Arthropod Diversity and Pest Dynamics in Various Production Input Levels and Cropping System Strategies

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Key Words: Insect pests, arthropod diversity, cropping systems

Abstract

Economic viability and soil degradation are major issues facing farmers in the grassland ecozone of the Northern Great Plains. Crop diversification, reduced fallow and reduced inputs are being promoted in an effort to address these issues. A systems approach is applied as the experimental framework with which to monitor and assess alternate input and cropping strategies. The design, data collection and evaluation are based on the collaborative efforts of crop, pest, economic and soil scientists. This paper highlights the role of arthropods (insects, spiders, mites) in the assessment of farming systems. Arthropods are the most diverse group of organisms in most ecosystems. Many species, including beneficial and pest species, are well-suited to characterizing the ecosystems that they inhabit. Ecosystem-based, arthropod baselines are viewed by the authors as an integral component in evaluating farming systems.

Introduction

Profitability, diminishing land resources and land degradation are major issues facing farmers in the grassland ecozone of the Northern Great Plains going into the new millennium. Crop diversification, reduced fallow and reduced inputs are being promoted in an effort to address these issues (Olfert *et al.,* 1999a; 1999b). While some agricultural practices and production systems have been evaluated for their short-term impact on sustainable production, few have been evaluated for their long-term impacts (Paoletti *et al.,* 1993). 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.

The study objective is to monitor and assess alternative input and cropping strategies based on three levels of production inputs and three levels of cropping diversity. Specifically, the study will evaluate different strategies over an 18-year period with respect to: (i) biodiversity; (ii) pest dynamics; (iii) farm profitability; (iv) soil quality; and (v) food safety. In addition to the nine cropping systems, the diversity of arthropods is being evaluated in four uncultivated areas: native prairie, a 50-year old grass ecosystem, a 30-year old alfalfa/brome grass ecosystem; and the grassy margins next to the study site. This paper will focus primarily on two issues, minimizing pre-harvest yield loss and maintaining soil health relative to the diversity and abundance of arthropods in diverse cropping systems of Saskatchewan.

Methods

This on-going study is located at Scott, Saskatchewan (52^o 22' N; 108^o 50' W), located in the Dark Brown soil zone; the area is categorized as moist mixed grassland.

The experimental framework of the cropping portion of the study is based on a matrix of three levels of input use, and three levels of cropping diversity. The input levels, Organic, Reduced and High Input represent the main plots. The three levels of cropping diversity are assigned to sub-plots (15m by 40m) within each main plot (replicated four times) to enhance detection of diversity level differences. The levels of cropping diversity follow a six-year rotation and are described as Low (Fallow-wheat-wheat-fallow-canola-wheat), Diversified Annual Grains (Canola-fall rye-pea-barley-flax-wheat) and Diversified Annual and Perennial(Canola-wheat-barley-brome/alfalfa- brome/alfalfa- brome/alfalfa). All phases of each rotation are present each year.

The native grass site has not supported any livestock for about 30 years; the old grassland site was cultivated approximately 50 years ago and seeded back to mixed grass shortly thereafter. It also has been managed similarly to the native grass site for the last 30 years. The alfalfa/brome grass site was cultivated and seeded to an alfalfa/ brome grass mix about 30 years ago and is harvested annually. The grass area in the fence line adjacent to the crop study site is about 5 m wide and is primarily crested wheat grass. The field plot margins were seeded about 40 years ago and are mowed several times during the summer months.

Soil core samples are taken on three occasions each year (pre-season, mid-season and post growing season) to quantify the richness and abundance of soil arthropods. Each sample consists of 4 cores (4 cm diameter) divided into upper 3" and lower 3". Four samples were also taken at each of the grass areas

The soil core samples are processed using two extraction methods. The Tullgren funnel method uses heat and light to force soil arthropods that live in the soil into a vial of alcohol. Acari, Nematodes, Collembola, Enchytraeids and larvae of Diptera and Coleoptera are counted and saved in alcohol. Whenever possible the mites and insects were sorted to species level. In addition, a sub-sample of soil is process in a Baermann funnel system to extract the micro-arthropods living in the soil water. Again, light and heat forces the water-born organisms from the soil and into collection container. Organisms such as Nematodes, Rotifers, Enchytraeids, Protozoans and Tardigrades are counted and recorded.

Insect pest species are monitored using sweep nets, visual counts and pheromone traps.

