Organic No-Tillage Winter Rye-Soybean Systems: Agronomic, Economic, and Environmental Assessment

Emily R. Bernstein, Joshua L. Posner, David E. Stoltenberg and Janet L. Hedtcke
Department of Agronomy, University of Wisconsin – Madison

Introduction

Organic soybean and corn production in Wisconsin has rapidly increased to meet demand of the expanding organic dairy industry. A major challenge that organic row crop growers face is the intensive tillage needed for successful weed management. Growers have shown great interest in an alternative approach based on no-till crop establishment in a winter rye mulch. However, this alternative also presents many challenges. 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. Specific 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.

Methods

Field Sites and Operations

Research was conducted at the University of Wisconsin Arlington Agricultural Research Station near Arlington, WI in 2008 and 2009 on a Plano silt loam soil. Four replications of six treatments were arranged in a RCB design. Plot size was 9-m wide by 55-m long in 2008 (0.050 ha plot^{-1}); in 2009 plot length was 50-m long (0.045 ha plot^{-1}). Winter rye variety 'Rymin' was planted in early October (2007 and 2008) at a rate of 180 kg ha^{-1}. Organic feed-grade soybean varieties 'Viking 0.1832' and 'Blue River 16A7' (both Maturity group I) were planted in 2008 and 2009, respectively.

Treatments

Abbreviation	Rye management	Soybean planting date	Soybean row spacing	Soybean viable seeding rate
	(Month)	Month	cm	Seeds ha^{-1}
Plowed	Plowed (April)	Mid-May	76	556,000
Mowed	Mowed (June)	Mid-May	76	556,000
Crimped Drilled	Crimped (June)	Mid-May	19	680,000
Mowed Drilled	Mowed (June)	Mid-May	19	680,000
Crimped Drilled Late	Crimped (June)	Early June	19	680,000
Mowed Drilled Late	Mowed (June)	Early June	19	680,000

Data Collection

- *Early season rye mass:* Aboveground mass was harvested immediately prior to rye management in April or June.
- *Early season soil moisture:* Volumetric soil moisture was measured in plowed and crimped treatments at 0- to 6-, 15- to 21-, 38- to 44- and 51- to 57-cm depths in late May.
- *Soybean establishment*: Soybean plant density was measured in 5.3-m of row in treatments with 76-cm row spacing, and in a radius of 37-cm in treatments with 19-cm row spacing.
- *Late season weed mass*: Peak aboveground weed mass was harvested in late August.
- *Soybean grain yield*: Soybean grain was harvested by machine from the center 4.6-m of each plot in late October, weighed using a weigh wagon, and adjusted to 13% moisture.
- *Profitability*: The number and type of field operations, inputs, and the local November price for organic feed grade soybean were used to estimate gross margins.
- *Soil loss and Quality*: The Revised Universal Soil Loss Equation 2 model was used to predict treatment effects on soil loss and organic matter based on a run of 200 feet, contours of 0.5%, and 1 and 4.5% slopes.

Statistical Analysis

Mixed effects models were fit with year, block(year), and year by treatment considered random effects, and treatments as a fixed effect. 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 no-till and plowed treatments.

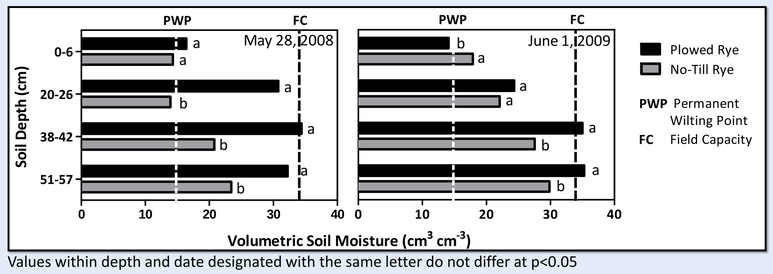
Results

Early Season Rye Mass

Rye Management	Rye aboveground dry mass	
	2008	2009
	----------Mg ha^{-1}----------	
Plowed (mid-April)	1.9	0.5
No-till (June)	13.3	5.3

- At the time of rye management (plowing, crimping, or mowing), rye mass was 7 to 10-fold greater in no-till than plowed systems in each year ($p < 0.0001$). In no-till systems, rye mass exceeded the minimum (3.8-4.0 Mg ha^{-1}) considered necessary for effective weed suppression.

Early Season Soil Moisture



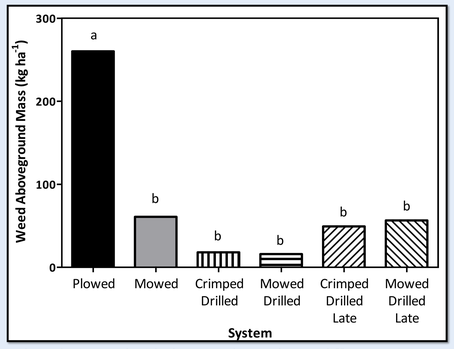
Values within depth and date designated with the same letter do not differ at p<0.05

- At soybean planting in each year, soil moisture was the same or greater at the surface in no-till than plowed rye, but at deeper depths, soil moisture was less in no-till than plowed rye.

