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Addition of crop residues affects a detritus-based food chain depending on litter type and farming system

Elvira Sereda[a,*], Volkmar Wolters[a], Klaus Birkhofer[b]

[a]Department of Animal Ecology, Justus Liebig University, Heinrich-Buff-Ring 26-32, 35392 Giessen, Germany
[b]Department of Biology, Biodiversity and Conservation Science, Lund University, Sölvegatan 37, 223 62 Lund, Sweden

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Abstract

The addition of crop residues is a common farming practice to increase the organic carbon content of agricultural soils with particular importance in organically managed crops. Residues can be added either from the crop plant itself or from other plants and the type of litter may differentially affect decomposer populations. Effects of litter addition may cascade up to affect generalist predators via trophic cascades or modifications of structural microhabitat properties with unknown consequences for the role of these predators in below- and aboveground food webs. Wheat and maize litter were added to organically and conventionally managed wheat fields and effects on generalist predator and Collembola numbers, litter decomposition and carbon utilization as estimated by stable isotope analysis were studied. Significantly more predators were sampled in plots with maize litter compared to plots with wheat litter and under organic farming. Collembola numbers were not significantly affected by litter type or farming system. Litter mass loss was highest in plots that received wheat litter under organic management and was negatively related to predator, but not Collembola numbers. Individuals of *Lepidocyrtus* spp. (Collembola) incorporated high percentages of maize-borne carbon compared to predator species. Two linyphiid spider species were more closely linked to the maize-consuming prey in organically managed fields and one carabid species showed this pattern in conventionally managed fields. High litter decomposition levels and generalist predator numbers were only observed in wheat litter plots in organically managed fields. The addition of crop residues from the growing crop under organic management may therefore be a promising farming practice to simultaneously promote decomposition services and numbers of natural enemies. Future studies need to address this practice and potential effects on the litter–decomposer–predator food chain across sites that cover a range of different soil types and climatic conditions.

Zusammenfassung

Das Ausbringen von Pflanzenstreu ist eine Bewirtschaftungsmaßnahme um den organischen Kohlenstoffgehalt in Ackerböden zu erhöhen, welche besonders in der ökologischen Landwirtschaft angewandt wird. Pflanzenstreu stammt dabei entweder von der angebauten Feldfrucht oder anderen Pflanzenarten. Streutypen können sich in ihrer Qualität als Nahrungsressource für Streuzersetzer unterscheiden und dadurch die Zersetzergemeinschaft verändern. In Folge dieser Effekte können Veränderungen von trophischen Kaskaden oder der strukturellen Eigenschaften des Mikrohabitats die Aktivitätsdichte von Raubarthropoden

*Corresponding author. Tel.: +49 0641 9935717; fax: +49 0641 9935709.
E-mail address: Elvira.Sereda@allzool.bio.uni-giessen.de (E. Sereda).

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beeinflussen. In dieser Studie wurde Weizen- und Maisstreu auf ökologisch und konventionell bewirtschafteten Weizenfeldern ausgebracht und die Auswirkungen auf die Aktivitätsdichte von Collembolen und Raubarthropoden, die Zersetzerleistung und die Ressourcennutzung untersucht. Die Nutzung verschiedener Kohlenstoffquellen wurde anhand der Verhältnisse von stabilen Kohlenstoff-Isotopen in den Konsumenten ermittelt. Auf ökologisch bewirtschafteten Flächen war die Aktivitätsdichte der Raubarthropoden höher als auf konventionell bewirtschafteten Flächen. Die Aktivitätsdichte der Collembolen wurde weder durch den Streutyp noch die Bewirtschaftung signifikant beeinflusst. Die Aktivitätsdichte der Raubarthropoden war außerdem signifikant höher auf Teilflächen mit Maisstreu im Vergleich zu Teilflächen mit Weizenstreu. Der Streuverlust aus Netzbeuteln war auf Teilflächen mit Weizenstreu in den ökologisch bewirtschafteten Weizenfeldern am höchsten. Individuen aus der Gattung *Lepidocyrtus* spp. (Collembola) nutzten vor allem Maisstreu als Kohlenstoffquelle. Zwei Spinnenarten waren auf ökologisch bewirtschafteten Agrarflächen Teil der Maiskohlenstoff-Nahrungskette und eine Laufkäferart zeigte dieses Muster in konventionell bewirtschafteten Feldern. Eine hohe Aktivitätsdichte von Raubarthropoden bei gleichzeitig hoher Streuzersetzung wurde nur auf ökologisch bewirtschafteten Feldern auf Teilflächen mit Weizenstreu beobachtet. Das Ausbringen von Pflanzenstreu der angebauten Feldfrucht auf ökologisch bewirtschafteten Getreideflächen ist eine mögliche Option für die gleichzeitige Erhöhung der Zersetzerleistung und der Anzahl von Raubarthropoden. Zukünftige Untersuchungen sollten zeigen, wie sich solche Praktiken bei unterschiedlichen klimatischen Bedingungen und Bodentypen auf die Nahrungsnetz-Beziehungen von Zersetzern und Räubern auswirken.

