was the third most diverse order (Table 6), and its average density (hundreds/m²) ± standard error in 1973 and 1974 was: corn 7.69±2.25 and 8.92±3.75, soybeans 6.80±1.51 and 6.17±1.07, and rotation 5.80±0.81 and 6.38±0.71. The collembolan percentage of the
Table 7. Population density (hundreds/m²) of edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1973

<table>
<thead>
<tr>
<th>Taxa</th>
<th>C-1</th>
<th>C-2</th>
<th>C-3</th>
<th>C-4</th>
<th>S-1</th>
<th>S-2</th>
<th>S-3</th>
<th>S-4</th>
<th>R-1</th>
<th>R-2</th>
<th>R-3</th>
<th>R-4</th>
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</thead>
<tbody>
<tr>
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<td>34.44</td>
<td>13.36</td>
<td>26.72</td>
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<td>30.62</td>
<td>32.31</td>
<td>31.43</td>
<td>27.23</td>
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<td>0.18</td>
<td>0.07</td>
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<td>0.22</td>
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<td>2.54</td>
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<td>0.66</td>
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<td>0.15</td>
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<td>0.04</td>
<td>0.11</td>
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<td></td>
<td></td>
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<td>0.04</td>
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<td>0.11</td>
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<tr>
<td>TOTAL</td>
<td>24.80</td>
<td>47.96</td>
<td>17.38</td>
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<td>70.36</td>
<td>40.48</td>
<td>36.57</td>
<td>45.45</td>
<td>31.50</td>
<td>22.74</td>
<td>42.72</td>
<td>34.44</td>
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</table>

Table 8. Population density (hundreds/m²) of edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1974

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Corn Fields</th>
<th>Soybean Fields</th>
<th>Rotation Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C-1  C-2  C-3  C-4</td>
<td>S-1  S-2  S-3  S-4</td>
<td>R-1  R-2  R-3  R-3</td>
</tr>
<tr>
<td>Acarina</td>
<td>47.80  78.94  35.92  43.50</td>
<td>23.00  18.99  18.40  42.39</td>
<td>61.79  50.38  84.49  60.13</td>
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<tr>
<td>Araneida</td>
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<td>0.15  0.40  0.07  0.04</td>
<td>0.04  0.07  0.04</td>
</tr>
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</tr>
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<td>0.07  0.04  0.22  0.04</td>
<td>0.37  0.22  0.04</td>
</tr>
<tr>
<td>Lithobiomorpha</td>
<td>0.11  0.07  0.37  0.04</td>
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<td></td>
</tr>
<tr>
<td>Polydesmida</td>
<td>0.77  0.04  0.04  0.04</td>
<td>0.04  0.04  0.04  0.04</td>
<td></td>
</tr>
<tr>
<td>Pauropoda</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symphyla</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Collembola</td>
<td>4.23  16.08  0.88  14.50</td>
<td>8.94  4.49  4.45  6.81</td>
<td>6.88  6.96  7.40  4.27</td>
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<tr>
<td>Diplura</td>
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<td></td>
</tr>
<tr>
<td>Protura</td>
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<td>0.04</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>0.77  0.55  0.33  0.26</td>
<td>0.44  0.37  0.29  0.66</td>
<td>0.48  0.81  1.14  3.05</td>
</tr>
<tr>
<td>Diptera</td>
<td>0.33  0.11  0.18  0.66</td>
<td>0.22  0.07  0.26  0.22</td>
<td>0.26  0.29  0.44  0.33</td>
</tr>
<tr>
<td>Hemiptera</td>
<td>0.04  0.04  0.04  0.04</td>
<td>0.04  0.11  0.04  0.04</td>
<td>0.04  0.07  0.04  0.15</td>
</tr>
<tr>
<td>Homoptera</td>
<td>0.04  0.22  0.04  0.26</td>
<td>0.04  0.04  0.04  0.04</td>
<td>0.04  0.04  0.04  0.11</td>
</tr>
<tr>
<td>Hymenoptera</td>
<td>0.04  0.11  0.04  0.04</td>
<td>0.04  0.04  0.04  0.04</td>
<td>0.04  0.04  0.11  0.11</td>
</tr>
<tr>
<td>Thysanoptera</td>
<td>0.07  0.26  0.26  0.48</td>
<td>0.07  0.07  0.04  0.11</td>
<td>0.04  0.11  0.11  0.11</td>
</tr>
<tr>
<td>TOTAL</td>
<td>53.36  97.00  37.61  60.51</td>
<td>33.06  24.45  24.47  50.34</td>
<td>70.41  59.00  93.73  68.48</td>
</tr>
</tbody>
</table>

*Corn in 1974.
total microarthropod populations in 1973 and 1974 were: corn 23.85% and 14.38%, soybean 14.11% and 18.67% and rotation 17.64% and 18.67%. From 1973 to 1974, density of Collembola decreased in soybean fields, but its percentage of the total population increased.

Spinisotoma (Collembola) was recorded for the first time in Iowa, as being associated with coniferous vegetation and sloping topography (Wonio and Pedigo, 1974). Spinisotoma is here recorded for the first time in soybean agroecosystems, and collected at a depth of 0.6 cm in a sandy clay loam soil, with pH 8.2, 23.7 Pw, and 21.3 °C of soil temperature in June 21, 1973.

The remaining microarthropod orders each had population density averages (hundreds/m^2) less than 1.00 in every crop studied. Likewise, each had a total percentage of less than 1.00, except for Coleoptera and Diptera.

Of the remaining Apterygota orders, predaceous Diplura were represented by 2 families and 2 genera, and Protura 1 family and 1 genus (Table 6). Diplura density was about 1% of the total population in the S-3 field in 1973. In the other fields, each of these two orders was less than 1%.

Coleoptera was the second most diverse order (Table 6), and had the third highest total population density. Coleoptera total percentage in corn (1973) was 1.06, in soybean (1973) 1.68 and in rotation (1974) 1.88. In general, Coleoptera sampled were characterized by few individuals of many genera (Tables 7 and 8). Anthicidae larvae were the most numerous Coleoptera for the 1973-1974 sampling period, but Prinella was the most abundant in 1973. Diabrotica longicornis larvae
and eggs were recorded for the first time in Iowa soybeans.