Soybean Establishment

- Establishment (stand density as a percent of viable seeding rate) of no-till soybeans planted prior to rye crimping or mowing was greater (80%) than when planting was delayed until after crimping or mowing (60%) ($p = 0.0406$; data not shown).
- However, soybean establishment did not differ between plowed and no-till treatments, nor was it affected by rye management (crimped or mowed) or row spacing (76 or 19 cm) (data not shown).

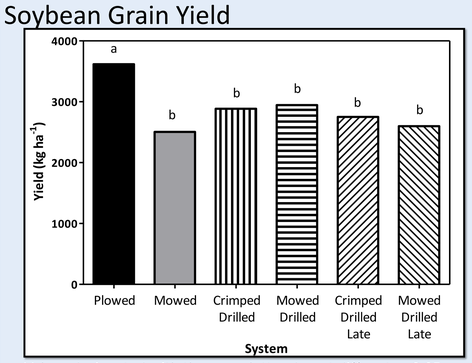
Late Season Weed Mass



Values designated with the same letter do not differ at p<0.05

- Weed aboveground mass was several-fold greater in the plowed treatment than any of the no-till treatments ($p = 0.0058$).
- At the 10% level of significance, weed mass among no-till treatments was less for early- than late-planted soybean treatments ($p = 0.0612$) and less for narrow- than wide-row spacing ($p = 0.0991$).
- Weed mass did not differ between crimped and mowed treatments ($p = 0.9566$).

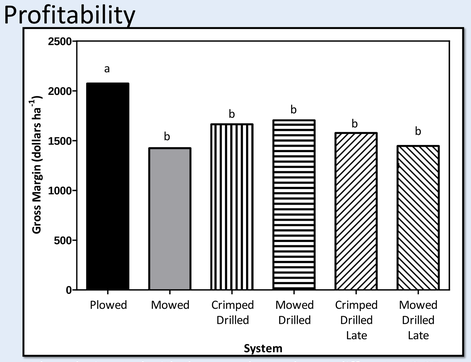
Soybean Grain Yield



Values designated with the same letter do not differ at p<0.05

- Yield was greater for the plowed treatment than any of the no-till treatments ($p = 0.0041$).
- At the 10% level of significance, yield was greater for narrow- than wide-row spacing ($p = 0.0883$).

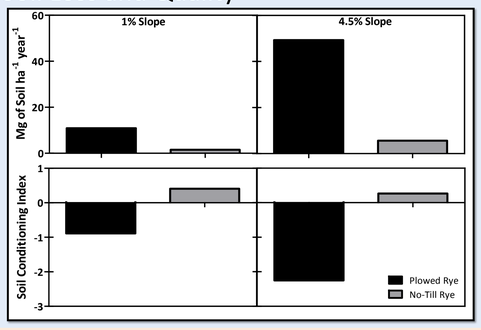
Profitability



Values designated with the same letter do not differ at p<0.05

- Plowed rye was more profitable than no-till rye treatments ($p = 0.0054$).
- However, profitability was not affected by rye or soybean management in no-till treatments.

Soil Loss and Quality



- Predicted soil loss is several-fold greater in plowed rye than in no-till rye for both 1 and 4.5% slopes. Soil loss in no-till rye is less than T (11 Mg ha^{-1} year^{-1}) in each scenario.
- Predicted changes in soil organic matter (SCI) are positive in no-till rye and negative in plowed rye for both 1 and 4.5% slopes; SCI is highly negative for plowed rye on a 4.5% slope.

Conclusions

- No-till rye-soybean systems were associated with less soybean yield and economic return than an intensive-tillage approach, but beneficial tradeoffs included greater weed suppression, less soil loss and greater soil organic matter.
- Early-season soil moisture availability did not appear to be an important risk factor affecting soybean stand establishment in no-till rye systems.
- Within no-till systems:
  - Soybean stand establishment was greater when planted into standing rye prior to crimping or mowing (mid-May) than when planted after crimping or mowing at rye anthesis (early June).
  - Early planting and narrow-row spacing were associated with greater weed suppression than late planting or wide-row spacing.
  - Soybean stand establishment, weed suppression, yield and economic returns were similar between crimped and mowed rye.
  - Economic returns did not differ among no-till treatments.
- These results suggest that the greater weed suppression and environmental benefits of no-till systems were offset by reduced short-term productivity and profitability. However, the no-till systems were viable alternatives to a tillage-intensive approach, providing grain yields above 2500-3000 kg ha^{-1} and positive economic returns. Future research should focus on further optimizing these systems.