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Effects of fungicides and biofungicides on population density and community structure of soil oribatid mites

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HIGHLIGHTS

- A field study showed that two biofungicides have little side-effects on soil invertebrates.
- Chemical fungicides affected density and egg number in a species-specific manner.
- Oribatid mites represent a sensitive indicator for effects of pesticides on the soil ecosystem.

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ABSTRACT

To compare the side-effects of chemical versus biofungicides on non-target organisms in agricultural soil, a study of population structure, spatial distribution and fecundity of oribatid mites, a diverse and species-rich group of microarthropods indicative of decomposer activity in soil was done. Plots laid out in agricultural fields of a research station in Egypt, were cultivated with cucumber and treated with two chemical fungicides: Ridomil Plus 50% wp (active ingredients = metalaxyl and copper oxychloride) and Dithane M-45 (active ingredient = mancozeb), and two biofungicides: Plant Guard (containing the antagonistic fungus *Trichoderma harzianum*) and Polyversum (containing the fungi-parasitic oomycete *Pythium oligandrum*). All treatments were done using both low-volume and high-volume spraying techniques to check whether any effects were dependent on the method of application. Oribatid mite communities were assessed from soil core samples collected during the growing season. Total abundance of oribatids was not different across the plots, but some species decreased in number, while one species increased. Species diversity and community equitability decreased with the application of chemical and biofungicides especially when using high-volume spraying. In control plots most oribatid species showed a significant degree of aggregation, which tended to decrease under fungicide treatment. Ridomil Plus, Plant Guard and Polyversum had a negative effect on the gravid/ungravid ratio of some species. Egg number averaged over the whole adult population was not directly related to the application of chemical and biofungicides but it showed a species-specific relationship with population density. In general biofungicides had a smaller effect on population size and community structure of oribatid mite species than chemical fungicides. The results indicate that biofungicides may be the preferred option when aiming to prevent side-effects on sensitive groups among the species-rich soil detritivore community.

1. Introduction

Fungicides, herbicides and insecticides are used in agriculture to maximize crop production; they are credited for increasing food production and helping to protect man and animals against crop loss and diseases. When pesticides are sprayed, depending on the crop's canopy, a significant amount of the dose may reach the soil. Under normal agricultural practice, pesticide residues will be mixed into the top 15 cm layer of soil, the region of greatest activity of microorganisms and soil fauna (Blasco and Picó, 2009; Van Straalen and Van Rijn, 1998).

Most studies of pesticide effects on soil communities have focused on earthworms and Collembola, and few on soil-living mites. This contrasts with their great diversity, abundance and functional significance (Al-Assiuty et al., 1993; Seastedt, 1984). Oribatida (also known as Cryptostigmata) are one of the most numerically dominant arthropod groups in the organic horizons of most soils, where their densities can reach more than a hundred thousand individuals per square meter (Norton, 1990). Oribatida have a great variety of feeding niches

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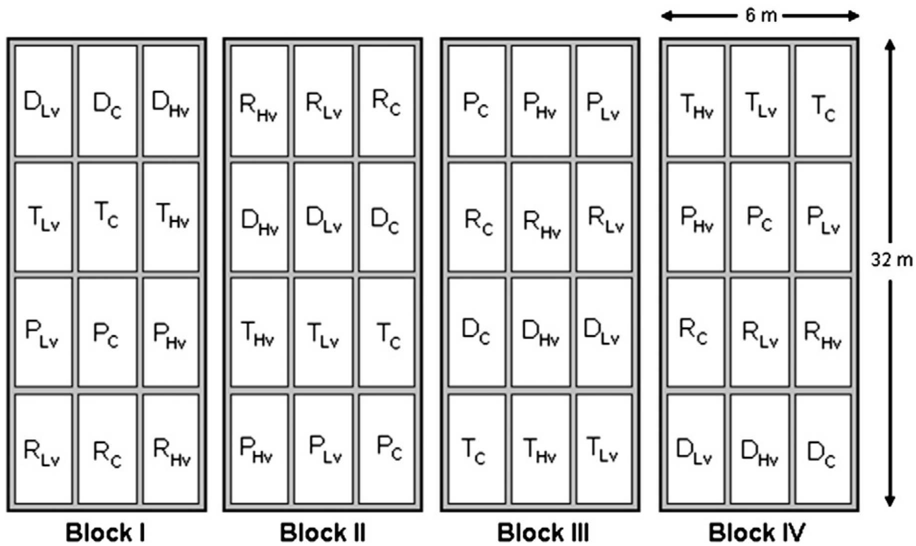

Fig. 1. Showing the layout of plots used in this study to assess effects of fungicide applications. Please note that length and width are drawn to different scales. Treatments are indicated by capital letters: D = Dithane M-45, R = Ridomil Plus, T = Plant Guard, P = Polyversum, C = control (water only); methods of application are indicated by subscripts: Hv = high volume, applied with a knapsack sprayer and Lv = low volume, applied with a motorized knapsack.

and are actively involved in decomposition of organic matter and in nutrient cycling (Behan-Pelletier, 1999).