Diptera was the fourth most diverse order (Table 6), and had the fourth highest total population density. Similar to Coleoptera, Diptera collections were made up of few specimens of many genera. Cecidomyiidae larvae were the most abundant Diptera for the 1973-1974 sampling period (Tables 4 and 5). Diptera percentage of the total microarthropod population in soybeans (1973) was 2.16%.

Each Myriapoda order was represented by 1 family and 1 genus. Lithobiomorpha was the most abundant myriapod, and, in 1973, had the fifth highest total microarthropod density in the agroecosystems studied. In 1974, Pauropoda had that position in corn agroecosystems.

In an edaphic microarthropod community, populations are not equal in determining the characteristics of the whole community. It is the high density of a few populations that exert the major influence on community properties. Thus, in the 1973-1974 sampling period, the 6 or less genera that comprized about 50% of the total PV in each field are listed in Tables 9 and 10.

From the preceding 1973-1974 data on population density, diversity, and PV, it is evident that: (1) Acarina (80.35%) and Collembola (16.23%) comprised 96.58% of the total microarthropod population, (2) 6 or less genera in each sampled field totaled about 50% of the total PV, (3) the great majority of the genera comprising ca. 50% of the total PV belonged to the Acarina and the Collembola, (4) Acarina and Collembola together represented about 48% of the total number of genera, (5) the remaining microarthropod orders, except for Coleoptera and Diptera, each had a total population density (hundreds/m²) less than 1.00 in every
Table 9. Percentage of the total PV of the most prominent edaphic Arthropoda in 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1973.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Corn Fields</th>
<th>Soybean Fields</th>
<th>Rotation Fields</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>C-1  C-2 C-3 C-4</td>
<td>S-1  S-2  S-3  S-4</td>
<td>R-1  R-2  R-3  R-4</td>
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<td>Entomobrya</td>
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</tr>
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<td>Lepidocyrtus</td>
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<tr>
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</tr>
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<td>Cepheus</td>
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<td>53.19</td>
<td>50.14</td>
<td>57.18  60.11</td>
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^b Immature.
Table 10. Percentage of the total PV of the most prominent edaphic Arthropoda in 4 continuous corn, 4 continuous soybean and 4 oats-soybean-corn rotation agroecosystems. Ames, June to October 1974

<table>
<thead>
<tr>
<th>Taxa</th>
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^Corn in 1974.

b Immature.
crop studied, and (6) Lamyctes (Lithobiomorpha) was the most abundant myriapod and the second most numerous predator sampled. Consequently, the effect of the soil components on the edaphic microarthropods will be analyzed, emphasizing the most important orders.

The soil environment 1973-1974

Hydrogen-ion concentration Measurements of the abiotic soil components of the agroecosystems studied are listed in Tables 11 to 16. Acidic fields were C-1 (1973), R-1 (1973), S-1 and S-3 (1973-1974); the remaining fields were alkaline. In 1973, ratios between Acarina and Collembola were higher in acidic than in alkaline fields, except in field C-1. This trend was also noticed in the 1972 study. But in 1974, those ratios were higher in alkaline than in acidic fields, except in field R-2. Therefore, the relationship between pH concentration and microarthropod populations should be analyzed in association with the factors affecting each agroecosystem.

Parajapyx (Diplura) seemed not to be affected by the pH range 6.2-8.1. The number of the basophilic Campodea was too small to permit conclusions about interaction between pH and the specimens found. Acerentomidae specimens were basophilic, and these data agreed with Raw's (1956) statements that Protura is affected by pH concentration.

Lamyctes (Chilopoda) and Polydesmida (Diplopoda) were found from slightly acid to medium alkaline fields. Pauropus (Pauropoda) and Symphylella (Symphyla) were found in very slightly acid to slightly alkaline soils. Arenophylus (Geophilomorpha) was basophilic. Of these myriapods, Lamyctes showed the widest pH range.
Table 11. Measurements of abiotic soil components in 4 continuous corn agroecosystems. Ames, June to October 1973

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<tr>
<th>Date</th>
<th>Field</th>
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<th>Temperature °C</th>
<th>% Moisture Content</th>
<th>% Pore Space</th>
<th>% Clay</th>
<th>% Sand</th>
<th>% Silt</th>
<th>Soil Texture</th>
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^aAverage of 2 aliquot samples.

^bAverage of 16 samples.
Table 12. Measurements of abiotic soil components in 4 continuous soybean agroecosystems. Ames, June to October 1973

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<th>% Pore</th>
<th>% Clay</th>
<th>% Sand</th>
<th>% Silt</th>
<th>Soil Texture</th>
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\( ^a \) Average of 2 aliquot samples.

\( ^b \) Average of 16 samples.
Table 13. Measurements of abiotic soil components in 4 oats-soybean-corn rotation\textsuperscript{a} agroecosystems. Ames, June to October 1973

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<th>Temperature\textsuperscript{c} \degree C</th>
<th>% Moisture\textsuperscript{c} Content</th>
<th>% Pore\textsuperscript{c} Space</th>
<th>% Clay</th>
<th>% Sand</th>
<th>% Silt</th>
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\textsuperscript{a}Soybean in 1973.

\textsuperscript{b}Average of 2 aliquot samples.

\textsuperscript{c}Average of 16 samples.
Temperature  No significant difference ($P > 0.05$) was found in soil temperature among the fields in 1973 and 1974, as indicated by analyses of variance of the data of the Tables 11 to 16. Soil temperature ranged from 17-21 °C in 1973. This range fell within the range (15-30 °C) reported to have little affect on microarthropods (Vannier, 1971). On October 3, 1974 the soil temperature was at its lowest throughout the study (8-11.4 °C). On that date, the highest total number of microarthropods was sampled in fields S-1, S-2, S-3, R-1, and R-3, with the second highest total found in fields C-1, C-4, S-4, and R-2 in 1974. Consequently, during the sampling period, temperature did not seem to be a limiting factor to the microarthropods studied.

