MICROARTHROPODS AS PREDATORS OF NEMATODE PESTS IN SUGARCANE SOILS: LITERATURE REVIEW AND PRELIMINARY STUDIES

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Abstract

SOIL MICROARTHROPODS (PRIMARILY springtails and mites) are integral components of the decomposer subsystem, but are essentially unstudied in Australian sugarcane soils. Many of these tiny arthropods are beneficial, as they help regulate the rate of decomposition and nutrient cycling through their feeding processes and by dispersing microbial propagules. Some are also known to feed on nematodes, including those that are significant pests of crops. Herein we review what is known about nematophagous soil microarthropods and present preliminary results from a survey of mineral soil in Queensland cane fields. Densities ranged from 89–529 per 600 mL soil and were dominated by springtails and oribatid mites, indicating a fungus-dominated system. Additionally, about two dozen species of predatory mesostigmatic mites were identified, including many that are known to feed on nematodes. We conclude that sugarcane soils contain a soil microarthropod community with the potential to contribute to the suppression of nematode pests.

Introduction

The soil food web is the term used to describe the community of microorganisms and small animals that live in soil, interact directly or indirectly with plants through the rhizosphere, and perform functions that are vital to the long-term productivity and sustainability of agriculture. Primary among these functions are decomposing organic matter, maintaining soil structure, storing and cycling nutrients, and regulating populations of soil borne pests and pathogens.

In natural ecosystems, regulatory forces within the soil food web generally prevent root pests from increasing to damaging levels. However, there is overwhelming evidence to indicate that this function has been lost from Australia's sugarcane-growing soils. Soilborne pests and pathogens now dominate the soil biological community, with *Pachymetra*, *Pythium*, numerous plant-parasitic nematodes and a suite of unidentified pathogens being associated with an industry-wide problem known as yield decline (Pankhurst *et al*., 2003). Yield responses of more than 40% are obtained when soil is fumigated (Garside *et al*., 2005) and poor root health is common (Stirling *et al*., 2011 a, b). Nematode pests are one of the contributing factors, causing estimated annual losses of more than $80 million (Blair and Stirling, 2007).

From the perspective of nematodes, 5–8 pest species are found in most Australian sugarcane fields, but lesion nematode (*Pratylenchus zeae*) and root-knot nematode (*Meloidogyne* spp.) are the most damaging. The former species occurs in all cane-growing soils and is often present at high population densities, while the latter nematode is a major yield-limiting factor in coarse-textured soils. Previous research has mainly focused on managing these nematodes with rotation crops, resistant varieties and nematicides, but recent work has shown that in some sugarcane soils, pest

nematodes do not multiply readily in the soil immediately under the trash blanket. Biological suppressiveness to these pests is associated with high soil carbon levels, high numbers of bacterial- and fungal-feeding nematodes, and the presence of a diverse range of predatory fungi and nematodes (Stirling *et al*., 2011a, b). Presumably, organic inputs from crop residues and roots fuel an active and diverse soil biological community capable of regulating populations of *P. zeae* and other plant-parasitic nematodes.

Microarthropods are one group of antagonists that may have contributed to suppressiveness in the above study. Mites and collembolans are abundant in soil and many species are known to prey on nematodes (Gilmore, 1970; Walter and Ikonen, 1989; Beaulieu and Walter, 2007; Heidemann *et al*., 2011; Stirling, 2014). This paper briefly reviews the literature on nematophagous microarthropods, identifies the groups known to prey on nematodes, and considers the impact of agricultural management practices on their population densities. It then presents preliminary results from a survey aimed at identifying the microarthropods that occur in Queensland sugarcane soils.

Literature review

Soil fauna are often divided into three categories, as suggested by Lavelle (1997): microorganisms such as bacteria, mycorrhizal and other fungi, protozoa, nematodes, rotifers and tardigrades; mesofauna such as pot worms (Enchytraeidae) and the smaller arthropods (collectively known as microarthropods and including Collembola, Acari, Protura and Diplura); and macrofauna such as earthworms, snails and slugs, and the larger arthropods (e.g. Arachnida, Coleoptera, Diptera, Isopoda and Myriapoda).

Most soil microarthropods are springtails (Collembola) and mites (Acari) and are an integral part of the soil food web. These animals live in soil pore spaces and are known to feed on microbes and decomposing organic matter, and prey on small invertebrates (Wardle, 1995). Due to the variety of feeding behaviours they exhibit, microarthropods have numerous roles within the soil food web and contribute to the regulation of decomposition, nutrient cycling and populations of soil fauna. Predation on nematodes, including agriculturally important species, has been demonstrated in a variety of springtails and mites, and recent work has shown that they are able to reduce nematode populations (Abou El-Atta *et al*., 2014; Heidemann *et al.*, 2014; Xu *et al*., 2014).

