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Management intensity interacts with litter chemistry and climate to drive temporal patterns in arthropod communities during decomposition

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ABSTRACT

Shifts in the density and composition of arthropod communities can alter soil carbon and nitrogen cycling dynamics. However, it is uncertain how factors such as land use intensity, litter chemical composition, and climate structure arthropod communities during decomposition. During a 730-day study, we characterized temporal changes in litter-colonizing arthropod communities in two litter types (corn, *Zea mays*, and grass, predominantly *Bromus inermis*) decomposing in three ecosystems representing an agricultural management intensity gradient (conventionally tilled, no-till, and old field). Further, to assess the relationships between litter chemistry and arthropod communities, we also correlated changes in arthropod densities and community composition with shifts in litter molecular chemical characteristics. Arthropod densities were greater in decomposing grass litter than in corn litter for seven out of thirteen taxa collected and all but two taxa increased in litter with management intensity (spiders – negative, Entomobryidae – no response). In contrast, total arthropod densities in soil decreased with management intensity. Temporal variation in arthropod density and community composition in litter corresponded with precipitation events and changes in litter chemistry during decomposition. For example, collembolan, oribatid, and mesostigmatid mite densities were negatively correlated with the relative abundance of lignin and positively correlated with nitrogen containing compounds. Our study demonstrates that the influence of agricultural management intensity on arthropods in litter is strikingly different from that in bulk soil, and suggests that management intensity interacts with litter chemistry and climate over the course of decomposition to determine both the density and composition of arthropod communities inhabiting litter at the soil surface.

Introduction

Plant litter serves as a habitat and basal resource for soil arthropods. These animals make an important contribution to soil carbon and nitrogen cycling but their specific contributions can vary with arthropod density and community composition (Bradford et al. 2007; Eisenhauer et al. 2011). Consequently, factors that alter arthropod communities such as land use intensity may fundamentally alter litter decomposition dynamics; yet, despite decades of research on the ecology of soil arthropods, we still lack a clear understanding of the plant, soil, and management factors that determine the structure of their communities during long-term litter decomposition.

Land use practices such as agricultural production influence the density and composition of litter-colonizing arthropods. For example, crop diversity and plant residue management practices can alter the quantity and distribution of available plant litter while soil management practices influence the location and accessibility of litter in soil. These practices also influence plant litter chemistry, which is known to play a significant role in structuring soil arthropod communities (Cotrufo et al. 1998; Hansen and Coleman 1998; Scheu et al. 2003; Nielsen et al. 2010). However, while we know that litter chemical traits determine arthropod community composition during very early stages of decomposition (Smith and Bradford 2003; Yang and Chen 2009; Aubert et al. 2010), few studies have examined the relationship between litter chemistry and soil arthropod communities throughout the entire litter decay sequence, which often spans multiple years (Tian et al. 1995; Irmler 2000).

In addition to determining plant residue dynamics, tillage and other agricultural management practices cause physical damage or death to many detritivorous and predatory arthropods (Wardle 1995). Tillage also alters edaphic factors such as soil pore structure, and microclimate (Pagliai et al. 1995; Duiker and Lal 1999; Grandy and Robertson 2006), which have well known effects on soil conditions important to arthropods (Nielsen et al. 2008). These habitat modifications can have mixed effects on arthropods that depend on the life history characteristics of the taxon in question

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and the intensity of disturbance. While large bodied arthropods, including carabid beetles and spiders, typically exhibit a negative response to management intensity (Sunderland and Samu 2000; Shrestha and Parajulee 2010; Ward et al. 2011), the response of microarthropods is less consistent (Wardle 1995; Miura et al. 2008), likely due to their small body size, and high variability in dispersal potential, generation time, dormancy capacity, and fecundity. For example, oribatid mites, which are slow-moving and relatively long-lived typically respond negatively to tillage, whereas taxa which exhibit fast generation times and high fecundity, such as astigmatid and some prostigmatid mites, can respond positively to tillage (Kladivko 2001). Taken together, however, it is clear that soil disturbance associated with agricultural management can substantially alter the density and community composition of arthropods involved in litter decomposition.

In addition to their independent effects, agricultural management practices may have numerous interactive effects on litter-colonizing arthropods (Cookson et al. 1998; Vreeken-Buijs et al. 1998; Wickings et al. 2011). High quality litter, for example, may buffer arthropod communities against the effects of tillage (Wardle et al. 1999), but these interactions may be hard to predict over time because tillage and litter chemistry exhibit unique temporal patterns. Thus, the importance of tillage and plant residue chemistry in structuring arthropod communities during decomposition may depend heavily upon agricultural management timelines as well as plant residue decay stage.

