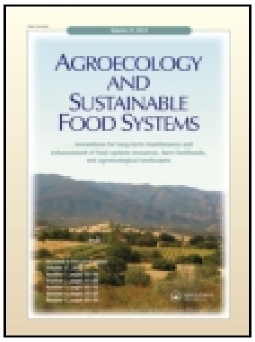

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Screening Five Fall-Sown Cover Crops for Use in Organic No-Till Crop Production in the Upper Midwest

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Organic no-till systems continue to draw interest from organic producers across the upper Midwest in the United States. Fall-planted cover crops, terminated in the spring through the use of a roller-crimper or a mower, are a key component of these systems. In this study, five different cover crops (hairy vetch, Austrian winter peas, winter rye, winter barley, and winter triticale) were planted in the fall and terminated in the spring in preparation for no-till organic row crop production. This study compared the cover crops through measurements of: a) the amount of biomass produced by the cover crops before termination; b) the weed suppression potential of the cover crops terminated with either a roller-crimper or sickle-bar mower; and c) volumetric soil water content throughout the row crop production season. Biomass production of each of the cover crops differed significantly by variety and by year, ranging from 3.67 to 14.56 Mg DM ha^{-1}. Significant differences in weed densities and weed biomass were also found, with almost complete elimination of weed establishment in the rye treatment in 2011. Roll-crimping and sickle-bar mowing treatments demonstrated similar weed suppression and soil moisture from May through October during 2010 and 2011.

KEYWORDS *no-till, organic agriculture, cover crops, roller-crimper*

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INTRODUCTION

The acreage of land under certified organic management continues to grow in the United States. According to the 2008 U.S. Department of Agriculture Organic Production Survey, 1.9 million ha of land were certified organic, with 50,847 ha of organic soybean [*Glycine max* (L.) Merr.] and 78,767 ha of organic corn (*Zea mays* L.) (United States Department of Agriculture [USDA] 2008). Organic farmers must implement a soil-building plan as set forth in the regulations (7 CFR §205.203 and 205.205) of the USDA's National Organic Program. These strategies include cover cropping, diverse crop rotations, additions of compost and manure, and judicial use of tillage and cultivation.

No-till production has become a common practice across the United States in conventional cropping systems. Approximately 35.5% of U.S. cropland planted to eight major crops (barley (*Hordeum vulgare* L.), corn, cotton (*Gossypium hirsutum* L.), oats (*Avena sativa* L.), rice (*Oryza sativa* L.), sorghum (*Sorghum bicolor* L.), soybeans, and wheat (*Triticum aestivum* L.)) was managed through no-till operations in 2009 (Horowitz et al. 2010). No-till systems provide environmental benefits, such as reduced soil erosion (Moldenhauer et al. 1983; Langdale, West, et al. 1992), increased soil organic matter (Edwards et al. 1992; Langdale, Mills, et al. 1992), decreased runoff and improved soil infiltration (Uri 1999), and improved soil structure and aggregate stability. No-till systems can also provide economic benefits with reduced fuel and labor costs due to less tractor passes over the field (Siemans and Doster 1992).

No-till production systems rely on herbicides for weed management, thus, the techniques of conventional no-till cropping systems remain challenging for organic growers (Mulvaney et al. 2011). However, research has demonstrated that cover crops producing high amounts of biomass can be terminated to produce a physical barrier for the prevention of weed emergence (Teasdale and Mohler 1993; Williams et al. 1998). By creating a mulch with the residue of these terminated cover crops, weed growth is inhibited through the prevention of sunlight reaching the soil surface or through allelopathy (Barnes and Putnam 1987). The quantity of mulch produced through cover crop management is highly correlated with the degree of weed suppression (Teasdale and Mohler 2000).

Farmers and researchers are increasingly interested in the use of mulches created from killed cover crops to create no-till phases of production within the organic rotation. In areas of the country with similar climates as Wisconsin, this typically involves planting a fall-sown cover crop that is grown through the winter and terminated in the spring prior to cash crop planting. The cash crop is sown directly into the cover crop mulch without any tillage prior to planting; thus, during the cash crop year, a no-till phase is established.

