# Arthropod Diversity and Pest Dynamics as a Function of Production Input Levels and Cropping System Strategies

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## Introduction

Sustainable management strategies, crop loss prevention and maintenance of soil health are central to our capacity to maintain the biological productivity of agricultural systems. Arthropods, including insects, spiders and mites, are integral to crop loss and to soil health because they include both beneficial and pest species. Cropping systems must incorporate the relationships between farm practices and the ecosystem to create an equilibrium where farm inputs enhance rather than replace natural processes.

### Preserving Yield

Until recently, control of insect pests to reduce crop loss was not a particularly perplexing problem because of the wide acceptance of highly effective chemical insecticides. However, despite an estimated 2.5 million tonnes of insecticides used world-wide annually, pests destroy about 35% of all potential crops before harvest (Albert *et al.*, 1992). Approximately 12% of potential crop loss was attributed to arthropods (Pimentel, 1986). This strongly suggests that a significant number of other factors must be considered when developing strategies to preserve crop yield.

From an agronomic perspective, the major innovations in farming systems in the last decade have been crop diversification and the soil conservation practices of reduced- and zero-tillage. The extent to which these innovations have influenced, or may influence in the future, insect pest population dynamics is not fully documented. The Manitoba-North Dakota Zero Tillage Farmers Association published a manual for integrated management of insect pests in zero-tillage (Ellis, 1994), however, the manual does not document the impact that zero-tillage may have on the pest status of these insects.

From a pest management perspective, the major factors that influence pest status of insects are weather, habitat, food, and natural enemies. Cropping systems (crop residues, crop rotation and soil tillage) can play a major role in all of these factors. Much of the knowledge required to fully understand the complexities of relationships between beneficial arthropods and their habitat is still being developed. However, it is understood that cropping systems can play a significant role in the conservation of natural enemies through habitat management, crop structure, and diversity (Altieri, 1994).

### Soil Health

The desire to maintain the capacity of the soil to sustain biological productivity has positively influenced the study of soil properties that contribute to the quality and health of our prairie soils. Acton and Padbury (1993) defined soil quality in terms of measurable soil properties that influence the capacity of the soil to perform crop production or environmental functions. Doran and Safley (1997) defined soil health as a living system that has the capacity to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health.

Communities of arthropods that live in the soil are influenced generally by the same factors that influence those living above ground. Species richness and the biological success of specific communities, are related positively to the diversity of niches, and soil micro-environments (van Straalen, 1997). As a result, cropping diversity, rotational regimes, and soil preparation which influence the diversity of micro-environments in the soil also impact arthropod populations (Pankhurst *et al.*, 1997). Unfortunately, even less is known about most of the soil arthropods and the agro-ecological role they play than those living above ground (Freckman, 1994).

Soil micro-fauna are implicated in a number of soil processes such as decomposition of organic matter, nutrient mineralization, regulating micro flora (including plant pathogens), decomposition of agricultural chemicals and improving soil structure (Gupta and Yeates, 1997). Thus, protozoa, nematodes, and rotifers have potential as indicators of soil health because they tend to respond quickly to environmental changes in the soil.

Soil meso-fauna (mites, millipedes, collembolans are referred to as micro-arthropods by some authors) also are thought to be involved in processing organic matter and augmenting processes involved in soil structure (van Straalen, 1997). Because soil meso-fauna are still relatively sedentary they do reflect the conditions of the soil habitat more than more mobile macro-fauna. Meso-fauna are abundant in agricultural soils but much more needs to be learned about their contribution to soil processes (Crossley *et al*., 1992). It has been reported that they are sensitive to agricultural chemical inputs and, as a result, they may also have potential as biological indicators of chemical impact on the ecosystem (Koehler, 1992).

Soil macro-fauna are sometimes involved in predation (spiders, ants) of pest species, however, others tend to play a role similar to meso-fauna in that their diet consists of primary and secondary consumers, they process organic matter and contribute to soil structure (van Straalen, 1997; Doube and Schmidt, 1997).