Given our uncertainty regarding the factors regulating arthropod communities during decomposition, our overall objective was to explore the roles of agricultural management intensity and litter chemistry in structuring litter-colonizing arthropod communities over the course of long-term decomposition. We were specifically interested in determining whether (a) management intensity (i.e. conventional and no-till agriculture and an early successional old field) and litter type (i.e. corn and grass) influence arthropod density and community composition in litter decomposed at the soil surface, (b) management effects on arthropod communities are regulated by litter chemistry, and (c) relationships between management intensity, litter chemistry and arthropod communities vary across three growing seasons of field decomposition.

Materials and methods

A 730-day litter decomposition experiment was conducted at the W.K. Kellogg Biological Station, Long Term Ecological Research Site (KBS, LTER), MI from June 2008 through July 2010 (Wickings et al. 2012). The site receives approximately 890 mm of precipitation annually and soils are characterized as fine- to coarse-loamy, mixed, mesic Typic Hapladulfs of the Oshtemo and Kalamazoo series. At the LTER site, we used twelve 1 ha experimental plots under three management practices (conventionally tilled, no-till and old field), each replicated four times. Both conventionally tilled (CT) and no-till (NT) treatments follow a corn–soy–wheat rotation. CT and NT plots were treated with a pre-emergence herbicide and planted in May with corn (2008) and soybean (2009) following chisel plowing in CT plots. Harvest occurred in October in 2008 and 2009. Following soybean harvest in 2009, CT and NT plots were planted with winter wheat for the 2010 growing season. During 2010, CT and NT plots were treated with herbicide in April and were harvested on July 14. All agronomic practices were conducted according to Michigan State University best management practices (Crum et al. 2009). Old fields (OF) were previously under conventional tillage agriculture until 1989 when agricultural practices were halted and the sites transitioned to an early successional community. OF plots support a mixture of grasses, forbs, shrubs and small trees but are dominated by grasses, primarily *Bromus* spp., and are annually burned in March or April to maintain an early successional stage. Soil characteristics associated with each treatment are reported in Table 1.

Litterbag experiment

A litterbag study was conducted during three growing seasons (yr1 – corn, yr2 – soybean, yr3 – wheat for CT and NT plots) from June 2008 through July 2010 (Wickings et al. 2012). Litterbags measuring 18 cm × 18 cm were constructed from nylon mesh with approximately 1.5 mm square openings to allow entry by arthropods. Litterbags were filled with approximately 7 g of grass or corn litter. Living grass shoots and stems of *Bromus inermis* were harvested from nearby old field sites during May 2008. Standing dead corn plants (stalks and leaves) were collected during fall of 2007 from a conventionally managed site near the KBS LTER main site. These plant litter types were selected in order to achieve substantial differences in initial litter chemical composition (see Table 1). All litter was air dried and cut to approximately 2–4 cm pieces before placement into litterbags. Litterbags were placed on the soil surface, ensuring uniform contact with the soil by removing both living and dead plant biomass where necessary. Bags were secured to the soil surface at their corners with stainless steel nails. In all treatment plots, two rows of litterbags, one for grass litter and one for corn litter, were placed 4 m apart. Within rows, litterbags were spaced approximately 60 cm apart. In OF plots, corn and grass litterbag rows were created that ran the same cardinal direction as those placed in agricultural plots. Litterbags were placed in the field on June 06, 2008 and corn and grass bags were collected after 6, 17, 26, 39, 72, 108, 368, 411, 452, 482, 712 and 730 days of decomposition. During management activities, all litterbags were removed from the field and placed into open plastic bags just outside of the plots until all management was completed.

Arthropod extraction and identification

Upon collection, litterbags were transported on ice and later stored at 4 °C for arthropod extraction using collapsible Berlese funnels (Bioquip, Rancho Dominguez, CA). Extractions were conducted for 5 days during which extraction temperatures were increased daily from room temperature (22 °C) to a maximum of 50 °C. Arthropods were extracted into 90% ethyl alcohol for storage and identification. Mite identifications were made to suborder using keys provided by the Ohio State Soil Acarology Summer Program, collembolans were identified to family, centipedes and millipedes were identified to class, and spiders were identified to order following Triplehorn and Johnson (2005). Total arthropod abundances are presented here as the number of individuals per litterbag while the density of individual arthropod taxa are presented as the number of individuals gram^{-1} of ash-free dry litter remaining to correct for litter mass loss. Ash-free dry mass was determined by incinerating a subsample of air dried litter at 500 °C, determining the amount of ash remaining after incineration, and then subtracting the ash percentage from total litter dry mass. In addition, arthropod densities were determined in the top 5 cm of bulk soils adjacent to the litterbags on June 17, and July 18, 2008 and are reported here as the total number of individuals cm^{-2} soil.

Litter chemistry

Litter chemistry was assessed using pyrolysis–gas chromatography and mass spectrometry (py-GC/MS) on ~5 mg subsamples of air dried and pulverized litter from litterbags using three of the four replicate litterbags collected at days zero, 108, 487, and 730. Litter was pyrolyzed at 600 °C for 20 s on a CDS Pyroprobe 5150 pyrolyzer (CDS Analytical, Inc, Oxford, PA) and products were