The lowest soil temperature, 8.0 °C, was recorded in field C-1. At that temperature, density of Acarina (Cepheus, Rhysotritia, Oppiella, Tectocephus, Ameroseius, Amblyseius, specimens of Rhodacaridae, and Imparipes) and Collembola (Orchesella, Pseudosinella, Isotoma and Sminthurinus) seemed not to be limited.

Moisture  The soil moisture content recorded had values above the wilting point for all of the texture classes in this study. Thus, it is assumed that the soil atmosphere was saturated in those fields studied. Significant differences in soil moisture content were found in corn ($F = 24.74, P < 0.05$) in 1973, and soybeans ($F = 6.24, P < 0.05$) in 1974, as indicated by analyses of variance of data in Tables 11 and 15. The results of the Duncan's Multiple Range Test ($P < 0.05$) of average of soil moisture content for corn and soybean agroecosystems are given in Table 17.
Table 14. Measurements of abiotic soil components in 4 continuous corn agroecosystems. Ames, June to October 1974

<table>
<thead>
<tr>
<th>Date</th>
<th>Field</th>
<th>pH</th>
<th>Temperature</th>
<th>% Moisture</th>
<th>% Pore</th>
<th>% Clay</th>
<th>% Sand</th>
<th>% Silt</th>
<th>Soil Texture</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>°C</td>
<td>Content</td>
<td>Space</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>June 25</td>
<td>C-1</td>
<td>7.7</td>
<td>19.8</td>
<td>24.9</td>
<td>52.8</td>
<td>15.0</td>
<td>58.7</td>
<td>26.3</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Jul 30</td>
<td></td>
<td>5.7</td>
<td>19.0</td>
<td>34.7</td>
<td>47.1</td>
<td>21.0</td>
<td>52.8</td>
<td>26.3</td>
<td>Sandy Clay Loam</td>
</tr>
<tr>
<td>Aug 21</td>
<td></td>
<td>8.0</td>
<td>20.0</td>
<td>20.4</td>
<td>53.2</td>
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<td></td>
</tr>
<tr>
<td>Oct 3</td>
<td></td>
<td>8.0</td>
<td>8.0</td>
<td>18.5</td>
<td>49.1</td>
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</tr>
<tr>
<td>Grand X</td>
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<td>7.5</td>
<td>17.5±6.36</td>
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<tr>
<td>Aug 21</td>
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<td>27.6</td>
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<td>9.0</td>
<td>20.6</td>
<td>44.5</td>
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<tr>
<td>Grand X</td>
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<td>17.6±5.35</td>
<td>27.3±5.39</td>
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</tr>
<tr>
<td>Jun 25</td>
<td>C-3</td>
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<td>19.0</td>
<td>17.0</td>
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<td>15.0</td>
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<td>C-4</td>
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<td>55.0</td>
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<td>Sandy Clay Loam</td>
</tr>
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<td>27.7</td>
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<td>Aug 21</td>
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<td>22.0</td>
<td>24.7</td>
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<td>18.7</td>
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</tbody>
</table>

a Average of 2 aliquot samples.

b Average of 16 samples.
Table 15. Measurements of abiotic soil components in 4 continuous soybean agroecosystems. Ames, June to October 1974

<table>
<thead>
<tr>
<th>Date</th>
<th>Field</th>
<th>pH&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Temperature&lt;sup&gt;b&lt;/sup&gt;</th>
<th>% Moisture&lt;sup&gt;b&lt;/sup&gt;</th>
<th>% Pore Space</th>
<th>% Clay</th>
<th>% Sand</th>
<th>% Silt</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 25</td>
<td>S-1</td>
<td>6.5</td>
<td>18.4</td>
<td>22.6</td>
<td>42.0</td>
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<td>61.2</td>
<td>18.5</td>
<td>Sandy Loam</td>
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<td>17.4</td>
<td>42.7</td>
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<td>68.0</td>
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<td>17.7</td>
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<tr>
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<td>8.3</td>
<td>20.3</td>
<td>23.7</td>
<td>49.4</td>
<td>20.0</td>
<td>44.0</td>
<td>36.0</td>
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<td>Jul 30</td>
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<td>27.2</td>
<td>53.8</td>
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<td>50.2</td>
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<tr>
<td>Oct 3</td>
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<td>11.4</td>
<td>11.4</td>
<td>20.5</td>
<td>46.4</td>
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<tr>
<td>Grand X</td>
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<td>18.6±4.87</td>
<td>24.6±3.17</td>
<td>49.9±3.04</td>
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</tbody>
</table>

<sup>a</sup>Average of 2 aliquot samples.

<sup>b</sup>Average of 16 samples.
Table 16. Measurements of abiotic soil components in 4 oats-soybean-corn rotation^ agroecosystems. Ames, June to October 1974

<table>
<thead>
<tr>
<th>Date</th>
<th>Field</th>
<th>pH</th>
<th>Temperature (°C)</th>
<th>% Moisture Content</th>
<th>% Pore Space</th>
<th>% Clay</th>
<th>% Sand</th>
<th>% Silt</th>
<th>Soil Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jun 25</td>
<td>R-1</td>
<td>6.3</td>
<td>20.3</td>
<td>16.9</td>
<td>48.3</td>
<td>20.0</td>
<td>55.0</td>
<td>25.0</td>
<td>Sandy Loam</td>
</tr>
<tr>
<td>Jul 30</td>
<td></td>
<td>20.5</td>
<td>30.1</td>
<td>54.3</td>
<td></td>
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<td>Aug 21</td>
<td></td>
<td>22.0</td>
<td>21.5</td>
<td>46.8</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Oct 3</td>
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<td>9.1</td>
<td>14.6</td>
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<tr>
<td>Grand X</td>
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<td>18.0</td>
<td>20.8±6.85</td>
<td>48.1±4.70</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