## Methods

### Pitfall Traps

The ground-dwelling predator fauna was sampled using pitfall traps constructed from 1L round plastic containers with an opening 11 cm in diameter. The traps were placed in the center of each of the 36 plots as well as out in the grassed margins surrounding the field site. The traps were installed in the ground, flush with the soil surface and fitted with a clear plastic funnel. When not in use the traps were covered with plastic lids to prevent the unnecessary capture of beetles and to keep debris and rain out of the traps. The pitfall captures were based on a 48 hour period. The period of collection was during the growing season (June - August). Insects, spiders, phalangids and chilopods were identified to the family level; carabid beetles were identified to species level.

### Soil Sampling

Soil core samples were taken on three occasions each year: pre-cultivation, mid-growing season and post-harvest in 1995-1996. In subsequent years, samples were taken only once. Biological activity in soils primarily takes place in topsoil, and is concentrated in the top 5-10 cm. As a result, each sample consisted of four soil cores (4 cm diameter, 15 cm depth ) divided into upper and lower sub-samples. The four samples were bulked and stored at +2 $^{o}$C until processed. Because the samples were split into upper and lower portions only half of the 216 subplots were sampled (odd- numbered subplots ). Four samples were also taken along the north edge of the field in a grassy fence-line. As well, an alfalfa-brome field (seeded about 30 years ago), an old grass field (seeded to grass about 60 years ago) and a native prairie field were also sampled. All of these fields are located at the Scott farm. At these uncultivated sites, four replicates of four soil cores were taken at random from within each area. **Tullgren** funnels and **Baermann** funnels were used to extract the organisms from the soil.

*Tullgren funnels*

Tullgren funnels use heat and light to force arthropods living within the soil into a container of alcohol at the bottom of the funnel stem. The arthropods have been sorted and counted. The mites were sorted into four sub-orders; Actinendida, Acaridida, Gamasida, and Oribatida. Whenever possible the mites were sorted to family level. Mites were saved in alcohol and representative specimens were mounted on slides for further identification. The remaining micro-organisms such as nematodes and enchytraeids (Annelida) were also counted and sorted. Collembola and the larvae of Diptera and Coleoptera were sorted to the family level when possible.

*Baerman funnels*

Baermann funnels also use light and the heat to force organisms living in the soil water from the soil. Thirty grams of the soil sample were placed in a glass funnel and covered with water. The intensity of light and heat is gradually increased over time to force the water-born organisms from the soil and into the bottom of the funnel stem. This water is drained into a vial and is examined under a stereo microscope. A black background is used so that the movement of the living organisms can be detected. Nematodes, Rotifers, Enchytraeids (Annelida), Tartigrades and protozoa were counted live under a microscope with a dark background.

## Results and Discussion

Over the course of the study, more than 800, 000 arthropods have been collected, sorted and identified. The collection involves approximately 280 guilds (Species, Family, Order, etc). All specimens have been preserved in alcohol, catalogued and coded for entry into the ACS database.

### Pitfall Trap Sampling

In order of decreasing abundance, the following arthropods have been enumerated from pitfall traps: Collembola > Arachnida > Coleoptera > Homoptera > Hymenoptera > Diptera > Hemiptera. The ground beetles (Carabidae; Coleoptera) represent one of the largest insect Families in North American with approximately 2500 species described (Arnett, 1968). They can be found in a wide range of temperate habitats including arable, boreal, riparian, and wetland environments. Carabid beetles are quite mobile on the soil surface, a characteristic that facilitates their capture using pitfall traps. The large number of species, their wide distribution, their relative ease of capture and their importance as biological control agents have made them a favoured group for agro-ecological research. The underlying assumption is that agricultural sustainability is enhanced in farming systems with a higher abundance and diversity of ground-dwelling predators. In this study, the predominant beetle Family captured in the pitfall traps was Carabidae (Coleoptera).