Impact of agricultural management on microarthropods

Although the benefits of maintaing a healthy assemblage of microarthropods in soil is becoming more apparent, there are a variety of farming practices that are known to affect the number and diversity of these animals in agroecosystems. Tillage is perhaps the most detrimental. When soil is disturbed by conventional tillage (CT) practices, microarthropods may be killed outright by laceration, crushed during the tillage operation, or become entrapped and perish in newly formed clumps of soil (Wardle, 1995).

There are a variety of long-term impacts associated with CT practices, and they include decreased pore space availability and continuity, reduced soil moisture content, and reductions in litter density (Kladivko, 2001; Holland, 2004). The diverse physical characteristics of the mites and collembolans found within the soil food web mean the impacts of CT may vary with taxon. However, the majority of studies on the effects of CT on soil microarthropod assemblages provide evidence of overall decreases in mite and collembolan diversity and activity (Holland, 2004; Tabaglio *et al.*, 2009; Dubie *et al.*, 2011).

Another aspect of modern sugarcane farming systems that is likely to affect soil microarthropod communities is compaction caused by tillage, harvesting and haul-out machinery. Similar to impacts associated with CT, soil compaction has been shown to reduce the abundance of soil microarthropods via changes to soil physical characteristics (Schrader and Lingnau, 1997). As bulk density increases, pore spaces decrease, and since most microarthropods are unable to dig their own burrows, they are unable to find food resources and reproduce. A study with collembolans, for example, indicated that their abundance was reduced by about 80% in the bulk densities typically found in wheel tracks (Larsen *et al*., 2004).

In natural ecosystems, the presence of plant residues can alter soil chemical composition and change microclimate, and these factors have been shown to increase microarthropod abundance (Villarreal-Rosas *et al*., 2014). The absence of such residues in agroecosystems results in low densities of this group of animals (Badejo *et al*., 1995), a result that was confirmed by a meta-analysis of 62 studies on the response of invertebrates to changing complexity in a variety of habitats, including agricultural systems (Langellotto and Denno, 2004).

Mite populations increased significantly when detritus layer complexity increased through the addition of leaf litter and mulch. The authors suggested that the response was not only a result of increased resource availability but also that increasing habitat complexity enabled animals to gain refuge from predation.

A continuous supply of organic matter is integral to the vitality of the soil system as it stabilises pore spaces by forming aggregates and provides resources for bacteria and fungi. These organisms are a valuable food source for a variety of microfauna, including nematodes, which are in turn food for mesofauna. In a recent study conducted throughout a variety of agricultural settings in India, soil organic matter was found to be a key factor governing the abundance and diversity of arthropods in soil, primarily members of the microarthropod assemblage (Shakir and Ahmed, 2014).

Microarthropods in sugarcane soils

Little is known about the microarthropod fauna associated with sugarcane in Australia, as arthropod research has focused on the biology and control of the much larger root-feeding pests such as cane grubs, soldier flies, ground pearls, cicadas, funnel ants and symphylans (Allsopp *et al*., 1993).

Preliminary studies

Methods

Given the negative effects of tillage, compaction and lack of ground cover on microarthropods (see above review), our survey focused on sites where sugarcane was grown under minimum tillage, traffic was controlled to minimise compaction, and a permanent cover of crop residues was retained on the soil surface. These practices, together with the inclusion of a legume crop in the rotation, are key elements of a sugarcane farming system developed by the Sugar Yield Decline Joint Venture (Garside *et al*., 2005).

Since this farming system has not yet been widely adopted by growers, conventionally farmed sites were also sampled. This meant sampling farms where wheel spacing and row spacing did not match, and where the soil had been tilled prior to planting.

To provide the greatest chance of retrieving microarthropods in these situations, soil was collected from second, third, fourth or later ratoon crops, as it was thought a post-tillage period of at least 3 years may have given microarthropod populations time to recover from the negative effects of tillage. In an attempt to avoid the compacted zones that inevitably occur in the conventional sugarcane farming system, soil was always collected from the middle of the row.

Soil samples were collected between July and September 2014 from the Mackay and Bundaberg districts. Each sample consisted of about 3 L of soil from a depth of 0–10 cm. Any crop residue remaining in the trash blanket was scraped from the soil surface and about 500 mL of soil was collected with a spade from six randomly-selected points in each field.