| June 25 | R-2   | 7.2 | 17.9             | 23.5               | 50.2         | 19.0   | 55.0   | 26.0   | Sandy Loam    |
| Jul 30  |       | 20.5| 22.7             | 40.4               |              |        |        |        |                |
| Aug 21  |       | 22.0| 23.6             | 43.8               |              |        |        |        |                |
| Oct 3   |       | 9.0 | 15.8             | 44.5               |              |        |        |        |                |
| Grand X |       | 17.4| 21.4±3.75        | 44.7±4.07          |              |        |        |        |                |

| Jun 25  | R-3   | 8.3 | 19.5             | 23.4               | 55.5         | 31.0   | 49.0   | 20.0   | Sandy Clay Loam|
| Jul 30  |       | 20.3| 27.7             | 42.6               |              |        |        |        |                |
| Aug 21  |       | 22.0| 30.3             | 51.3               |              |        |        |        |                |
| Oct 3   |       | 8.4 | 18.2             | 44.5               |              |        |        |        |                |
| Grand X |       | 17.6| 24.9±5.30        | 48.5±5.99          |              |        |        |        |                |

| Jun 25  | R-4   | 7.2 | 18.8             | 25.4               | 50.2         | 20.0   | 58.0   | 22.0   | Sandy Clay Loam|
| Jul 30  |       | 20.0| 19.9             | 40.0               |              |        |        |        |                |
| Aug 21  |       | 21.8| 28.3             | 49.8               |              |        |        |        |                |
| Oct 3   |       | 8.6 | 23.0             | 46.8               |              |        |        |        |                |
| Grand X |       | 17.3| 24.2±3.57        | 46.7±4.72          |              |        |        |        |                |

^Corn in 1974.

^Average of 2 aliquot samples.

^Average of 16 samples.
Table 17. Duncan's Multiple Range Test of averages of soil moisture content for 4 continuous corn (1973) and 4 continuous soybean (1974) agroecosystems in Ames

<table>
<thead>
<tr>
<th>Corn Agroecosystem</th>
<th>Soybean Agroecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>% Moisture Content&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>C-3</td>
<td>19.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>C-1</td>
<td>21.73&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>C-4</td>
<td>30.92&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>C-2</td>
<td>32.50&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Values followed by the same letter do not differ significantly at the 5% level.

Consequently, a hydric deficit should not be considered as a potentially limiting factor affecting microarthropods in those agroecosystems. In corn agroecosystems (1973), a direct relationship was observed between soil moisture content and population density of Acarina, Collembola, and the total microarthropod population (Table 7). This relationship was not found in soybeans (1974).

Diplura, Protura, Lithobiomorpha, Geophilomorpha, Polydesmida, Pauropoda and Symphytula favored soil with high moisture content. Of these orders, *Lamycetes* (Lithobiomorpha) was found over the widest range of soil moisture content, 15.3-32.1%. In general, these findings substantiate previous statements (Blower, 1955; Edwards, 1961; Kevan, 1968; Wallwork, 1970) that these orders are dependent on high soil moisture.

Pore space Tilled soil usually has less total percentage pore space than untilled soil of the same type, and this percentage varies
within the texture class, e.g., 48.8-59.2% in silt loam (Thompson, 1957).

In 1974, significant differences in total percentage soil pore space was found in corn fields \( (F = 4.27, P < 0.05) \), as indicated by an analysis of variance of data in Table 14. The results of the Duncan's Multiple Range Test \( (P < 0.05) \) of average of total percentage of soil pore space for corn agroecosystems are given in Table 18.

Table 18. Duncan's Multiple Range Test of averages of total percentage of soil pore space for 4 continuous corn agroecosystems. Ames, 1974

<table>
<thead>
<tr>
<th>Corn Agroecosystem</th>
<th>Field</th>
<th>% Pore Space^</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C-3</td>
<td>43.20^b</td>
</tr>
<tr>
<td></td>
<td>C-4</td>
<td>50.72 c</td>
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<td>C-2</td>
<td>51.33 c</td>
</tr>
<tr>
<td></td>
<td>C-1</td>
<td>51.50 c</td>
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</tbody>
</table>

^Values followed by the same letter do not differ significantly at the 5% level.

During 1973, field C-3 had the lowest population density sampled (Table 7), and in 1974 was lowest in this respect among corn fields (Table 8). Therefore, the total percentage of soil pore space cannot be dismissed as a potentially causal factor of the dissimilarity of field C-3.

**Texture** A clay content of about 20-25% of the soil particles provides desirable qualities of aeration, water-holding capacity, and nutrient-holding capacity (Thompson, 1957).
Fields C-1, C-3, S-2, S-3, and R-2 had percentage clay lower than 20% in the sampling period 1973-1974. Also, these fields had the smallest population density in each crop (Tables 7 and 8). Thus, the percentage of clay should be considered as a potential factor, affecting microarthropod densities in these fields.

Agricultural practices  Surface plowing in autumn and disk ing the following spring were the general tillage practices in the fields studied. Hemiedaphic microarthropods tend to rapidly decrease after soil tillage, and abundant arthropods in uncultivated soil are rare or absent in crop soils. In this study, the absence of Blattaria and Damaeidae, the presence of a few Polydesmida, Geophilomorpha, and Galumnidae, and relatively small numbers of Sminthuridae, indicated that these populations tended to quickly decline after plowing and disk ing. However, Onychiurus, Tullbergia and Oppiella were still abundant in the agroecosystems after tillage. These data agreed with Ghilarov's (1975) statement.

Therefore, monoculture and disturbance of the agroecosystems by tillage practices are considered of great importance in explaining the low microarthropod density in the fields studied (Tables 7 and 8).

Pesticides  In 1974, cornfields C-2 and C-3 received carbofuran treatment (1.12 kg actual ingredient/ha), and the remaining fields had not received soil insecticide treatment for at least 4 years prior to the study. Carbofuran was applied in these alkaline corn fields during the third week of May.