Effective termination of a cover crop is a critical aspect to organic no-till production and several methods have been used successfully, including mowing and rolling-crimping. The roller-crimper consists of a hollow drum (which can be filled with water for additional weight) and blunt, chevron-patterned blades that bend and flatten the plant stems (Rodale Institute 2011). While rolling-crimping and mowing can serve as an effective means of cover crop termination if perform at the appropriate growth stage (anthesis for cereal cover crops and early pod set for legume cover crops), issues with cover crop regrowth may occur when termination occurs too early or too late in cover crop maturity. In addition, mowing may lead to uneven distribution of cover crop residues due to accumulation of cover crop residue in the mower, creating open spaces in the mulch for weeds to emerge (Creamer and Dabney 2002).

Many types of cover crops are commonly used on organic farms in Wisconsin, including winter barley, cereal rye (*Secale cereal L.*) winter wheat, hairy vetch (*Vicia villosa* L.), and crimson clover (*Trifolium incarnatum* L.) as well as other legumes and cereal crops (Nelson et al. 1991). However, these cover crops have not typically been optimally managed for organic no-till production using mowing and rolling-crimping of the cover crop. Appropriateness of a given cover crop for inclusion in a no-till organic production system is dependent on several factors, including planting date windows, overwintering ability, potential biomass production, and date of anthesis (pollen shed). To be incorporated into the successful organic rotation strategies used in Wisconsin, the cover crop must ideally have the potential to be planted approximately mid-August through mid-November, experience little if any winterkill, and reach anthesis or the appropriate stage of bloom by mid-May. With these characteristics, the cover crops could readily be planted after several cash crops commonly grown in an organic rotation in Wisconsin (alfalfa, corn, soybean, or small grain), maintain a strong stand throughout the Wisconsin winter that commonly experiences frequent freeze-thaw cycles and cold temperatures, and be successfully terminated to synchronize with corn and soybean planting windows.

The objective of this study was to screen five different fall-sown cover crops (winter rye, winter triticale (*x Triticosecale* spp. L.), winter barley, Austrian winter pea (*Lathyrus hirsutus* L.,), and hairy vetch) for potential integration into a no-till organic systems when terminated using two different methods, roll-crimping and sickle-bar mowing. These cover crops were chosen due to the presence of the traits outlined above, and thus, their suitability for adoption in a no-till phase of an organic rotation. As cover crops are an essential aspect for the successful implementation of organic no-till systems, this study focuses on the collection of biomass, weed suppression, and soil moisture data related to cover crop selection and management. This research was conducted in a systems-based context evaluating their potential use in no-till over the corn-soybean phase of the organic rotation (corn-soybean-oat/alfalfa-alfalfa) and was conducted on the certified organic site at the University of Wisconsin Agricultural Research Station.

MATERIALS AND METHODS

Site and Treatment Description

Research was conducted from 2009 to 2011 at the University of Wisconsin Arlington Agricultural Research Station (UWAARS; 43°18' N; 89°21' W; 315 masl) near Arlington, WI from 2009 to 2011. The experimental plots were located within the 31-ha block of certified organic land at the research station (certified organic by the Midwest Organic Services Agency, Viroqua, WI). The soil type was a Plano silt loam (fine-silty, mixed, superactive, mesic Typic Argiudoll). Soil tests indicated 3.7% organic matter and pH 7.3, with excessively high levels of soil test P and K (University of Wisconsin Soil Testing Laboratories 2010). Prior to planting the cover crop, an alfalfa stand was terminated though chisel plowing (Glenco SS7400, AGCO, Duluth, GA), and disking (Sunflower 1434, Sunflower Mfg., Beloit, KS), with these field operations occurring from August 19 through August 23. The experimental design was a split-plot design with four replications, with termination strategy (mowed versus crimped) as the main factor and cover crop type (cereal rye, hairy vetch, Austrian winter pea, winter barley, winter triticale, and tilled treatments) as the subplot factors. The tilled treatment included standard management (tillage and cultivation) typical of organic row crop production in Wisconsin (Table 1). Plot sizes measured 9.14 m × 15.24 m.