Results

Minimizing pre-harvest yield loss. The following insect pests are monitored throughout the growing season: Flea beetle (*Phyllotreta* species); Orange wheat blossom midge (*Sitodiplosis* *mosellana*); Grasshoppers (*Melanoplus* species); Bertha armyworm (*Mamestra configurata*) and Diamondback moth (*Plutella xylostella*). Prior to 1999, insect control measures have been restricted to high-input plots where insecticidal dressings were applied to canola seed to protect the emerging crop from flea beetles; there were no post-emergent insect control measures required in the study prior to 1999. However, in 1999 and 2000, insecticide treatments were applied to all wheat subplots in the high input plots to control wheat midge. Grasshopper populations in the grass margins around the study sites were also controlled with insecticides in 1999 and 2000.

Maintaining soil health. Soil biota were lumped into three categories, segregated by their relative size into macro-, meso- and micro-fauna. Soil macro-fauna included soil-inhabiting life stages of insects, and spiders. Soil meso-fauna included mites, collembolans and millipedes. Soil micro-fauna included organisms such as protoza, nematodes, tartigrades and rotifers. 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.

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. Micro-fauna such as protozoa, nematodes, and rotifers have potential as indicators of soil health because they tend to respond quickly to environmental changes in the soil. The constraint with using these groups as indicators is the requirement for considerable technical expertise to identify groups or species.

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. Because soil meso-fauna are still relatively sedentary they do reflect the conditions of the soil habitat more than more mobile macro-fauna.

Soil macro-fauna are often 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.

Example: Oribatid mites live in the soil, feed on microbial and higher plants, are important in regulating organic matter and tend to respond negatively to cultivation.

Using Oribatid mites as an example, (numbers per sample; over all mean for 1995-1999), results indicate that all cultivated areas (irrespective of cropping diversity) had significantly fewer Oribatid mites than the non-cultivated grass areas (Figure 1.)

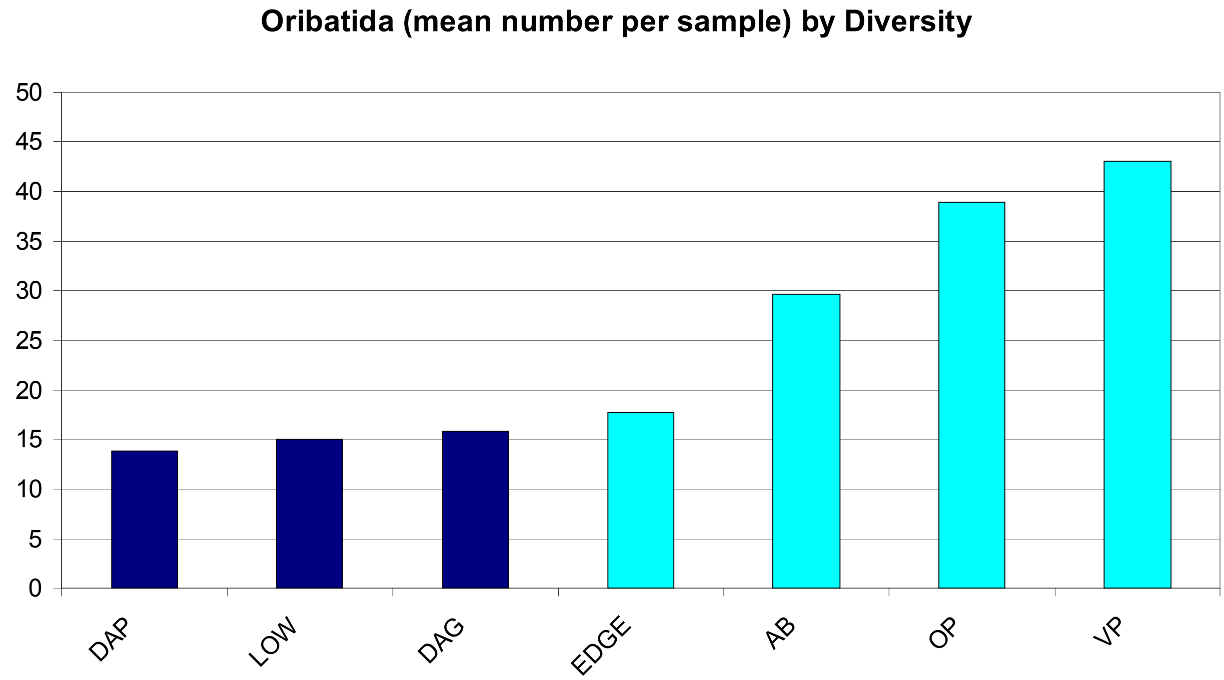

Figure 1: Mean number of Oribatid mites (per sample; 1995-1999) in relation to cropping diversity (DAP = diversified annual and perennial; LOW = low diversity annuals; DAG = diversified annual grains; EDGE = grass margins around plot; AB = alfalfa brome plots; OP = old prairie grass area; VP = virgin prairie (native grass)

The corresponding comparison based on input levels, indicates that the reduced input levels permitted a significantly higher population of Oribatid mites than either organic or high input levels (Figure 2). However, the populations were still significantly less than the uncultivated grass areas.