In the agroecosystems studied, the quantity (ppb) of chlorinated hydrocarbon insecticide residues recovered from soil were: DDE 8-50,
DDT 40-160, and Dieldrin 14-198. The small amounts found are considered unharmful to the microarthropods studied. The recovery of these pesticides is understandable because they had been widely used in Iowa, although not in these agroecosystems in the last few years.

Carbofuran was recovered from soil samples on July 30, 1974, and the quantities found were 30 ppb in field C-2 and 6 ppb in C-3. Carbofuran treatment adversely affected Mesostigmata populations, and the ratios of decline in Mesostigmata PV between 1973 and 1974 are given in Table 19.

Table 19. Ratio of decline between 1973 and 1974 Mesostigmata PV in 4 continuous corn, 4 continuous soybean and oats-soybean-corn rotation\textsuperscript{a} agroecosystems in Ames

<table>
<thead>
<tr>
<th>Corn Agroecosystems</th>
<th>Soybean Agroecosystems</th>
<th>Rotation Agroecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>Ratio</td>
<td>Field</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>C-1</td>
<td>0.77</td>
<td>S-1</td>
</tr>
<tr>
<td>C-2\textsuperscript{b}</td>
<td>6.70</td>
<td>S-2</td>
</tr>
<tr>
<td>C-3\textsuperscript{b}</td>
<td>4.17</td>
<td>S-3</td>
</tr>
<tr>
<td>C-4</td>
<td>0.68</td>
<td>S-4</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Corn in 1974.

\textsuperscript{b}Carbofuran treated fields.

Thus, Mesostigmata populations decreased in carbofuran treated fields and increased in untreated C-1 and C-4. These populations decreased in all rotation and soybean fields, except for S-2. The Mesostigmata decrease in treated cornfields was substantially greater than that in rotation and soybean fields. This difference in decline is believed to be attributed to the carbofuran treatment to fields C-2 and C-3.

From 1973 to 1974, Cryptostigmata populations (Cepheus, Tectocepheus,
Ceratozetes and Oppiella) substantially decreased in carbofuran treated cornfields. In untreated cornfields, Cepheus, Oppiella, and Ceratozetes (C-4) increased, but the Tectocepheus population was about the same (Tables 4 and 5). Thus, the carbofuran treatment was considered a limiting factor affecting these populations in cornfields. The effects of a single carbofuran application on these Cryptostigmata differed from those of a single DDT application studied by Dindal et al. (1975).

During the same sampling period, Acarina density increased in all fields, except for S-1, S-2, and S-3 (Tables 7 and 8). Consequently, carbofuran selectively affected Mesostigmata and certain Cryptostigmata populations.

During the sampling period 1973-1974, the lowest Collembola population (prey) coincided with the highest Mesostigmata population (predator), and vice-versa, except for fields C-4, R-3, and R-4 (Tables 4 and 5). Carbofuran application did not quantitatively change the ratio between prey and predator.

From 1973 to 1974, the population density of edaphic microarthropods increased in all fields, except for soybean S-1, S-2, and S-3 (Tables 7 and 8). Therefore, carbofuran did not affect the total microarthropod density studied.

Ordination

The location of an agroecosystem in the ordination is the result of all genera present and their densities and frequencies. However, to explain ordination using all microarthropod genera would be difficult. Therefore, relationships among microarthropod populations and the agroecosystems in the ordination will be based on the most prominent
populations, viz., those comprising ca. 50% of the total PV.

To explain the ordination calculated in this study, gradients of fields were established for each abiotic factor measured. When these gradients were compared to those of the ordination X- and Y-axis, no relationship could be seen. Therefore, it was believed that these factor should be considered in total, as they relate to prominent genera.

**Ordination of agroecosystems: 1972**

Results of the ordination for 1972 are presented in Fig. 6. The most prominent Acarina genera, Ceratozetes, Oppiella, and Rhysotritia, were found in all sampling sites. Common Collembola genera were Onychiurus, Tullbergia, and Sinella. Hypogastrura, Proisotoma, Katianinna were restricted to only 2 or less sites, and Isotoma was intermediate in presence.

The great dissimilarity of the Ames site is primarily caused by its high number of a restricted Proisotoma, and to the unusually high occurrence of a common Rhysotritia. These 2 genera comprised 75.5% of the total PV at Ames site.

The dissimilarity of the Shenandoah site is primarily caused by its high number of a restricted Proisotoma and to the unusually high occurrence of the common genera Tullbergia and Sinella. Sutherland, Independence, and Bloomfield sites are clustered. Their closeness was primarily caused by the high number of specimens of common genera found in those sites. Onychiurus, Oppiella, Isotoma and Tullbergia made up 53.3% of the total PV at the Sutherland site. Tullbergia, Oppiella,
Figure 6. Ordination of 5 soybean agroecosystems: 1972
and Ceratozetes comprised 52% of the total PV at the Independence site. The Bloomfield site was characterized by the unusually high numbers of the restricted genera Hypogastrura and Katianinna, and a relatively high number of the common genera Ceratozetes, Oppiella, Onychiurus, and Tullbergia.

The Ames site (the first reference point in the X-axis) is characterized by having the only alkaline soil, the highest soil moisture content ($\bar{X} = 24.4\%$), the highest sand content (63.8%), and the lowest silt content (18.92%) of any site studied.

Bloomfield, the most dissimilar site from Ames on the X-axis, is characterized by having acidic, loam soil, the lowest moisture content ($\bar{X} = 10.8\%$), and the lowest sand content (40.87%). Also, this site had both the highest soil temperature ($\bar{X} = 25.3\%$) and silt content (30.38%).

Usually, the remaining sampling sites had abiotic soil components whose values were intermediate between those of the Ames and Bloomfield sites. Independence also had the most acidic soil (pH = 6.15) and the lowest clay content (15%). Shenandoah and Sutherland sites had the highest clay content (20%).

Population diversity, expressed by numbers of genera, was highest in Bloomfield (59), followed by Independence (51), Ames (44), Sutherland (38), and Shenandoah (23).

