ORGANIC NO-TILLAGE WINTER RYE-SOYBEAN SYSTEMS: AGRONOMIC, ECONOMIC, AND ENVIRONMENTAL ASSESSMENT

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Organic soybean and corn production in Wisconsin has rapidly increased to meet demand of the expanding organic dairy industry (USDA-ERS, 2006). A major challenge that organic row crop growers face is the intensive tillage needed for successful weed management (Posner et al., 2008), spurring interest by growers in improving weed management techniques (Walz, 1999). The use of a rye cover crop to facilitate no-till organic soybean production may improve weed management for organic growers, and provide additional ecosystem services including reduced soil erosion and runoff, increased soil organic matter and water infiltration, and trapping of excess nitrogen. This organic no-till rye mulch system has been limited in part due to uncertainty regarding the reliability of mechanical methods of terminating the cover crop, difficulty in establishing soybeans in the rye residue (Williams et al., 2000; Reddy et al., 2003), and the potential risk of competition between the rye cover crop and soybeans for soil moisture and nutrients resulting in reduced yields and economic returns (De Bruin et al., 2005; Westgate, 2005).

We conducted research to determine some of the agronomic, economic, and environmental risks associated with the use of winter rye cover crop in no-till organic soybean production systems. Our objectives were to determine the effect of rye management (plowing, crimping, and mowing), and soybean planting date (mid-May or early June) on soil moisture availability, soybean stand establishment, weed suppression, and soybean yield. Treatment effects on economic gross margins, soil loss, and soil quality were also predicted.

Materials and Methods

Research was conducted at the Univ. of Wisconsin Arlington Agricultural Research Station (UWAARS) near Arlington, WI in 2008 and 2009. The soil type was a Plano silt loam (fine-silty mesic Typic Argiudoll) with 4.7% organic matter and pH 6.7 in 2008 and 3.6% organic matter and pH 6.0 in 2009. Research sites changed each year to place the study following corn silage. The experimental design was a randomized complete block with four replications of six treatments (Table 1). The tilled treatment represented a typical organic soybean production system, while the other five treatments were no-till rye cover crop treatments with varying factors of rye management, soybean planting date, and row spacing (seeding rate). Plot size was 30-ft wide by 180-ft long in 2008 (0.12 acre) and 30-ft wide by 165-ft long (0.11 acre) in 2009.

Winter rye variety ‘Rymin’ was planted in early-October (Oct. 5, 2007 and Oct. 10, 2008) at a rate of 160 lb acre^{-1}. Rye in the tilled treatment was disk-chiseled in mid-April at the second node growth stage (Feekes growth stage 7; Apr. 23, 2008) and at tillering (Feekes growth stage 4; Apr. 17, 2009) (Zadoks et al., 1974). The subsequent stale seedbed was lightly disked (two passes) and field cultivated (two passes) for weed management and seedbed preparation prior to soybean planting. Feed-grade soybean varieties (Maturity Group I) ‘Viking 0.1832’ in 2008 and 'Blue River 16A7' in 2009 (due to unavailability of 'Viking 0.1832' in 2009) were planted with a conservation corn planter (30-inch row spacing) or no-till drill (7.5-inch row spacing). In the mowed, crimped drilled, and mowed drilled treatments, soybeans were planted/drilled approximately two weeks prior

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to crimping (crimped drilled) or mowing (mowed and mowed drilled) the rye, on the same date soybeans were planted in the tilled treatment. Rye in no-till treatments was roller-crimped or sickle-bar mowed in early June after the rye reached late anthesis (Feekes stage 10.5.1) (Ashford and Reeves, 2003; De Bruin et al., 2005). Soybeans were planted in the crimped drilled late and mowed drilled late treatments in early-June immediately after the rye was crimped or mowed. In the tilled treatment, flex-tine weeding, rotary hoeing, and inter-row cultivation were used for weed management as needed, typically 2-3 passes each, spaced a week apart from mid-May until soybean canopy closure in July.

Table 1. Treatments for experiments conducted at the UW-Arlington Agricultural Research Station in 2008 and 2009.