The total number of carabid beetle species captured in Year 6 (2000) varied between 15 and 24 species depending on crop diversity and input level (Table 1). The results show that the diversified annual grain rotation (DAG) had the greatest number of beetles species, followed by diversified annual and perennial rotation (DAP) and low rotation (LOW). Comparing the three input levels, organic production slightly favoured species richness.

Table 1. The total number of carabid species captured (1995-1996) in each of nine farming systems and in the grass margin surrounding the research site.

| **Input** | **LOW** | **DAG** | **DAP** | **EDGE** | **Mean** |
|---|---|---|---|---|---|
| Edge | | | | 2.8 | **2.8** |
| Organic | 5.2 | 4.5 | 5.5 | | **5.1** |
| Reduced | 3.1 | 5.7 | 2.9 | | **3.9** |
| High | 3.3 | 6.8 | 4.0 | | **4.7** |
| **Mean** | **3.8** | **5.7** | **4.2** | **2.8** | |

The overall mean abundance (1995 – 1996) of carabid beetles captured per trap over a 48h trapping period varied from 0.28 - 2.23 beetles per trap. The results show that beetle abundance was higher in the organic input system, followed by high input and reduced input. In relation to cropping diversity, the diversified annual perennial rotation (DAP) supported a higher population of carabid beetles than did the other two rotations. The grass margin surrounding the plot supported the least.

Table 2. The overall mean abundance of carabid beetles captured (1995 - 1996) per trap in each of nine farming systems and in the grass margin surrounding the research site.

| **Input** | **LOW** | **DAG** | **DAP** | **EDGE** | **Mean** |
|---|---|---|---|---|---|
| Edge | | | | 2.23 | **2.23** |
| Organic | 0.43 | 0.57 | 0.81 | | **0.60** |
| Reduced | 0.28 | 0.37 | 0.49 | | **0.38** |
| High | 0.30 | 0.49 | 0.40 | | **0.40** |
| **Mean** | **0.34** | **0.48** | **0.57** | **2.23** | |

### Soil Core Sampling

#### *Tullgren funnels*

In order of decreasing abundance, the following arthropods were enumerated from the Tullgren funnels: Collembola > Acari > Coleoptera >Hymenoptera > Diptera. Mites (Acari or Acarina) are the most diverse and abundant of all arachnids, but because of their small size (usually less than a millimeter in length) we rarely see them. Mites are also among the oldest of all terrestrial arthropods, about 45,000 species of mites have been described (Lindquist 1984). Mites are truly ubiquitous. They have successfully colonized nearly every known terrestrial, marine, and fresh water habitat. Mites found in agricultural crops may be economic pests, useful biocontrol agents of those pests or living in the soil as contributors to soil health.

The Acari were sorted into four main sub-orders Astigmata, Mesostigmata, Prostigmata and Oribatida. The overall (all species, all years) mean abundance per sample of mites in the study ranged from 83.9 - 202.9 mites per sample (Table 3). Abundance of mites was high in the grass margin (Edge) and in the native prairie (NP). On average, all rotations within the reduced input system (RED) supported a greater number of soil mites than the other two input levels.

Table 3. The overall (all species, all years) mean abundance per sample of mites extracted from soil samples in the nine farming systems and the four uncultivated areas (Edge = grass margin, AB = alfalfa/brome, OP = old grass, NP = native grass).

| | **Organic** | **Reduced** | **High** | **Edge** | **AB** | **OP** | **NP** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **LOW** | 124.8 | 201.9 | 83.9 | | | | | **136.9** |
| **DAG** | 116.6 | 202.9 | 130.1 | | | | | **149.9** |
| **DAP** | 117.5 | 165.1 | 102.4 | | | | | **128.3** |
| **EDGE** | | | | 183.2 | | | | |
| **AB** | | | | | 136.5 | | | |
| **OP** | | | | | | 114.8 | | |
| **NP** | | | | | | | 183.6 | |
| **Mean** | **119.6** | **190.0** | **111.5** | | | | | |

Each of the different sub-orders of Acari responded somewhat different to the nine cropping systems and to the different levels of disturbance in the uncultivated areas (Tables 4-7). The sub-order Astigmata appears to be more successful in the organic input system relative to reduced and high input systems. In general, the study showed that Astigmata abundance was lowest in the reduced input and the uncultivated grass sites (Table 4).