**Ordination of agroecosystems: 1973**

The results of the ordination for 1973 are presented in Fig. 7. In this ordination, the agroecosystems presented characteristic patterns of distribution. Cornfields were characterized by two distinct groups,
Figure 7. Ordination of 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems: 1973
CORN

SOYBEANS

ROTATION
(SOYBEANS IN 1973)

X-AXIS

UNITS OF DISSIMILARITY

Y-AXIS

UNITS OF DISSIMILARITY
well apart from each other. Fields C-3 and C-1 were grouped in the first 1/3 of the X-axis, and fields C-4 and C-2 were paired in the last 1/3 of this axis. Soybean fields also comprised two different groups. Fields S-3, S-2, and S-4 were clustered in the middle 1/3 of the X-axis, whereas S-1 is positioned at the distal end of this axis. Rotation fields form a loose group in the middle 1/3 of the X-axis.

The most prominent microarthropods in corn, soybean, and rotation agroecosystems are listed in Table 9, and the measurements of the abiotic soil components of these systems are cited in Tables 11 to 13. But each field had its own faunal and edaphic peculiarities that should be pointed out.

Cornfield C-3, the first reference point on the X-axis (x = 0.0), and C-1 (x = 22.5), the closest field to C-3, had sandy loam soil. Fields C-4 (x = 62.4) and C-2 (x = 64.5) had sandy clay soil. The soil moisture content was significantly different in cornfields C-3 and C-1 from fields C-4 and C-2 (Table 17). Rhodacaridae was the most abundant in field C-3, and *Scutacarus* the most numerous Acarina in field C-1. An unusually high number of *Entomobrya* occurred in the field C-4, and common genera were the most prominent arthropods in the field C-2. Number of genera in fields C-3, C-1, C-4, and C-2 was 31, 43, 47, and 40, respectively.

Rotation fields R-2 (x = 30.5) and R-1 (x = 31.8) had sandy loam soil, and R-3 (x = 48.6) and R-4 (x = 48.7) had sandy clay loam soil. Field R-1 had acidic soil, and the remaining rotation fields were alkaline. Field R-2 had the lowest total percentage of soil pore space and the lowest amount of clay. Field R-3 had the lowest silt
content found during the entire study. Fields R-2 and R-1 had completely
different prominent genera, but R-3 and R-4 had 2 prominent genera in
common. Rhodacaridae was the most prominent Acarina in field R-1, and
an unusually high number of Isotoma occurred in R-2 and R-4. Only common
genera were the most prominent in field R-3. Number of genera in the
fields R-2, R-1, R-3, and R-4 was 29, 35, 45, and 45, respectively.

Soybean fields S-3 (x = 34.8) and S-2 (x = 47.2) had sandy loam
soil, whereas S-4 (x = 55.4) and S-1 (x = 85.2) had sandy clay loam soil.
Fields S-1 and S-3 had acidic soil, and S-2 and S-4 had alkaline soil.
Fields S-3 and S-2 had 3 prominent genera in common, and an unusually
high number of Pseudosinella. Only common genera were prominent in the
field S-1. Field S-4 had an unusually high number of Folsomia and
Cecidomyiidae larvae. Number of genera in the fields S-3, S-2, S-4,
and S-1 was 45, 56, 47, and 52, respectively.

Ordination of agroecosystems: 1974

Results of the ordination for 1974 are presented in Fig. 8. The
major characteristic of this ordination is that, in general, the agro-
ecosystems maintained the same pattern of distribution as in 1973.
Only soybean field S-1 changed its position substantially. A stronger
clustering of both soybean and rotation fields was more prevalent in
1974 than in 1973. A single application of carbofuran did not change
the general pattern of distribution of the cornfields between the 2
years. Fields C-3 and C-1 maintained their positions in the first 1/3
of the X-axis, and fields C-2 and C-4 on the last 1/3 of this axis.

The most prominent microarthropods in corn, soybean, and rotation
Figure 8. Ordination of 4 continuous corn, 4 continuous soybean, and 4 oats-soybean-corn rotation agroecosystems: 1974
agroecosystems are listed in Table 10. The measurements of the abiotic soil components of these systems are cited in Tables 14 to 16. Only the main difference from 1973 in the fauna and in the edaphic factors will be pointed out.

Cornfield C-3, the first reference in the X-axis (x = 0.0), and C-1 (x = 31.5) maintained approximately the same position in the ordination as in 1973. But fields C-2 (x = 80.3) and C-4 (x = 94.0) change their position relative to those of 1973. The total percentage of soil pore space was significantly different in field C-3 from those of the other cornfields (Table 18). Field C-1 had a soil pH of 6.9 in 1973 and 7.7 in 1974. Cornfields C-3 and C-2 received carbofuran treatments and the remaining fields had not received a soil insecticide treatment. The predators Rhagidia and Rhodaceridae were the most prominent taxa in the field C-3. In field C-1, the most prominent genera were quite different from those in 1973. In field C-2, 1 Collembola genus and 3 Cryptostigmata genera were the most prominent microarthropods in 1973, but in 1974 1 Cryptostigmata and 2 Collembola genera were the most prominent. From 1973 to 1974, Lepidocyrtus was the most prominent genus in common in field C-4. Number of genera in fields C-3, C-1, C-2, and C-4 was 32, 44, 46, and 48, respectively.

In rotation field R-4 (x = 35.4), from 1973 to 1974, the soil pH changed from 8.1 to 7.2. In the same period, in the field R-3 (x = 60.8) amounts of clay and silt increased. Field R-2 (x = 40.1) maintained approximately the same position as in the 1973 ordination. In field R-4 the most prominent Collembola genera were the same in 1973 and 1974, but the most prominent Cryptostigmata genera changed. Field R-2 was
characterized by an unusually high number of **Folsomides**, and by the highest number of **Proisotoma** during the 1973-1974 sampling period. Common genera were the most prominent microarthropods in the field R-1. Field R-3 was characterized by an unusually high number of **Metakatianna**. Number of genera in fields R-4, R-2, R-1, and R-3 was 45, 40, 40, and 55, respectively (Table 5).

