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Effects of Collembola and fertilizers on plant performance (*Triticum aestivum*) and aphid reproduction (*Rhopalosiphum padi*)

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Abstract

Effects of Collembola (*Protaphorura fimata)* on the development of wheat (*Triticum aestivum)* and the reproduction of aphids (*Rhopalosiphum padi)* were investigated at different soil nutrient concentrations in a laboratory experiment. Fertilization with N and NPK increased biomass and nitrogen content of wheat, aphid reproduction and abundance of Collembola. Presence of Collembola tended to decrease biomass of leaves and ears, and caused a delayed ear production of the plants. Aphid reproduction was significantly reduced in the presence of Collembola (−14%) and most pronounced in fertilizer treatments. We suggest that the reduction of aphid reproduction is caused by Collembola-mediated changes in resource allocation and growth of wheat.

Zusammenfassung

In einem Laborexperiment wurde der Einfluss von Collembolen (*Protaphorura fimata)* auf die Entwicklung von Weizen (*Triticum aestivum)* und die Reproduktion von Aphiden (*Rhopalosiphum padi)* in Böden mit verschiedenen Nährstoffgehalten untersucht. Durch Düngung mit N und NPK wurden Biomasse und Stickstoffgehalt von Weizen, die Reproduktion von Aphiden und die Abundanz von Collembolen erhöht. Collembolen verringerten tendenziell die Biomasse von Blättern und Ähren und verzögerten die Ährenbildung. In Anwesenheit von Collembolen war die Reproduktion von Aphiden signifikant reduziert (−14%); dies war in den gedüngten Behandlungen am deutlichsten. Die Ergebnisse deuten daraufhin, dass Collembolen durch Beeinflussung des Wachstums von Weizen die Reproduktion von Aphiden verringern können.
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Keywords: Soil organisms; Soil nutrients; Herbivory; Belowground–aboveground interactions; Microcosm; Fecundity

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Introduction

Below- and aboveground processes in terrestrial communities have usually been investigated separately from each other but the awareness of the interrelationships between below- and aboveground systems is increasing (Wardle et al., 2004). Studies investigating the effects of soil organisms on plants and the aboveground system have focussed on beneficial effects caused by mycorrhiza or detrimental effects caused by root herbivores (Bardgett & Chan, 1999; Bezemer et al., 2005; Harris & Boerner, 1990). However, the majority of soil organisms derive their energy from decomposition of soil organic matter. Since decomposers are responsible for nutrient recycling, the aboveground foodweb strongly depends on the activity of the belowground community.

Recent studies have shown that decomposers affect the development and reproduction of aphids (Bonkowski, Geoghegan, Birch, & Griffiths, 2001; Scheu, Theenhaus & Jones, 1999; Wurst & Jones, 2003). Aphids are good indicators of plant quality since they are sensitive to changes in nutrient supply within their host plants (Dixon, 1985). Aphid development and reproduction is known to be limited by nitrogen (Mattson, 1980; McNeill & Southwood, 1978; VanEmden, 1966; VanEmden & Bashford, 1969).

Collembola are the most important grazers of fungal mycelia in soil (Lussenhop, 1992; Shaw, 1992). Collembola grazing releases nutrients locked in fungal biomass (Filser, 2002; McGonigle, 1995). In addition, moderate grazing may keep fungi and particularly mycorrhiza in an active state, thus further promoting plant growth (Ek, Sjögren, Arnebrant, & Söderström, 1994; Gange, 2000). However, high grazing leads to decreasing mycorrhizal infection and, consequently, to negative effects on plant growth (Harris & Boerner, 1990; Lussenhop, 1996).

Scheu et al. (1999) were the first to investigate the effects of Collembola on the performance of aphid herbivores. They documented that Collembola increased aphid reproduction on the grass *Poa annua* by a factor of 3, whereas aphid reproduction on the legume *Trifolium repens* was reduced by about 45%. The authors suggested that Collembola decrease aphid reproduction on more palatable hosts with high tissue nitrogen concentrations but increase aphid reproduction on hosts of low food quality and low tissue nitrogen concentrations. Presumably, Collembola increased nutrient availability in soil thereby facilitating the growth of *P. annua* and accordingly that of aphids. By fixing atmospheric nitrogen legumes are less dependent on soil nutrient availability. Therefore, by mobilizing nutrients Collembola may little affect the growth of legumes and also that of plant sucking aphids. However, to prove whether Collembola affect aphid reproduction via increasing plant nutrient supply, studies investigating a single plant species growing at different soil nutrient concentrations are necessary.

To test whether the effect of Collembola on aphid reproduction indeed varies with host nutrient status, we investigated the effects of Collembola (*Protaphorura fimata*) on aphid (*Rhopalosiphum padi*) reproduction feeding on a single host species (wheat; *Triticum aestivum)* grown at different nutrient regimes. Wheat as model plant was chosen since grasses (Poaceae) vigorously respond to soil nutrient availability. We hypothesized that the presence of Collembola increases aphid reproduction by enhancing nutrient availability to unfertilized plants and that these effects resemble those of fertilizers.

Materials and methods

Experimental set-up

The experiment was set up in 42 experimental chambers consisting of PVC tubes (inner diameter 9.8 cm, height 20 cm). The tubes were closed at the bottom by lids and equipped with ceramic suction cups for drainage of leaching water. On the top of each chamber a wire-scaffold (height 40 cm) was installed to support plants and to fix clip cages (height 2 cm, diameter 4 cm) for aphids.

The chambers were filled with 960 g dry wt of a nutrient poor loamy soil (pH 7.0, 1.58% C, C/N ratio 18.2), which had been collected at a fallow site near Darmstadt (Roßberg, Hessen, Germany). The soil was sieved (1 cm) and defaunated from larger soil fauna by freezing at –22 °C for 9 days. Freezing is known to effectively kill soil arthropods including Collembola but to little affect soil microorganisms and soil nutrient status (Kampichler, Bruckner, Baumgarten, Berthold, & Zechmeister-Boltenstern, 1999; Stenberg et al., 1998). A layer of grass litter (3.7 g dry wt) was added on the top of each microcosm. The grass material had been collected at the same fallow site.

Seedlings of *T. aestivum* L. were pregrown in a climate chamber (18 ± 2 °C, 16 h light). After 10 days, when the plants had reached 8–10 cm, three plants were transplanted into each microcosm. Two days later 20 specimens of the euedaphic springtail *P. fimata* were added to half (21) of the chambers. Five days later the fertilizer treatments were established. One-third (14) of the microcosms received distilled H_2O (control), one-third 50 ml N fertilizer (+N) and the remaining third 50 ml NPK fertilizer (+NPK). The mass ratio of nitrogen: phosphorus: potassium was 1:1:2.5, which is comparable to commercial fertilizers. In both fertilizer treatments the same amount of N was added (11.6 g $NaNO_3$ in 1 l H_2O dest.). P and K were added as