Table 4. The overall mean abundance per sample of Astigmata mites extracted from soil samples in the nine farming systems and the four uncultivated areas (Edge = grass margin, AB = alfalfa/brome, OP = old grass, NP = native grass).

| | **Organic** | **Reduced** | **High** | **Edge** | **AB** | **OP** | **NP** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **LOW** | 21.0 | 18.2 | 13.7 | | | | | **17.6** |
| **DAG** | 24.5 | 11.4 | 24.5 | | | | | **20.3** |
| **DAP** | 25.2 | 10.6 | 18.1 | | | | | **18.0** |
| **EDGE** | | | | 4.4 | | | | |
| **AB** | | | | | 5.6 | | | |
| **OP** | | | | | | 1.9 | | |
| **NP** | | | | | | | 2.6 | |
| **Mean** | **23.6** | **13.4** | **18.8** | | | | | |

The sub-order Mesostigmata appears to be more successful in the reduced input system relative to organic and high input systems (Table 5). Cropping diversity had little effect on Mesostigmata abundance.

Table 5. The overall mean abundance per sample of Mesostigmata mites extracted from soil samples in the nine farming systems and the four uncultivated areas (Edge = grass margin, AB = alfalfa/brome, OP = old grass, NP = native grass).

| | **Organic** | **Reduced** | **High** | **Edge** | **AB** | **OP** | **NP** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **LOW** | 13.2 | 22.5 | 9.0 | | | | | **14.9** |
| **DAG** | 11.3 | 27.0 | 14.3 | | | | | **17.5** |
| **DAP** | 12.4 | 22.5 | 10.3 | | | | | **15.1** |
| **EDGE** | | | | 26.3 | | | | |
| **AB** | | | | | 7.3 | | | |
| **OP** | | | | | | 11.7 | | |
| **NP** | | | | | | | 13.9 | |
| **Mean** | **12.3** | **24.0** | **11.2** | | | | | |

The sub-order Prostigmata also appears to be much more successful in the reduced input system relative to organic and high input systems (Table 6). In general, the study showed that Prostigmata abundance was lowest in the high input. In relation to cropping diversity, the diversified annual grains rotation (DAG) had a mean abundance of Prostigmata greater than the other two rotations. All of the grass sites supported a significantly larger population of Prostigmata than did the cropped area except for the old prairie (OP) plot.

Table 6. The overall mean abundance per sample of Prostigmata mites extracted from soil samples in the nine farming systems and the four uncultivated areas (Edge = grass margin, AB = alfalfa/brome, OP = old grass, NP = native grass).

| | **Organic** | **Reduced** | **High** | **Edge** | **AB** | **OP** | **NP** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **LOW** | 52.8 | 83.5 | 31.4 | | | | | **55.9** |
| **DAG** | 48.5 | 92.8 | 53.3 | | | | | **64.9** |
| **DAP** | 46.9 | 71.6 | 40.0 | | | | | **52.8** |
| **EDGE** | | | | 107.1 | | | | |
| **AB** | | | | | 86.9 | | | |
| **OP** | | | | | | 59.4 | | |
| **NP** | | | | | | | 84.2 | |
| **Mean** | **49.4** | **82.6** | **41.5** | | | | | |

The sub-order Oribatida appears to be much more successful in the reduced input system relative to organic and high input systems (Table 7). In relation to cropping diversity, the low diversity rotation had a mean abundance of Oribatida only slightly greater than the other two rotations.

