Nematode-trapping fungi in conventionally and organically managed corn-tomato rotations

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Abstract: We tested the hypothesis that nematode-trapping fungi would be more abundant in organically-managed than in conventionally-managed plots (corn-tomato rotation) in the Long Term Research on Agriculture Systems Project (Yolo County, CA). The replicated plots were established in 1992, began receiving different levels of organic matter (no organic amendments or incorporation of a winter legume crop plus composted manure) in 1993, and were sampled for fungi four times, twice near harvest (Sep 1995 and Nov 1996) and twice near planting (May 1996 and 1997). Fungi were quantified using soil dilution and soil sprinkle plates combined with most probable number procedures. The following fungi were detected: Arthrobotrys haptotyla, A. oligospora, A. thaumasia, Dactylella leptospora, Harposporium anguillulae, Meristacrum sp., Monacrosporum eudermatum, Nematoctonus leiosporus, and Stylapage sp. Arthrobotrys thaumasia was the most abundant (about 10 propagules/g of soil) followed by A. oligospora (about 1 propagule/g of soil). Population densities of the other fungi were usually less than 1 propagule/g of soil. Except for N. leiosporus, which was detected more frequently in the organic plots, and Meristacrum sp., which was more abundant in the organic plots, detection frequencies and population densities of nematode-trapping fungi were similar in conventional and organic plots.

Key Words: nematode, nematophagous, organic amendments, organic matter

INTRODUCTION

In laboratory experiments, nematode-trapping fungi often increase in numbers or activity when organic matter is added to soil (Stirling 1991). The increase may be explained by two possible mechanisms. According to one, nematode-trapping fungi obtain carbon and energy from the organic amendment and obtain nitrogen, which is often in short supply, by trapping nematodes (Cooke 1968, Thorne and Baron 1984). According to the second possible mechanism, nematode-trapping fungi obtain most or all of their carbon, energy, and nitrogen from nematodes, whose numbers increase when organic matter is added to soil (Gray 1987, Jaffee 1993, Linford et al 1988).

Whereas both mechanisms seem reasonable and are supported to various degrees by laboratory experiments, field data are scarce, and it is therefore unclear whether organic amendments actually enhance nematode-trapping fungi in agricultural fields (Jaffee et al 1998). Part of the problem is that the fungi are difficult to quantify (Persson et al 2000). In addition, replicated field plots receiving different levels of organic inputs are expensive to establish and maintain. Both problems, however, are solvable. Traditional dilution plating (Eren and Pramer 1965), although time consuming, has provided meaningful and reproducible estimates of population densities of nematode-trapping fungi in the field (e.g., Jaffee et al 1996, 1998, Persmark et al 1996, Persmark and Jansson 1997) and in the laboratory or greenhouse (e.g., Jaffee 1998, Persson and Jansson 1999). With respect to the second problem, field experiments with large and replicated plots receiving different quantities of organic matter have become more common as interest in organic farming has increased.

Two such field experiments exist at the University of California at Davis: the Sustainable Agriculture Farming Systems Project (SAFS) (Temple et al 1994) and the Long Term Research on Agricultural Systems Project (LTRAS) (Chen et al 1995, Denison et al 1996, McGuire et al 1998). A previous paper (Jaffee et al 1998) provided data on nematode-trapping fungi during the early years of the SAFS project. In the present paper, we examine nematode-trapping fungi at the LTRAS site 2–3 yr after the project was started. We describe which species are present and whether numbers of species and population densities of individual species differ in conventionally managed and organically managed plots.

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MATERIALS AND METHODS

The LTRAS field is located in Yolo County, California, about 9 km west of the SAFS field, and consists of 72 contiguous plots (0.4 ha/plot) (McGuire et al. 1998). The soil is a silt or silt clay, with 1–2% organic matter content and pHwater values ranging from 7.0 to 7.5 (R. Ford Denison pers comm). The plots were established and planted with sudan grass in 1992 and 1993. In Nov 1993, a split-plot design was started, with water (dryland vs irrigated) as the main factor and nitrogen source as the subplot factor. We sampled only a subset of the treatments. The sampled plots were on a 2 yr, corn-tomato rotation that received full irrigation. Nitrogen was supplied either by inorganic fertilizer (conventional management) or by annual inputs of composted manure (about 9 x 10³ kg/ha when tomato was planted and about 27 x 10³ kg/ha when corn was planted) plus incorporation of a winter legume crop (organic management). Both management systems also received crop residues. The winter legume crop (a mix of woolly-pod vetch and field pea) was first planted in the organic plots in fall 1993 and composted manure was first added in spring 1994. Herbicides were applied to the conventional plots but not to the organic plots; in addition, both kinds of plots were mechanically cultivated and hand-hoed to control weeds. No other pesticides were applied.