Microarthropods were extracted from each of the soils by placing a 600 mL subsample in a Tullgren funnel for 5 days. Collected animals were stored in 85% ethanol and exemplars mounted on microscope slides. The microarthropods were identified using a variety of published keys, papers, and books (Krantz and Walter, 2009; Walter and Proctor, 2013)

Results

Preliminary results from 18 samples (16 different sites and 2 sites each with 2 samples) revealed a diverse microarthropod assemblage (range 89–529 individuals per sample) dominated by

fungivores and detritivores (Table 1). For purposes of preliminary analysis, the 2795 microarthropods identified have been sorted into four guilds based on the probable degree of nematophagy among the constituent species.

Miscellaneous microarthropods

These are primarily hexapods (insects, diplurans, proturans), myriapods (millipedes, symphylans, centipedes) and arachnids (small spiders, pseudoscorpions, prostigmatic and endeostigmatic mites) and isopods. Mostly these animals are predators of arthropods, fungivores or plant parasites (symphylans, some of the insects), and are not known to feed on nematodes.

Fungivore/detritivores

This group is composed of springtails (Collembola) and oribatid mites (Oribatida) that feed primarily on the microbes that cause decomposition, but also on root-parasitic fungi. Many species also opportunistically feed on nematodes and may be important background biocontrol agents. They also spread the spores of nematode-trapping fungi.

Predatory Mesostigmata Group 1

Most Mesostigmata will feed on nematodes and some are obligate nematophages. For this analysis, we are using a size/taxonomy division. Group 1 contains about a dozen medium-sized (adult length >0.35 mm) species, typically with oval bodies, entire dorsal shields and long legs in the families Parasitidae, Veigaiidae, Ologamasidae, Laelapidae, Eviphididae, Macrochelidae, Blattisociidae and Uropodidae.

Species in the representative genera that have been studied are primarily general predators that take both arthropods and nematodes (e.g. *Gaeolaelaps, Cosmolaelaps, Gamasiphis*) and those that seem to prefer nematodes to arthropods (e.g. *Evimirus*, *Cheiroseius*) (Walter and Ikonen, 1989; Walter and Kaplan, 1990a; Beaulieu and Walter, 2007). Since their bodies are inflexible, these mites are restricted to relatively large soil pore spaces; however, their mouthparts (chelicerae) are elongate and can be used to probe smaller soil pore spaces contiguous with the ones they travel.

Predatory Mesostigmata Group 2

Group 2 are small to minute (adult length <0.35 mm) mites with a narrow body and usually a divided dorsal shield. Their shape and flexibility allow them to penetrate relatively small pore spaces and some species have muscles that allow the posterior to be bent or wiggled to move past obstructions.

Additionally, their chelicerae can be used to probe even smaller recesses. Most species belong to the Rhodacaridae (species of *Rhodacarus, Rhodacarellus, Multidentorhodacarus, Protogamasellopsis*) and Ascidae (species of *Gamasellodes, Protogamasellus, Asca*). They are avid nematophages and sometimes nematode specialists (Walter and Ikonen, 1989; Walter and Kaplan, 1990b).

Table 1—Mean number of microarthropods by guild recovered from sugarcane mineral soils in an initial survey of 16 sites in the Bundaberg and Mackay regions, and food sources based on the literature.

Guild	No. of sites	No./600 mL soil	Possible food sources			
			Fungi	Nematodes	Arthropods	Other
Miscellaneous microarthropods	16	29	++		++	+
Fungivore/ detritivores	16	116	++++	+		
Predatory Mesostigmata Group 1	16	6		++	+++	
Predatory Mesostigmata Group 2	13	4		++++	+	

Discussion

Although we have reported only preliminary results from a much larger survey, it is clear that a diverse community of potentially beneficial soil microarthropods is present in Queensland sugarcane soils. Most of the species are oribatid mites and springtails that help regulate decomposition through comminution of litter, grazing on fungi, and dispersal of microbial propagules. However, many are also opportunistic predators of nematodes. Additionally, about two dozen species of predatory mesostigmatic mites were identified, including many that are known to feed on nematodes. The rarest of these, the very small species under 0.35 mm in length, are likely to be the most important nematode predators in the root-zone. We conclude that there is a soil microarthropod community in sugarcane soils, and that it has the potential to contribute to the suppression of nematode pests.

Over the course of our current project we intend to expand our survey work to include more sites and more cane-growing regions in Queensland. Once the predominant microarthropods in sugarcane soils are known, we hope to:

1) identify the microarthropods most likely to prey on plant-parasitic nematodes;

2) confirm their capacity to consume nematodes;

3) determine whether the trash blanket is an important habitat for microarthropods; and

4) determine whether tillage, soil compaction, and the pesticides applied for canegrub control have a negative impact on nematophagous species.

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