Treatment	Rye management	Soybean planting date	Soybean row spacing	Soybean viable seeding rate
	(month)	month	inches	seeds acre^{-1}
Tilled	Plowed (April)	Mid-May	30	225,000
Mowed	Mowed (June)	Mid-May	30	225,000
Crimped Drilled	Crimped (June)	Mid-May	7.5	275,000
Mowed Drilled	Mowed (June)	Mid-May	7.5	275,000
Crimped Drilled Late	Crimped (June)	Early June	7.5	275,000
Mowed Drilled Late	Mowed (June)	Early June	7.5	275,000

Rye shoot mass was harvested immediately prior to rye management in April (tilled treatment) or June (no-till treatments). Volumetric soil moisture was measured in tilled and crimped drilled late treatments at 0- to 2-, 6- to 8-, 15- to 17- and 20- to 22-inch depths in late May. Soybean plant density was measured in mid-July. Weed shoot mass was harvested in late August. Soybean grain was harvested by machine from the center 15 ft of each plot in late October, weighed, and adjusted to 13% moisture. The number and type of field operations, inputs, and the local November price for organic feed grade soybean were used to estimate gross margins using the Agricultural Budget Calculation Software (Frank and Gregory, 2000). The Revised Universal Soil Loss Equation 2 (USDA 2005) model was used to predict treatment effects on soil loss and organic matter (soil conditioning index, SCI) based on a run of 200 feet, contours of 0.5%, and 1 and 4.5% slopes.

Data were pooled across the two site-years and analysis of variance was conducted using the MIXED procedure in SAS/STAT (SAS Institute 2007) to test the effect of treatments on early-season soil moisture, soybean establishment, yield, and profitability. Treatment comparisons were made using Fisher's Protected LSD method ($\alpha = 0.05$). Pre-planned contrasts were made to compare rye and soybean management effects within no-till treatments, and between tilled and no-till treatments.

Results

At the time of rye management (plowing, crimping, or mowing), rye mass was 7 to 10-fold greater in no-till than tilled systems in each year (Table 2). In no-till systems, rye mass exceeded the minimum (1.5 ton acre^{-1}) considered necessary for effective weed suppression (Doll and

Mueller, 2005). Greater rye mass in 2008 was likely due to more timely precipitation and warmer spring temperatures as well as greater soil fertility than in 2009 (data not shown).

Table 2. Rye cover crop dry shoot mass at the time of plowing (4/23/08 and 4/17/09) and mowing or crimping (6/11/08 and 5/29/2009).

	Rye dry shoot mass	
Rye management	2008	2009
	tons acre^{-1}	
Tilled (mid-April)	0.7	0.2
No-till (June)	4.8	1.9

At soybean planting, soil moisture was the same at the surface in no-till rye and tilled systems (Figure 1), indicating that a reduction in soybean germination due to soil moisture use by rye would not be expected in no-till rye systems relative to the tilled system. However, at deeper depths, soil moisture was less in no-till rye than tilled systems. This reduction in available soil water at deeper depths was likely due to the growing rye cover crop, which in years of inadequate rainfall could pose a risk to early-season soybean growth in no-till rye systems.

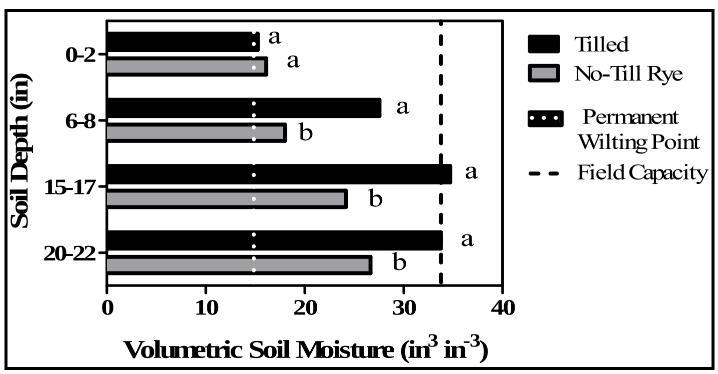

Figure 1. Mean early-season (5/28/08 and 6/1/09) volumetric soil moisture content at 0- to 22-inch depths for tilled and no-till (crimped drilled late) systems. Values within depth followed by the same letter do not differ at $p<0.05$ (Fishers protected LSD test).