Winter rye (variety not stated), winter triticale ("Fridge" awnless), winter barley ("McGregor"), Austrian winter pea (variety not stated), and hairy vetch (variety not stated) were planted on September 8, 2009 and September 13, 2010 (Table 1). Seed was purchased from Albert Lea Seed Co. (Albert Lea,

TABLE 1 Fall and spring management for cover crop and tilled plots, University of Wisconsin-Arlington Agricultural Research Station, 2009–2011

Fall management cover crop				Spring management cover crop			
Year	Chisel disk	Cultivator	Planting	Seedbed prep[a]	Termination	Tine weed[a]	Cultivator[a]
2009	19 Agu	07 Sept	08 Sept				
2010	15 Apr 19 Aug	09 Sept	13 Sept	27 May	28 May	11 Jun 14 Jul	30 Jun
2011			23 May	08 Jun 08 Jun	16 Jun	30 Jun 08 Jul	

[a]Only applied to the control plots.

MN). Common variety seed was chosen to be included in this experiment by request of the project's grower advisory group. All cover crop seeds except winter barley were organically produced. The field was prepared with two field cultivations (Sunflower 5035, Sunflower Mfg., Beloit, KS) occurring between August 30 and September 9. Cereal cover crops (winter rye, triticale, and barley) were planted with a 3-m wide no-till (NT) drill (Model 750, John Deere, Moline, IL) at a depth of 2.5 cm and a row width of 19 cm at a rate of 269 kg ha^{-1}. Vetch was drilled at a rate of 33.6 kg ha^{-1} and Austrian winter pea at a rate of 44.6 kg ha^{-1} with the same equipment, at a 5.0 cm depth and 19 cm row spacing. Seeding rates were determined based on input provided from the Rodale Institute (J. Moyer, personal communication). The tilled treatments were lightly disked (3.7 m wide) to manage early season weeds, and then prepared for row crop planting using a soil finisher (7.7 m wide). Small grain cover crops were rolled with a roller-crimper (4.6-m wide; I and J Manufacturing, Gap, PA) or mowed with a sickle-bar mower (2.1-m wide) perpendicular to their direction of planting on May 28, 2010 and June 8, 2011. Field operations were scheduled after visible observation of cover crop growth stage, when the cereal cover crops reached anthesis (Zadoks growth stage 60, visible pollen shedding; Zadoks et al. 1974) or legume crops reached flowering to early pod set (BBCH growth stages 59 to 70 (Feller et al. 1995) to ensure effective termination of the cover crop (Reberg-Horton et al. 2011; Table 1).

The roller-crimper was filled with water, for a total mass of 1360 kg. Row crops (corn and soybean) were planted into each of the treatment plots with a 4.6-m wide conservation-tillage planter (Model 1750 Max Emerge Plus, Conservation Tillage, John Deere, Moline, IL) set at a 76-cm row width at the same time as crimping and mowing to simulate a typical organic rotation. The tilled treatment included typical organic row crop production management, with no cover crop planted in the fall. In the tilled treatment, flex-tine weeding (4.6-m wide) and inter-row cultivation (4.6-m wide) were used for weed management as needed (Table 1).

Data Collection

Cover crop aboveground biomass (excluding weeds) was measured by harvesting three 0.50-m^{-2} quadrats per plots at a 2.5 cm cutting height three to seven days before termination in mid-May. Samples were dried at 50°C until constant weight. Volumetric soil moisture content was measured approximately every 30 days during May through September at 7.6 and 20 cm depths at three locations in each plot with a FieldScout TDR300 soil moisture meter using the calibration methods outlined in the user manual (Spectrum Technologies, Plainfield, IL).