From 1973 to 1974, soybean fields S-3 (x = 45.9), S-2 (x = 51.6), S-1 (x = 71.6), and S-4 (x = 72.4) had an increase in the amount of clay measured. Only soybean field S-1 changed its position substantially. The soil moisture content was significantly different in soybean fields S-3, S-1, and S-2 from field S-4. Field S-2 had the same prominent genera in 1973 and 1974. Field S-3 was characterized by an unusually high number of **Emtomobrya**, and S-1 by an unusually high number of **Folsomia**. In field S-4 the most prominent genera were **Acarina**, and an unusually high number of **Scutacarus** occurred in this field.
SUMMARY AND CONCLUSION

This study of edaphic microarthropods associated with typical Iowa agroecosystems was conducted in five counties in 1972, and in the vicinity of Ames during the cropping season of 1973 and 1974. Objectives of the study were: (1) to define both quantitatively and qualitatively the microarthropod populations in corn, soybean, and rotation agroecosystems; and (2) to assess the effects of selected edaphic physical factor and the impact of cultural practices on composition and structure of these populations.

A sampling area of 0.6 ha was established in each field. Soil samples were taken, with a metal cylindrical corer 6-cm deep, in the plant row, as close as possible to the plant stalks. Soil microarthropods were extracted with batteries of Tullgren funnels producing a gradient of temperature and moisture through the sample. A cold-sugar solution was used to extract microarthropods from the collecting vials and rid them of the debris that usually fell into these containers. Data collected yielded density-frequency information. Edaphic factor measurements taken in each field during the study were: pH, temperature, moisture content, pore space, clay, sand, and silt.

In 1972, soybean agroecosystems studied were located in Iowa near Sutherland (NW), Independence (NE), Shenandoah (SW), Bloomfield (SE), and Ames (central). The sampling time was June and August near Ames, and July and August in the remaining sites. In 197301974, the samples were taken monthly from June to October near Ames.

A total of 30,006 specimens were collected, representing 20 orders,
140 families, and 233 genera. Acarina (80.35%) and Collembola (16.23%) comprised 96.58% of the total microarthropod population in 1973-1974, and 89.3% in 1972. Six or less genera in each field comprised ca. 50% or more of the total PV, and the great majority of these genera belong to the Acarina and Collembola. Acarina and Collembola together represented about 47% of the total number of genera. Coleoptera and Diptera were characterized by few individuals of many genera. In general the densities of each remaining insect order was less than 1% in every location. Symphylella was the most abundant myriapod in 1972, but was replaced by Lamycetes in the 1973-1974 study.

Acarina was the most diverse taxon and presented the highest population density through the entire study. Oppeilla (1972) and Cepheus (1973-1974) were the most abundant Acarina. Rhodacaridae specimens were the most abundant Mesostigmata in the comparative agroecosystem study.

Collembola was the third most diverse taxon, and had the second highest population density. Proisotoma (1972) and Lepidocyrtus (1973-1974) were the most abundant Collembola genera. Spinisotoma was recorded for the first time in soybean agroecosystems.

Coleoptera was the second most diverse taxon and had the third highest density. Ptinella (1972-1973) and Anthicidae larvae (1974) were the most abundant Coleoptera. Ptiliidae outnumbered the two most cosmopolitan coleopteran families associated with soil, viz., Carabidae and Staphylinidae. Diabrotica longicornis larvae and eggs were recorded for the first time in Iowa soybeans.

Diptera was the fourth most diverse taxon and had the fourth highest density. Cecidomyiidae larvae were the most abundant of the dipteran
genera for 1972-1974 sampling period.

Symphyla (*Symphylella*) had the fifth highest population density, and was the most abundant myriapod in 1972. Lithobiomorpha (*Lamycetes*) was the most abundant myriapod in 1973-1974 sampling period.

The measurements of the abiotic soil components revealed no significant difference in temperature among fields in the entire study. Also, no correlation was found between temperature and density of Acarina and Collembola.

The soil moisture content recorded had values above the wilting point for all of the texture classes in this study. Thus, it is assumed that the soil atmosphere was saturated in those fields studied. The soil moisture content was significantly different in cornfields C-3 and C-1 from fields C-4 and C-2 (1973) and soybean S-3, S-1, and S-2 from field S-4 (1974). Rotation fields showed no significant difference.

The total percentage of soil pore space was significantly different in cornfields C-1 from C-4, C-2, and C-1 in 1974. Pore space is considered as a contributing causal factor of dissimilarity of the field C-3.

In 1972 and 1973 ratios between Acarina and Collembola were higher in acidic than in alkaline fields, except for cornfield C-1. But in 1974, these ratios were higher in alkaline than in acidic fields. Thus, the relationship between pH concentration and microarthropod populations was considered only in association with the factors affecting each agroecosystem.

Plowing in autumn, disking in the following spring, and monoculture were factors of great importance in explaining the low microarthropod
densities in these agroecosystems. In these studies, absence of Blattaria and Damaeidae, the infrequent occurrence of Polydesmida, Geophilomorpha, and Galumnidae, and the relatively small number of Sminthuridae, was indicative of the deleterious effects of plowing and disking.

The small amounts of DDE, DDT, and Dieldrin found in the fields studied were considered unharmful to the microarthropods studied. The recovery of these pesticides is understandable because they had been widely used in Iowa, although not in these agroecosystems in the last several years.

In 1974, cornfields C-2 and C-3 received carbofuran treatments, and the quantities recovered from these soils were 30 ppb and 6 ppb, respectively. Carbofuran treatments adversely affected Mesostigmata populations, and these decreasing about 2.5 times in treated fields from 1973 to 1974. Likewise, Cepheus, Tectocepheus, Ceratozetes and Oppiella (Cryptostigmata) substantially decreased in carbofuran-treated cornfields. Carbofuran treatments did not deleteriously affect the total microarthropod density or the total Acarina density.

During the sampling period 1973-1974, lowest Collembola-population densities (prey) coincided with highest Mesostigmata-population (predator) densities and vice-versa. Carbofuran treatments did not quantitatively change the ratio between prey and predator.