Soybean establishment (stand density as a percent of viable seeding rate) did not differ between tilled and no-till systems, suggesting that rye had little effect on soybean germination and emergence (p=0.3822; data not shown). However, within the no-till drilled treatments, contrasts indicated that soybean establishment was affected by planting date. Establishment in treatments planted prior to rye crimping or mowing (crimped drilled and mowed drilled) was 80%, greater than the 60% establishment in treatments in which planting was delayed until after crimping or mowing (crimped drilled late and mowed drilled late) (p = 0.0406; data not shown). Lower stand density was likely due to poor seed placement through the rye mulch, particularly in 2008. Soybean establishment was not affected by rye management (crimped or mowed, p=0.5423) or row spacing (30 or 7.5 inches, p=0.9317) (data not shown).

Weed mass across years was several-fold greater in the tilled system than in no-till systems (p = 0.0058) (Figure 2). Contrasts indicated that weed mass among no-till systems was less for early- than late-planted soybean (p = 0.0612) and less for narrow- than wide-row spacing (p = 0.0991). Weed mass did not differ between crimped and mowed rye treatments (p = 0.9566).

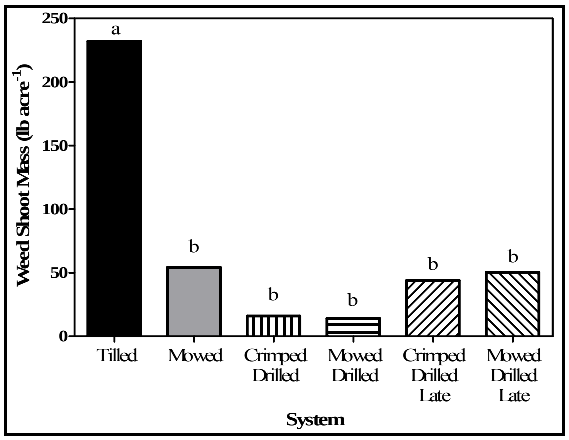

Figure 2. Mean late-season (late August) weed shoot mass in 2008 and 2009. Values designated by the same letter do not differ at p<0.05 (Fishers protected LSD test).

Soybean yield across years was greater for the tilled system than no-till systems (p = 0.0041) (Figure 3). Contrasts indicated that among no-till systems, yield was greater for narrow- than wide-row spacing (p = 0.0883), but yield was not affected by planting date (p = 0.1636) or rye management (p = 0.7667). Tilled rye was more profitable than no-till rye treatments (p = 0.0054) (Figure 4). However, profitability was not affected by rye or soybean management among no-till systems.

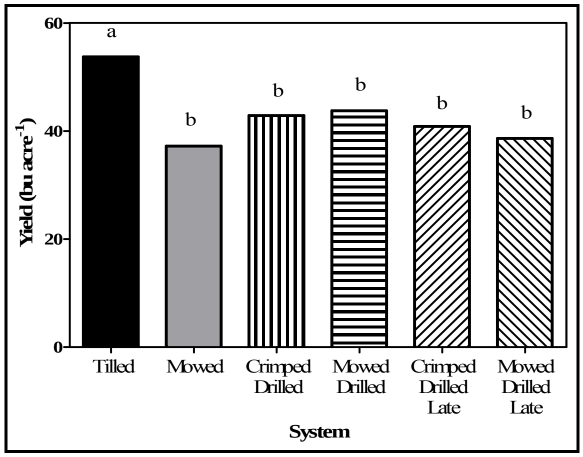

Figure 3. Mean soybean grain yield adjusted to 13% moisture in 2008 and 2009. Values designated by the same letter do not differ at $p<0.05$ (Fishers protected LSD test).