Keywords: Araneae; Carabidae; Collembola; Crop residues; Litter quality; Mulching; Organic farming; Predator–prey interactions; Stable isotopes; Trophic cascades

Introduction

The addition of crop residues increases soil organic carbon content (Kumar & Goh 1999) and enhances densities of natural enemies (Médiène et al. 2011) in agricultural fields. Residue management is therefore an important farming practice in organically fertilized systems (e.g. organic farming, Zehnder et al. 2007), which has been proposed to mitigate the loss of biodiversity due to agricultural intensification (Tuck et al. 2014) and may at the same time increase decomposition and pest control services. Abundances of generalist predators and Collembola are often higher under organic farming (Birkhofer, Bezemer, Hedlund, & Setälä 2012), but few studies have focused on functional consequences of individual farming practices in organic and non-organic farming systems (Letourneau & Bothwell 2008) or on how resource addition may alter trophic interactions in agricultural fields (Duyck et al. 2011).

Trophic links between predators and prey from the belowground system may be directly affected by the addition of crop residues (Halaj & Wise 2002). Litter resources that are either added from a different crop or from the standing crop may indirectly enhance generalist predator numbers via trophic cascades that include decomposer prey (Scheu 2001). These cascading effects are explained by the energy-shunt hypothesis (Oksanen et al. 1997) under which decomposer taxa benefit from the addition of a litter resource and generalist predators then show a numerical response to the enhanced availability of decomposer prey (“resource-mediated effects” sensu Diehl, Wolters, & Birkhofer 2012). Such trophic cascades have been documented in vegetable gardens (Halaj & Wise 2002), forests (Miyashita, Takada, & Shimazaki 2003) and conventionally managed cereal fields (Birkhofer, Wise, & Scheu 2008a). However, the addition of litter resources does not only increase food availability, but also alters the microhabitat structure (“microhabitat structure-mediated effects” sensu Diehl, Wolters & Birkhofer 2012). These alterations of habitat structure may lead to numerical responses by generalist predators independent of trophic cascades, which are often driven by a more favourable microclimate in areas with more complex microhabitat structure (e.g. Diehl, Wolters & Birkhofer 2012). In contrast, more complex vegetation structure can reduce the number of spiders caught by pitfall traps due to lower activity in such habitats (Topping & Sunderland 1992). Both, the density and activity of a species affect the number of individuals caught by pitfall traps and the term activity density is therefore used instead of abundance (Thiele 1977).

The addition of straw mulches is a common agricultural practice in vegetable crops (Snyder & Wise 1999) and cereals in tropical or arid regions (Buerkert, Bationo, & Dossa 2000). The food chain that includes straw mulches, Collembola and generalist predators is an ideal study system to identify effects of the addition of different litter types on decomposition processes and resource utilization in agricultural systems (e.g. Halaj & Wise 2002). Generalist predators consume significant numbers of Collembola in agricultural systems (Bilde, Axelsen, & Toft 2000) and Collembola are generally abundant in agroecosystems of temperate regions. The consumption of certain Collembola species contributes to a higher fitness of generalist predators (Toft & Wise 1999) and Collembola are important secondary decomposers of plant litter (Rusek 1998). However, the availability of basal resources in agroecosystems is often a limiting factor