Polar ordinations were constructed to simplify and condense the data into recognizable patterns among fields and relate these to prominent genera and soil components. Since these ordination procedures produced repeatable patterns in 2 years of study, this technique was considered a valuable tool in this synecological study.
No relationship could be seen when gradients of fields were established for each abiotic factor measured and compared with those of the ordination X- and Y-axes. The location of an agroecosystem in the ordination was the result of all genera present, their densities and frequencies, and the total abiotic soil factors as they related to those genera.

A major characteristic of the ordination of agroecosystems for 1972 was the clustering formed by Sutherland, Independence, and Bloomfield sites in the last 1/3 of the X-axis, the Shenandoah location on the middle 1/3 of this axis, and the Ames placement on the proximal end of the X-axis. The dissimilarity of the Ames site was primarily caused by its high number of Proisotoma and Rhysotritia. These genera may have been influenced the alkaline soil, the high moisture content, the high sand content, and the low silt content of the 1972 Ames site. The dissimilarity of the Shenandoah site was primarily caused by its most prominent genera, Proisotoma, Tullbergia, and Sinella. High clay content was an important characteristic of this site. The clustering formed by Bloomfield, Independence, and Sutherland was primarily caused by the high number of specimens of Onychiurus, Tullbergia, Ceratozetes, and Oppiella found in common at these sites. Bloomfield was characterized by the higher number of Hypogastrura, Katianinna and by having acidic loam soil, the lowest moisture content, the highest soil temperature and the highest silt content of any site. Also Bloomfield was the only weedy field in this study. In general, Independence and Sutherland had abiotic soil components whose values were intermediate between those of Ames and Bloomfield.
A major feature of the 1973 ordination is the characteristic pattern of distribution of the fields. Cornfields were characterized by two distinct groups, well apart from each other. Fields C-3 and C-1 were grouped in the first 1/3 of the X-axis, and fields C-4 and C-2 were paired in the last 1/3 of this axis. Soybean fields also comprised two different groups. Fields S-3, S-2, and S-4 are clustered in the middle 1/3 of the X-axis, whereas S-1 is positioned in the distal end of this axis. Rotation fields formed a loose group in the middle 1/3 of the X-axis. These patterns indicated that cultural practices contributed to the distribution of the fields. But, specific cultural parameters to explain the distribution were not identified. Further studies should be conducted to identify and quantify these parameters, particularly as they relate to prominent genera.

Considering the abiotic soil components, cornfields C-3 and C-1 had sandy loam soil, and C-4 and C-2 had sandy clay soil. The soil moisture content was significantly different in cornfields C-3 and C-1 from fields C-4 and C-2. Rhodacaridae was the most abundant microarthropod in field C-3. *Scutacarus* characterized field C-1, and *Entomobrya* characterized field C-4. Only genera common to all fields were prominent in field C-2.

Rotation fields R-2 and R-1 had sandy loam soil, and R-3 and R-4 had sandy clay loam soil. Field R-1 had acidic soil, and the remaining rotation fields were alkaline. Field R-2 had the lowest amount of clay, and R-3 the lowest silt content found during the entire study. Rhodacaridae was the most abundant Acarina in field R-1. An unusually high number of *Isotoma* occurred in fields R-2 and R-4. Only common genera were greatly prominent in field R-3.
Soybean fields S-3 and S-2 had sandy loam soil, and S-1 had sandy clay soil. Fields S-1 and S-3 had acidic soil and S-2 and S-4 had alkaline soil. Only common genera were greatly prominent in fields S-1, S-2, and S-3. Field S-4 had an unusually high number of Folsomia and Cecidomyiidae larvae.

The major characteristic of the ordination for 1974 was that, in general, the agroecosystems maintained the same pattern of distribution as in 1973. Only soybean field S-1 changed its position substantially. A stronger clustering of both soybean and rotation fields was more prevalent in 1974 than in 1973.

Cornfields C-3 and C-1 maintained approximately the same position in the ordination as in 1973. A single application of carbofuran did not change the general pattern of distribution of the cornfields from 1973 to 1974. Fields C-3 and C-1 maintained their position in the first 1/3 of the X-axis, and field C-2 and C-4 in the last 1/3 of this axis. But, fields C-2 and C-4 changed their position relative to those of 1973. Total percentage soil pore space is considered as a causal factor of dissimilarity of the field C-3. Field C-1 had a soil pH of 6.9 in 1973 and 7.7 in 1974. The predators Rhagidia and Rhodacaridae were the most prominent taxa in field C-3. In field C-1, the most prominent genera were quite different from those of 1973. From 1973 to 1974, Lepidocyrtus was the only prominent genus in common in field C-4. In field C-2, the two most prominent genera were the same in 1973 and 1974.

Rotation fields R-2 maintained approximately the same position as in the 1973 ordination, but the remaining rotation fields changed their position relative to those of 1973. From 1973 to 1974, the soil pH
changed from 8.1 to 7.2 in field R-4, as did amounts of clay and silt in field R-3. In field R-4 the most prominent Collembola genera were the same in 1973 and 1974, but the most prominent Cryptostigmata genera changed. Field R-2 was characterized by an unusually high number of Folsomides, and by the highest number of Proisotoma during the 1973-1974 sampling period. Common genera were the most prominent microarthropods in field R-1. Field R-3 was characterized by an unusually high number of Metakatianna.

Only soybean field S-1 changed its position substantially in the ordination relative to those of 1973. From 1973 to 1974 all soybean fields had an increase in clay content. Field S-2 had the same prominent genera in 1973 and 1974. Field S-3 was characterized by an unusually high number of Entomobrya, and S-1 by an unusually high number of Folsomia. In field S-4 the most prominent genera were Acarina, and an unusually high number of Scutacarus occurred in this field.

In summary, the present study clearly demonstrated the great diversity of edaphic microarthropods associated with typical Iowa agroecosystems. The description and definition of this edaphic fauna in corn, soybean, and oats-soybean-corn rotation agroecosystems is the major contribution of this study.
LITERATURE CITED


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