Weed densities were determined in each of the plots in 2010 and 2011 at one week before cover crop termination and at 12 weeks after termination (WAT) by counting all emerged weeds in three 0.5-m^{-2} quadrats per plot and by harvesting all weeds at ground level within three 0.5-m^{-2} quadrats and dried at 50°C to constant weight. At the sampling date 12 WAT, weed species were identified and classified as perennial broadleaves (PB), perennial grasses (PG), annual broadleaves (AB), and annual grasses (AG).

Weather data was obtained from a meteorological station located at the UW-AARS, operated by the Wisconsin State Climatology Office, from 2009 to 2011. Temperatures during the cash crop production season were calculated as growing degree units for soybean, using a base temperature of 10°C and an optimum temperature of 30°C (Zhang et al. 2001).

Data Analysis

Data analyses were performed using JMP Pro Software Version 11.0.0 (JMP 2013). The experimental design was analyzed as a split-plot design with termination strategy (mowed versus crimped) as the main factor and cover crop type (cereal rye, hairy vetch, Austrian winter pea, winter barley, winter triticale, and tilled treatments) as the subplot factors. The following model was used for analysis:

$$Y_{ijkl} = Y_i + B_j + WP_k + Y * WP_{ij} + WPEijk + SP_l + Y * SP_{il}$$
$$+ WP * SP_{kl} + Y * WP * SP_{ikl} + SPEijkl$$

where

Y = year,
B = Block,
WP = whole plot factor (termination treatment),
SP = subplot factor (cover crop species)
WPE = whole plot error term,
SPE = subplot error term,
i = a particular year,
j = a particular block,
k = a particular termination treatment, and
l = a particular cover crop species.

Year, termination treatment, and cover crop species are considered fixed effects and block is considered a random effect. Prior to analysis, all variables were checked for assumptions of normality (Kolmogorov-Smirnov-Lilliefors test of normality) and homogeneity of variance (Levene's test for equality of variances). Where assumptions were violated ($P = 0.05$), weed number and density data were normalized by subjecting them to square root transformation (Steel and Torrie 1980); however, means presented in tables are of untransformed data. If overall F values were found to be significant, means were separated using the Tukey-Kramer method. Soil moisture data were analyzed by repeated-measures multivariate analysis of variance (JMP Pro Software Version 11.0.0 (JMP 2013). The two soil depths and two years were analyzed separately, with cover crop species, termination treatment, and cover crop species by termination treatments as a between-subjects factors and time of sampling, time of sampling by cover crop species, time of sampling by termination treatment, and time of sampling by cover crop species by termination treatment as within-subjects factors.

RESULTS

Weather

Precipitation during cover crop establishment (September 1–December 31, 2009 and 2010) was greater in 2009 (280 mm) than in 2010 (236 mm); typical total precipitation during this period (average values of 1971–2000) totaled 234 mm. Precipitation during May–October was above average (664 mm) in 2010 and below average (302 mm) in 2011 (average precipitation 1971–2000, 529 mm; Wisconsin State Climatology Office 2013). Winter low temperatures were similar in both years and neared average values of 1971–2000 (average low temperatures: December, -10°C; January, -8°C; February, -13°C; March, -2°C). Snowfall was 86% of average in 2009–2010 and 108% of in 2010–2011(long-term average from 1981–2010, 1020 mm). Spring temperatures were lower in 2011 than in 2010 (375 and 617 growing degree unit, respectively), leading to a delay in cover crop maturity in 2011.

