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Using cover crops in headlands of organic grain farms: Effects on soil properties, weeds and crop yields

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ABSTRACT

Organic producers often rely heavily on tillage for weed management, which can create compaction, especially in headlands, and favor weed growth. To address Illinois organic grain farmers' concerns, we explored the effect of cover crops in headland areas of their farms on soil properties, weeds, and yields in a participatory on-farm approach. A split-plot arrangement with two replications at each of four Illinois locations was used in two consecutive years within field areas [FA: headlands – or turn-rows – HL; non-headlands NHL] randomly selected as main plots where four cover crop treatments were randomly assigned (CC: fallow control C; forage radish FR; mix of forage radish and buckwheat FRbw; and mix of forage radish with hairy vetch and cereal rye FRhvr). Collaborating farmers planted soybean [*Glycine max* (L.) Merr.] in 2012 and corn (*Zea mays* L.) in 2013. Each fall and spring, we measured soil penetration resistance (PR), bulk density (BD), water aggregate stability (WAS), total carbon (TC), nitrate ($N\text{-}NO_3$), ammonium ($N\text{-}NH_4$), available phosphorus (P), and pH. Additionally, cover crop and weed growth, and cash crop yields were determined each year. Our results indicate HL areas had greater PR (+22%) and BD (+3%), as well as higher WAS (+4%), TC (+10%), P (+36%), and pH (+7%) in comparison to NHL areas on average through the fall and spring seasons. Though FRhvr significantly reduced spring weed biomass (−30%) compared to the controls, higher density of grass weeds (+44%) were present in HL areas through spring and summer regardless of CC treatments. Due to the resilient nature of these particular Illinois soils and extreme weather pattern observations, the cover crop treatments did not alleviate compaction nor influence soil properties for the duration of this project. However, there was a trend toward lower available P in the FRhvr treatments and reduced crop yields in those treatments within the NHL areas. Though the cover crop treatments chosen for this trial did not seem to provide clear benefits, our results point toward a beneficial feedback between the weed community and the soil properties within headland areas in these organic systems.

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1. Introduction

Despite consumer demand and premium prices, adoption of organic practices for grain production has been slow and consequentially limited the expansion of organic livestock in the U.S (Greene et al., 2009). One of the main barriers to the expansion of organic management in grain crops is weed control (Sooby et al., 2007). Organic production increases the range of weed species, an important source of biological diversity, and crucial to the functioning of farming systems (Hawes et al., 2010; Zanin et al., 1997) yet weeds compete with cash crops, decreasing yields, lowering crop quality and increasing production inputs.

Organic farming uses a wide range of methods to manage weed populations, including diversified crop rotations, primary tillage for seedbed preparation, use of competitive crop cultivars, and

Abbreviations: FA, field areas; HL, headland areas; NHL, non-headland areas; CC, cover crop treatments; C, fallow control; FR, forage radish (*Raphanus sativus* L.); FRbw, forage radish and buckwheat (*Fagopyrum esculentum* Moench); FRhvr, mixture of forage radish, hairy vetch (*Vicia villosa* Roth), and cereal rye (*Secale cereale* L.); D, depth of sampling; ST, sampling time; SEM, standard error of the mean values; PR, penetration resistance; BD, bulk density; BDmax, maximum soil compactability; WAS, water aggregate stability; TC, total carbon stocks; $N\text{-}NO_3$, soil nitrates; $N\text{-}NH_4$, soil ammonium; P, available phosphorus; B:T, proportion of broadleaf weeds to total number of weeds.

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intensive between-row cultivation during the growing season (Liebman and Davis, 2009). Most of these methods require extensive time maneuvering in the field, heavy machine traffic, and intensive tillage of the soil, all of which can cause soil compaction (Ball and Crawford, 2009; Peigne et al., 2007) especially in headland areas (Bengough and Mullins, 1990). Headlands – or turn rows – are found along edges and corners of fields where heavy machinery maneuvering is more frequent than areas further within the field. Increased frequency of heavy machinery traffic causes these areas to be more susceptible to soil compaction, a densification of the soil due to the rearrangement of soil particles (Bengough and Mullins, 1990). Compaction in organic crop fields alters soil nutrient and water dynamics, reduces crop growth and yield, and increases weed problems and soil erosion (Ball and Crawford, 2009; Jackson et al., 2004; Sandhu et al., 2010). Place et al. (2008) found soil compaction limits cash crops' ability to compete with weedy species since weed roots penetrating compacted soil layers have access to nutrients and water that is otherwise unavailable to the cash crops. Cropping practices are needed that improve soil structure while reducing tillage.

Tillage profoundly shapes weed communities, for example creating microsites favoring weed seed survival and seedling emergence of annual grasses (Boyd and Van Acker, 2004; Hawes et al., 2010; Zanin et al., 1997). Often experienced organic farmers observe that weeds indicate soil quality or tilth. One reason is some perennial and annual weeds such as curly dock (*Rumex crispus* L.), bitter dock (*R. obtusifolius* L.), canada thistle [*Cirsium arvense* (L.) Scop.], Canada goldenrod (*Solidago canadensis* L.), quackgrass [*Elymus repens* (L.) Gould], sicklepod [*Senna obtusifolia* (L.) Irwin & Barneby], palmer amaranth (*Amaranthus palmeri* S. Watson), and wild oat (*Avena fatua* L.) can develop root systems in compacted soils better than crops (Boyd and Van Acker, 2004; Place et al., 2008; Zaller, 2004). With more weeds emerging, more cultivation and management is required, creating a negative cycle of tillage, compaction and increased weed emergence. Breaking this cycle is essential to improving organic grain production, and cover crops have been suggested as a critical tool to address both issues of soil compaction and weed suppression in the field.