Table 7. The overall mean abundance per sample of Oribatid mites extracted from soil samples in the nine farming systems and the four uncultivated areas (E = grass margin, AB = alfalfa/brome, OP = old grass, NP = native grass).

| | **Organic** | **Reduced** | **High** | **Edge** | **AB** | **OP** | **NP** | **Mean** |
|---|---|---|---|---|---|---|---|---|
| **LOW** | 37.8 | 77.7 | 29.8 | | | | | **48.4** |
| **DAG** | 32.3 | 71.3 | 38.0 | | | | | **47.2** |
| **DAP** | 33.0 | 60.4 | 34.0 | | | | | **42.5** |
| **EDGE** | | | | 45.4 | | | | |
| **AB** | | | | | 36.7 | | | |
| **OP** | | | | | | 41.8 | | |
| **NP** | | | | | | | 82.9 | |
| **Mean** | **34.4** | **69.8** | **33.9** | | | | | |

In addition, to the impact of different farming systems on Oribatid mites (Table 7), their abundance was influenced by the different crops being grown in rotation. Broad-leaf crops (flax, peas and canola) supported significantly fewer Oribatid mites than did the grass crops, especially fall rye. In general, the abundance of Oribatid mites was the greater in the un-cultivated areas than in the cropped areas, except for fall rye.

*Baermann Funnels*

In order of decreasing abundance, the following microfauna were enumerated from the Baermann funnels: Nematodes > Rotifers > Protozoans > Enchytraeids > Tartigrades. Nematodes are commonly found in most habitats, but are often overlooked because they are microscopic in size. At recent count, more than 15,000 species of nematodes had been described. Soil is a superb habitat for nematodes; it is estimated that 100 cc of soil contains thousands of individuals. Unfortunately, there is a much less known about soil nematodes than about those present on plants. In general those living in the soil do not parasitize plants, but are a major contributor to decomposition of organic matter. Because most nematodes inhabit the thin film of moisture around soil particles, the micro-environment surrounding plant roots and root hairs is a particularly suitable habitat. Therefore, it would be anticipated that different cropping systems would influence nematode populations in different ways.

Results indicate mean nematode populations were slightly greater in the reduced input and the diversified annual grains rotation than in the other cropping systems . In all cases, nematode populations were significantly lower in the cropped area than in the uncultivated grass areas. In the grass areas, nematode abundance appears to be negatively related to soil disturbance (ie. age of grass stand). The grass margins around the study site has not been cultivated for approximately 15 years, the alfalfa/brome is about 30 years old, and the older grass area was cultivated and seeded back to grass about 60 years ago. The native prairie grass area had significantly higher population density than any other site.

The primary features of the other Phyla were: the high input system had fewer Enchytraeids and protozoans than the Reduced input system and the organic input system; there was greater abundance of Protozoa in the grass ecosystems than in the crop land; there was greater abundance of Rotifera in the reduced input level plots than in the other input level systems; and Tartigrada have only been recorded in the reduced input plots.

## Summary

There appears to be a sound basis for investigating arthropods and other soil micro-fauna as indicators of soil health. Pankhurst *et al* (1997) reported that both nematodes and protozoa abundance and diversity had a medium and high ranking, respectively, as indicators of soil health. In their opinion, mites and Collembola abundance and diversity both had a medium ranking as suitable indicators of soil health. Emphasis is being placed on Oribatid mites because of the implications for soil health. They are responsible for breaking up organic matter and for recycling minerals in the soil. Hence they can play an important role in soil fertility. Population abundance, and more importantly, species richness can serve as a bio-indicator of soil health.

Much of the knowledge required to fully understand the relationships between beneficial arthropods and the soil is still being developed for the Northern Great Plains. However, it is understood that cropping systems can play a positive role in conservation of natural enemies through habitat management, crop structure, and diversity. Because, interactions among the biological, physical and chemical components of agricultural systems is inherently complex, the design, data collection and evaluation of the findings depends on the collaborative efforts of multi-disciplinary team of crop, pest, economic and soil scientists. In addition, such evaluations often involve a long-term commitment to monitoring specific components within the agricultural system to determine rate and direction of change over time. Arthropods are well-suited to characterizing the ecosystems that they inhabit. Ecosystem-based, baselines of arthropod diversity and abundance are an integral component in evaluating farming systems and will contribute to our understanding of the impact of cropping systems on sustainability issues.

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