Cover Crop Biomass

Analysis indicated significant year × termination method interaction and year × variety interactions for many of the variables measured; therefore, results are presented by year (results not shown). Cover crop biomass production, despite the year-to-year variability, fell within the reported ranges found in other research (Table 2; Ashford and Reeves 2003; Mischler et al. 2010). Due to the failure of the Austrian winter pea treatment in 2011, initial analyses of variance and analysis of cover crop growth was conducted using the balanced data set comprised of the three cereal cover crops, hairy vetch, and the tilled treatment. Information from the Austrian winter pea plots with one year's data was used in later stages of analysis. In 2010, winter triticale produced more biomass prior to termination than the other two cereal crops with winter rye and winter barley producing equivalent biomass (Table 2). The legume cover crops, Austrian winter pea and hairy

TABLE 2 Effect of cover crop type on pre-termination cover crop biomass, weed density, weed biomass at the University of Wisconsin-Arlington Agricultural Research Station, 2010 and 2011[a]

		Cover crop biomass	Weed density	Weed biomass
Year	Cover crop species	Mg DM ha^{-1}	no. m^{-2}	g m^{-2}
2010	Hairy vetch	3.67c	46.6a	1.2b
	Winter rye	10.17b	25.4bc	0.3b
	Winter triticale	14.56a	24.2bc	0.7b
	Austrian winter peas	6.29c	18.4c	0.3b
	Winter barley	11.71b	43.3a	1.0b
	Tilled	–	42.1ab	6.8a
2011	Hairy vetch	5.00b	3.6c	5.5b
	Winter rye	10.33a	0.9c	0.2b
	Winter triticale	6.38b	25.6ab	5.0b
	Austrian winter peas	0.0c	–	–
	Winter barley	10.33a	19.3b	0.4b
	Tilled	–	29.8a	22.5a

[a]Numbers in columns followed by different letters were significantly different at $P < 0.05$ according to an analysis of variance as analyzed for a split-plot design; means were compared through the Tukey-Kramer procedure.

vetch, did not differ in biomass production from each other (Table 2) but produced less biomass than the cereal crops. Stand loss was observed in the Austrian winter pea (100% loss) and winter triticale plots (70% loss as measured expected stand from target seeding rate) in 2011 (data not presented). This stand loss was most likely due to increased periods of bare ground through the winter, despite total snowfall of the season measuring in the above average range. Although the number of plants per plot was less than in the previous year, 6.38 Mg DM ha^{-1} of biomass was present prior to crimping.

Weed Numbers and Densities

An objective of this experiment was to compare the weed suppression of the different cover crop types after termination with the roller-crimper or sickle-bar mower. Analysis indicated a year × treatment effect and year × variety interaction; therefore, results are presented by year. The dominant weed species included lambsquarters (*Chenopodium album* L.), pigweed (*Amaranthus hybridus* L.) field pennycress (*Thlaspi arvense* L.), dandelion (*Taraxacum officinale* L.), common chickweed (*Stellaria media* L.), quackgrass (*Elymus repens* L.), barnyard grass (*Panicum Crus-Galli* L.), and yellow foxtail (*Setaria glauca* L.)

Weed populations prior to termination showed differences by year and by cover crop variety (Table 2). In 2010, weed densities at cover crop termination were greater in the vetch (46.6 weeds m^{-2}), barley (43.3 weeds m^{-2}), and tilled plots (42.1 weeds m^{-2}) and lowest in the Austrian winter pea plots (18.4 weeds m^{-2}). In 2011, weed densities at cover crop termination were higher in the tilled plots (29.8 weeds m^{-2}) and overall lower in the cover crop treatments with greatest in the triticale (25.6 weeds m^{-2}), most likely due to lower cover crop biomass resulting from winterkill. Weed densities at cover crop termination were lowest in the hairy vetch (3.6 weeds m^{-2}) and rye (0.9 weeds m^{-2}) plots in 2011. In both 2010 and 2011, weed biomass was lower in the cover crop plots than in the tilled plots.

Weed suppression of mowed and crimped cover crop 12 WAT differed significantly by year and by mode of termination (MOT) as measure by both weed density and weed biomass (Table 3). In 2010, differences in densities of PG, AG, and PB weeds were observed in the roll-crimped versus mowed treatments, with grasses occurring at higher densities in the roll-crimped plots, and perennial broadleaves occurring at higher densities in the mowed plots. No significant differences were observed in the annual broadleaf densities or the total weed biomass in the roll-crimped and mowed plots. In 2011, no differences for MOT were observed for weed densities or biomass of the weed classes.