Most oribatid mites can feed on a variety of fungal species (Maraun et al., 1998; Schneider et al., 2004; Schneider and Maraun, 2005). The spectra of fungi preferred by different species partly overlap and it is still unknown to what extent interspecific differences contribute to the coexistence of many seemingly similar species in a community (Maraun et al., 1998; Schneider and Maraun, 2005). Giving their dependence on fungal and other organic resources in the soil, oribatids will be affected by pesticides not only directly, but also indirectly, through shifts in the below-ground microbial community.

Several species have been found to be insensitive to insecticides, e.g., to chlorpyrifos (Stark, 1992). Other mites are positively affected by pesticides and still others are negatively affected, e.g., in response to the natural insecticide azadirachtin (Stark, 1992), copper and p-nitrophenol (Parmelee et al., 1993), and lindane (Scholz-Starke et al., 2013). Yet there are indications that oribatid mites as a group are more sensitive to toxic substances than other soil invertebrates (Streit, 1984; Lebrun and Van Straalen, 1995; Denneman and Van Straalen, 1991; Van Straalen et al., 1989).

The goal of the present study was to test whether biofungicides would have less severe side-effects on sensitive soil microarthropods than conventional chemical fungicides. In addition we tested two spraying devices differing in the amount of fungicide product applied per hectare, to investigate whether in addition to type of fungicide, possible side-effects could be minimized by a reduction of spray volume. In this way we aimed to develop the most environment-friendly method for plant protection in Egyptian cucumber culture. We assessed population structure, spatial distribution and reproductive status of oribatid mites as indicators of side-effects on the soil ecosystem.

2. Materials and methods

2.1. Study site

The experiment was carried out on a 24 × 32 m field at the experimental farm of Gemmeiza Agriculture Research Station, 15 km to the north-east of the city of Tanta, Governorate of Gharbia, Egypt (30° 49′ 14.62″ N, 31° 7′ 11.06″ E) in 2005. The soil was a clayey loam, pH 7.4–7.6; average soil temperature varied between 21 and 23 °C; daily average air temperature between 25 and 29 °C in the period of sampling. The field was divided into four equal blocks (I, II, III and IV, each 6 × 32 m), and each block further subdivided into 2 × 8 m plots (Fig. 1). Cucumbers were planted across the entire block with 50 cm distance in between them; a total of 64 plants were growing in each plot. Plant foliage initially covered about 10% of the surface area, increasing to 90% after one and a half month.

2.2. Application of fungicides

Two chemical fungicides were used in this study, Ridomil Plus 50% wp (active ingredients = metalaxyl-M and copper oxychloride) and Dithane M-45 80% wp (active ingredient = mancozeb, with manganese and zinc). The two biofungicides were Plant Guard (containing the antagonistic fungus *Trichoderma harzianum*), and Polyversum (containing the fungi-parasitic oomycete *Pythium oligandrum*). Both the conventional

Table 1
Active ingredients and application rates of the four fungicides used in this study. Fungicide treatments were repeated six times during the growing season of cucumber (3 months).

Fungicide product	Active ingredient	Concentration of a.i. in product	Tank concentration of product	Field application rate of a.i.	
				Lv (475 L/ha)	Hv (950 L/ha)
Ridomil Plus wp	Metalaxyl	15%	1.5 g/L	0.11 kg/ha	0.21 kg/ha
	Copper oxychloride	35%		0.25 kg/ha	0.50 kg/ha
Dithane M-45 wp	Mancozeb, ethylene-bisdithiocarbamate	62%	3 g/L	0.88 kg/ha	1.77 kg/ha
	Manganese	16%		0.23 kg/ha	0.46 kg/ha
	Zinc	2%		0.03 kg/ha	0.06 kg/ha
Plant Guard	*Trichoderma harzianum*	30×10^6 cells/mL	3 mL/L	43×10^9 cells/ha	86×10^9 cells/ha
Polyversum	*Pythium oligandrum*	No less than 10^5 cfu/g	1.5 g/L	71×10^6 cells/ha	143×10^6 cells/ha

wp, wettable powder; a.i., active ingredient; cfu, colony-forming units; Lv, low volume; Hv, high volume.