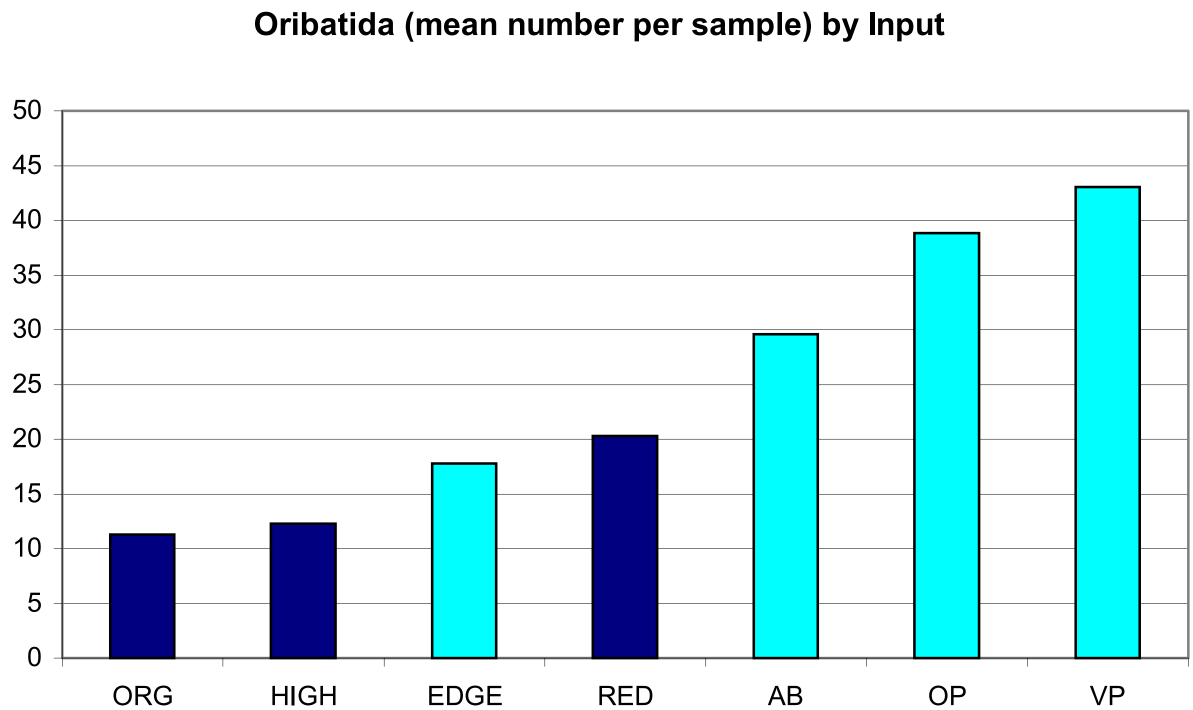

Figure 2: Mean number of Oribatid mites (per sample; 1995-1999) in relation to input levels. (ORG = organic productionl; HIGH = high input level; RED = reduced input level; EDGE = grass margins around plot; AB = alfalfa brome plots; OP = old prairie grass area; VP = virgin prairie (native grass)

Discussion

Much of the knowledge required to understand the relationships between beneficial arthropods and their habitat is still being developed for most cropping systems. This is because the interactions among the biological, physical and chemical components of agricultural systems is inherently complex. As a result, the design, data collection and evaluation of cropping systems is best addressed by 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.

Cropping systems can play a positive role in conservation of natural enemies through habitat management, crop structure, and diversity. Management strategies for insect pests have broadened into the concept of ecological pest management and consideration is now being given to broader ecological issues at the landscape level, such as the impact of cropping diversity on insect population abundance and species richness. Norris and Kogan (2000) present a thorough review of the many interactions between weeds, insect pests, their natural enemies and host plants in managed ecosystems. 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.

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 can destroy up to 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.

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. The extent to which cropping diversity, rotational regimes, and soil preparation influence the diversity of micro-environments in the soil has a tremendous impact on soil health (Pankhurst, 1997).

Acknowledgements

The authours would like to acknowledge the Canada -Saskatchewan Green Plan and the Saskatchewan Agriculture Development Fund.. Without their financial support, this project would not have been possible.

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