The three replicate plots for each management system were sampled in Sep 1995 (corn was ready to harvest), May 1996 (young tomato plants were present), Nov 1996 (the tomatoes had been harvested but a covercrop had not yet been planted in the organic plots), and May 1997 (young corn plants were present). Twenty soil cores (2 x 15 cm) were collected from each plot on each date. The cores were collected near roots if plants were present. The 20 cores were combined to form one sample per plot, which was passed through a sieve (6-mm openings) and mixed.

Within 3 d of sampling, a five-fold soil dilution series, with three dilution levels, was prepared for each sample. Soil (100 g dry weight equivalent per sample) was suspended in sterile distilled water (final vol = 200 mL) and shaken for 8 min. The suspension was diluted two more times. Aliquots (0.1 ml) for each dilution were pipetted onto quarter-strength corn meal agar (CMA/4) in 10-cm-diam petri dishes. There were five dishes per dilution per sample ( = 15 dishes per sample), and each dish contained 0.05, 0.01, or 0.002 g of soil, depending on the dilution. Because the dilution plates cannot be used to detect small numbers of fungi (Jaffee et al. 1998), soil sprinkle plates also were prepared by adding 2.0 g of soil to each of five CMA/4 dishes for each sample. Bait nematodes were added to the dilution and sprinkle plates to increase the probability of observing nematode-trapping fungi. Additional details are provided in Jaffee et al. (1998).

After 3 wk at 22 C, all plates were examined at ×70–140. Nematode-trapping fungi were identified based on reproductive structures and traps and by using a published key (Cooke and Godfrey 1964) and original descriptions. If a fungus produced conidia similar to those of trapping fungi (large, noncircular, and on long conidiophores) but was not producing traps, the fungus was isolated by transferring a single conidium to sterile CMA/4. Nematodes were added to the growing colony, and the fungus was identified after it sporulated and formed traps. Species were enumerated (propagules/g of soil) using a most probable number program (Klee 1993). If a fungus was detected on both the dilution and sprinkle plates, the larger number (from the dilution plates) was used.

SAS System for Windows software (SAS Institute Inc., Cary, North Carolina) was used for statistical analysis. Quantitative data were subjected to analysis of variance; population densities of fungi were log transformed before analysis. Frequency data (presence or absence of fungus species) were subjected to logistic regression analysis (SAS GENMOD procedure).

RESULTS

We found nine species of nematophagous fungi in the LTRAS plots (Table 1); although three of these are usually considered endoparasitic rather than trapping fungi, the distinction between the two groups is not clear (Barron 1977), and for simplicity we will call them all nematode-trapping fungi in this paper. When the entire data set was considered (independent variables were cropping system, sample date, and the interaction of cropping system and sample date), the mean number of species of trapping fungi detected per replicate sample did not differ (P > 0.05) between the cropping systems (Fig. 1). When the data set was restricted to the last sample date, however, the number of species detected was greater (P = 0.05) in the organic than in the conventional plots. The percentage of samples positive for individual species was not affected by cropping system (P > 0.05), except in the case of Nematoctonus leiosporus, which was detected more frequently (P < 0.01) in the organic than in the conventional plots (Fig. 2). The total number of propagules/g of soil for all the

<table>
<thead>
<tr>
<th>Fungus</th>
<th>Kind of trap or infective propagule</th>
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</thead>
<tbody>
<tr>
<td>Arthrobotrys haplotyla</td>
<td>adhesive knobs</td>
</tr>
<tr>
<td>Arthrobotrys oligospora</td>
<td>adhesive networks</td>
</tr>
<tr>
<td>Arthrobotrys thaumasia</td>
<td>adhesive networks</td>
</tr>
<tr>
<td>Dactylella leptospora</td>
<td>adhesive knobs and nonconstricting rings</td>
</tr>
<tr>
<td>Harposporium anguillulae</td>
<td>ingested conidia</td>
</tr>
<tr>
<td>Meristacrum sp.</td>
<td>adhesive conidia</td>
</tr>
<tr>
<td>Monacrosporum eudermatum</td>
<td>adhesive networks</td>
</tr>
<tr>
<td>Nematoctonus leiosporus</td>
<td>adhesive conidia</td>
</tr>
<tr>
<td>Stylopage sp.</td>
<td>adhesive hyphae</td>
</tr>
</tbody>
</table>

* Usually considered an endoparasitic rather than a nematode-trapping fungus.
nematode-trapping fungi was unaffected by cropping system ($P > 0.05$), sample period, or the interaction between the two (Fig. 3); cropping system also had no effect ($P > 0.05$) if the data were restricted to the last sampling date, when numbers appeared larger in the organic plots.