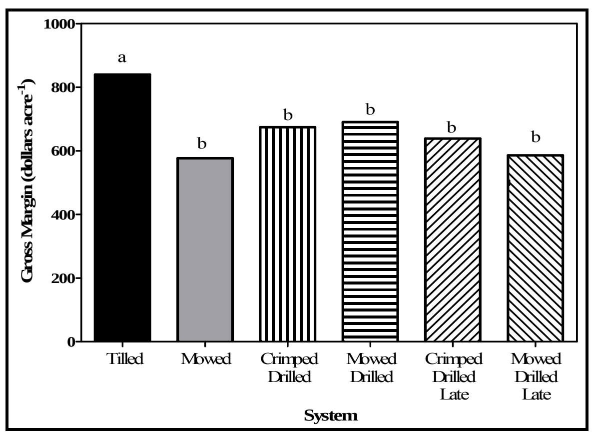

Figure 4. Mean estimated economic gross margins in 2008 and 2009. Values designated by the same letter do not differ at $p<0.05$ (Fishers protected LSD test).

Predicted soil loss was several-fold greater in tilled rye than in no-till rye systems for both 1 and 4.5% slopes (Figures 5A and 5B). Soil loss in no-till rye was less than T (5 tons $acre^{-1}$ $year^{-1}$) in each scenario. Predicted changes in soil organic matter (soil conditioning index, SCI) were positive in no-till rye systems and negative in the tilled rye system for both 1 and 4.5% slopes; SCI was highly negative for plowed rye on a 4.5% slope (Figures 5C and 5D).

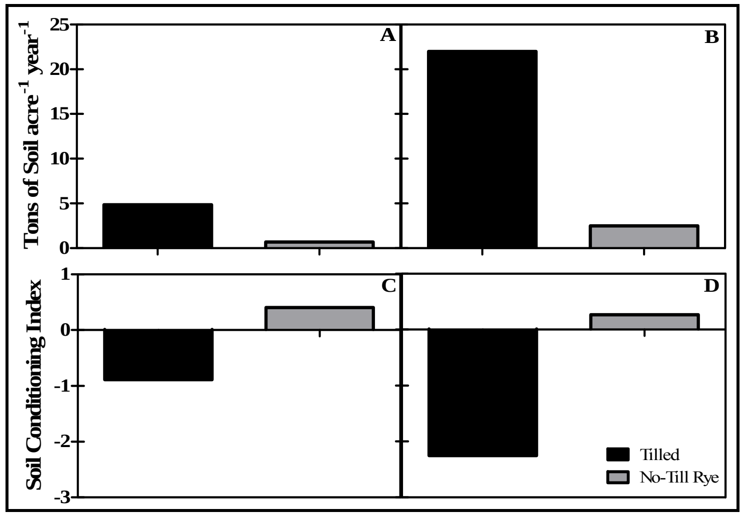

Figure 5. Predicted soil loss on (A) 1% slope and (B) 4.5% slope, and soil conditioning index on (C) 1% slope and (D) 4.5% slope for tilled and no-till rye systems.

Conclusions

Early-season soil moisture availability did not appear to be an important risk factor affecting soybean stand establishment in no-till rye systems, although rye depleted moisture deeper in the soil profile. While rye depleted available soil water at depths of 6-22 inches, adequate rainfall replenished the soil moisture in each year (data not shown). Soybean stand establishment was not affected by the rye cover crop between no-till and tilled systems.

Within no-till systems, soybean stand establishment was greater when planted into standing rye two weeks prior to crimping or mowing (crimped drilled and mowed drilled treatments) than when planted after crimping or mowing at rye anthesis (crimped drilled late and mowed drilled late treatments). Earlier planting was also associated with greater weed suppression, as was narrow-row spacing. Soybean grain yield was greater in narrow- than wide-row spacing. However, neither row spacing nor planting date affected economic returns. Soybean stand establishment, grain yield and economic returns were similar between crimped and mowed rye, although the sickle-bar mower may be preferable to growers since it cost half as much as the roller-crimper.

Organic no-till rye-soybean systems were associated with greater weed suppression, less soil loss and greater soil organic matter. However, these potentially long-term benefits were offset by 24% less soybean yield and 25% less economic return (due largely to high prices for organically-grown, feed-grade soybeans). Even so, the no-tillage systems were highly profitable and represent economically viable alternatives to a tillage-intensive approach. These systems are particularly attractive to organic growers due to the reduction in required labor.

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