Deep-rooted cover crops [i.e., radish and turnip (referred to as mustards)] penetrate compacted soil layers, ameliorating soil compaction (Williams and Weil, 2004), increasing nutrient use efficiency by capturing N from deeper soil layers (Kristensen and Thorup-Kristensen, 2004), and suppressing weeds through biofumigation (Haramoto and Gallandt, 2004). Yet environmental conditions, length of growing season, and management practices play a strong role in the success of these cover crops. In the U.S. Midwest region, the limited time between cash crop harvest and first winter frost in the fall and between appropriate growing conditions in early spring and cash crop planting times, can substantially limit the potential benefits from cover cropping (Acuna and Villamil, 2014). Additionally, the literature is greatly lacking cover crop research in organic grain production, especially in the poorly drained, highly fertile soils of Illinois.

Through discussions with our project collaborators, organic grain farmers around Illinois have identified potential headland compaction and weed control as major concerns. Thus a participatory on-farm research was planned with three experienced certified organic grain producers interested in the use of forage radish alone and in mixtures to alleviate soil compaction, improve nutrient cycling and suppress weed in headland areas of their farms. Our central hypothesis was that the inclusion of forage radish alone or in mixtures with cover crops of cereal rye and hairy vetch or buckwheat would help alleviate soil compaction, improve soil properties and better weed control in headland areas without affecting cash crop yields. This information is crucial for organic grain farmers to improve efficiency and productivity of their operations.

2. Materials and methods

2.1. Locations and soils

Our collaborating farmers own certified organic grain farms in three different locations in Illinois, where we set up four experimental sites, one in Cerro Gordo (39°54′N, 88°43′W), one in Malta (41°55′N, 88°56′W) and two sites at Pana (39°27′N, 89°03′W) that were less than 2.5 km apart. The 20-year climate normal for Illinois shows a mean annual total precipitation of 1015 mm with annual mean temperature of 11.3 °C (Midwest Regional Climate Center, 2015).

Farmers identified two headland areas (HL) of concern and two non-headland areas (NHL) in their fields that were examined for potential soil compaction and corroborated with measurements of penetration resistance and supported by preliminary statistical analysis. For all sites, headland areas were edges and corners of fields with heavy machinery traffic and, on two of the studied farms, manure was previously stockpiled. During our planning sessions, our farmers agreed on planting soybean the first year and corn the next and selected the three cover crop treatments under study, including a control without cover crops to satisfy research requirements. Additionally, farmers shared their machinery for tillage and soil preparation and were present during field selection, soil sampling and cover crop planting and suppression as well as during cash crop planting and harvesting each year.

Cerro Gordo plots were located on an approximately 650 ha farm with about 250 ha in organic grain production. The typical grain rotation for this farm is yellow organic corn, food grade soybeans and soft red winter wheat (*Triticum aestivum* L.). Since 1972, the farm has used a variety of cover crops, including red clover (*Trifolium pretense* L.), forage radish, cereal rye, annual rye (*Lolium multiflorum* Lam.) and oats (*Avena sativa* L.). Research plots were on Flanagan silt loam (Fine, smectitic, mesic Aquic Argiudolls) on less than 2% slopes. Flanagan silt loams are dark colored, somewhat poorly drained, and form in deep loess over loamy till. Permeability is moderately low and runoff potential ranges from low to high (Soil Survey Staff, 2012). The year prior to our study yellow organic corn was planted with 2 t of chicken litter and a mixture of cereal rye and hairy vetch as cover crops.

Malta plots were on a 770 ha farm primarily in organic grain production with 20 ha devoted to sheep and horses and 105 ha in transition to organic production. Typical crop rotation is corn, soybean, and small grains with several types of cover crops: red clover, alfalfa (*Medicago sativa* L.), radishes, oats, and buckwheat. Experimental plots were on Danabrook silt loam (Fine-silty, mixed, superacitve, mesic Oxyaquic Argiudolls) with slope of about 2%. Danabrook silt loams are dark colored, moderately well drained and form in deep loess over loamy till under prairie vegetation. Soils have moderate permeability and low to medium runoff potential (Soil Survey Staff, 2012). The year prior to our study corn was planted with spring applied manure from a local dairy.

The Pana farm is about 810 ha in total, primarily certified organic with 17 ha in transition. Grain production is the main activity on the farm with some land devoted to permanent pasture for 120 cows and hogs. The typical grain rotation is a seven year rotation of fallow, corn, oats, corn, soybean and meadow. The Pana farmer uses a variety of cover crops, including clover, alfalfa, orchard grass (*Dactylis glomerata* L.), cereal rye, hairy vetch and buckwheat. Both study sites at the Pana location were on Virden silty clay loams (Fine, smectitic, mesic Vertic Argiaquolls) with less than 2% slopes. Virden soils are dark colored, poorly drained, and form in deep loess over till plains. Soils have moderate

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