The number of propagules/g of soil by fungus species was unaffected ($P > 0.05$) by cropping system for any fungus except *Meristacrum sp.*, which was more abundant ($P < 0.01$) in the organic plots (Fig. 4). Numbers of *Meristacrum sp.*, however, were very small. In both conventionally- and organically-managed plots, numbers of *A. thaumasia* were substantially greater than those of other species.

**DISCUSSION**

Overall, the data from the LTRAS site did not support the hypothesis that organic amendments substantially enhance nematode-trapping fungi in commercial agriculture. Thus, organic amendments did not consistently affect the number of species of trapping fungi detected, the kinds of fungi detected, or their total population densities. Of the nine fungi observed, only *N. leiosporus* and *Meristacrum sp.* were stimulated by organic amendments. This stimulation

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**Fig. 1.** Number of species of nematode-trapping fungi detected per plot in conventional and organic plots. Values are the means ± SE of three replicate plots. Approximately 10 g of soil was processed per replicate.

**Fig. 2.** Detection of nematode-trapping fungi in conventional and organic plots. Detection indicates the number of positive samples divided by 12 (four sample dates × three replicate plots) × 100.

**Fig. 3.** Population density of all nematode-trapping fungi in conventional and organic plots. Values are the means ± SE of three replicate plots.

**Fig. 4.** Population density of species of nematode-trapping fungi averaged over four sample dates in conventional and organic plots. Values are the means ± standard error of three replicate plots × four sample dates.
was minimal, however, as their population densities were less than 1 propagule/g of soil.

The current results from the LTRAS site were in many ways similar to those from the SAFS site (Jaffee et al 1998). For example, the total population densities of nematode-trapping fungi at both sites averaged 16 propagules/g of soil, whether plots were amended or unamended with organic matter. Similar fungi were found at both sites, and organic amendments enhanced *N. leiosporus* at both sites. One difference was that organic amendments did not generally enhance the number of species of nematode-trapping fungi detected per plot per date at LTRAS but did so at SAFS; although statistically significant, the enhancement at the SAFS site was nevertheless small (3.8 species per conventional plot and 4.5 per organic plot).

A more dramatic difference between the sites occurred with *Arthrobotrys dactyloides*. This fungus, which uses constricting rings to capture nematodes, was much more abundant in organic than in conventional plots of SAFS (Jaffee et al 1998) but was not detected at all in the LTRAS plots. The failure to detect *A. dactyloides* at LTRAS cannot be explained by methodology because the same methods were used for both studies. The sites differ in soil texture (the LTRAS soil contains more clay), and the sites also differ with respect to when they were sampled; the LTRAS site was sampled nearer to project initiation.

Three fungi detected in LTRAS and in SAFS plots have been studied recently as potential control agents of plant-parasitic nematodes. When added to tomato fields, a granular formulation of *A. dactyloides* partially controlled root-knot nematodes (Stirling and Smith 1998). When added to conventional SAFS soil in pots, an alginate pellet formulation of *A. dactyloides*, *A. thaumasia*, or *A. haptoptyla* suppressed penetration of cabbage roots by root-knot nematodes (Jaffee 1998). In the latter study, population densities of the added fungi were 10 to 10 000 times greater than those found naturally in the SAFS and LTRAS plots. One is therefore tempted to infer that low resident levels of nematode-trapping fungi, like those in LTRAS and SAFS plots, are unlikely to control nematodes (Stirling 1991), but Koppenhöfer et al (1997) found otherwise, albeit with different nematode-trapping fungi, a noncultivated soil, and an entomopathogenic nematode as the target. More data are needed on the how population densities or biomass of nematode-trapping fungi relate to suppression of nematodes.

While our data indicate that organic amendments do not substantially enhance nematode-trapping fungi in commercial agriculture (as practiced in Yolo County, California), our interpretations should be cautious because our study has important limitations. First, enhancement by organic amendments may be transient (Cooke 1968) or spatially patchy (Persmark and Jansson 1997), and our coarse, biannual sampling may have missed numerical peaks in time and space. Second, the SAFS plots and especially the LTRAS plots were established for only a few years when sampled, and longer times may be needed for organic amendments to enhance the nematode-trapping fungi. In this regard, the data presented here will be useful for comparison with future data collected from the same plots.

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