Weed biomass at 12 WAT differed by cover crop treatment as well (Table 3). In 2010, weed biomass was greater in the cover crop treatments versus the control, ranging from 19.3 to 38.8 g m^{-2} (roll-crimped) and 15.3 to 52.0 g m^{-2} (mowed) in the cover crop treatments versus 1.6 g m^{-2} (roll-crimped) and 4.3 g m^{-2} (mowed) in the control treatments. The cereal cover crop plots demonstrated similar weed suppression as measured by total biomass in the crimped treatments and different in the mowed plots (Table 3). In 2011, all cover crop treatments led to less weed biomass production than the tilled plots, with rye exhibiting the lowest total weed biomass. In 2010, weed densities varied by weed class, with lower weed densities of annual broadleaves (crimped: 6.9 weeds m$^{-2;}$ mowed: 8.0 weeds m^{-2}) and highest density of perennial grasses (crimped: 98.7 weeds m^{-2}; mowed: 69.0 weeds m^{-2}; Table 3). In the crimped treatments, weed control of annual grasses and broadleaves as measured by density were not different in the cover crop and tilled treatments. Annual grass densities did differ by cover crop treatment in the mowed plots, with the rye and barley treatments containing lower densities of this weed class. In 2011, the crimped plots showed differences in cover crop treatments in the annual broadleaf densities, with 89.3 weeds m^{-2} in the tilled plots, and a range of zero to 74.0 weeds m^{-2} in the cover crop plots. In the mowed treatments, differences in weed densities were seen with both the AG and AB weed classes, with the greatest densities of these weed classes occurring in the tilled plots and lowest densities occurring in the rye cover crop treatment plots. Although weed numbers were much higher in 2011, total weed biomass 12 DAT was less than in 2010 due to smaller weeds at harvest.

TABLE 3 Effect of cover crop and mode of termination on weed density of perennial grass weeds (PG), annual grass weeds (AG), perennial broadleaf weeds (PB), and annual broadleaf weeds (AB) densities, total weed biomass 12 weeks after termination at the University of Wisconsin-Arlington Agricultural Research Station, 2010 and 2011

		PG[a]	AG	PB	AB	Weed biomass[b]	PG	AG	PB	AB	Weed biomass
		No. m^{-2}				gm^{-2}	No. m^{-2}				gm^{-2}
Termination	Cover crop	2011					2010				
Crimped	Hairy vetch	95.7b[c]	16.3	13.3a	6.7	20.7ab	4.7	4.0	19.3	26.7bc	364.6ab
	Winter rye	68.3b	31.7	18.0a	11.3	38.8a	0.0	0.0	0.0	0.0c	0.0b
	Winter triticale	277a	25	15.3a	7.0	35.0a	8.0	1.3	14.7	74.0ab	294.7b
	Winter peas	56b	10	16.0a	1.56	19.3ab	—	—	—	—	∞
	Winter barley	83b	51	18.0a	4.3	25.0a	17.7	2	2.0	54.0ab	307.1b
	Tilled	0c	18	7.0b	7.7	1.6b	16.7	8	4.7	89.3a	865.1a
	Crimped average	98.7A[d]	24.7A	14.6B	6.9	23.4	12.0	3.1	8.1	48.8	366.3
Mowed	Hairy vetch	62bc	17a	17.3ab	7.3	19.4bc	16.0	3.3ab	12.7	24.0bc	362.3ab
	Winter rye	37bc	1b	23.3a	11.3	30.2b	0.7	0.0b	0.0	6.0c	42.1b
	Winter triticale	220a	32a	20.7a	11.0	52.0a	7.3	0.7ab	11.3	57.3ab	319.3ab
	Winter peas	62bc	18a	16.0ab	6.0	15.3bc	—	—	—	—	—
	Winter barley	26bc	6b	22.0a	3.3	16.2bc	12.0	0.0b	3.3	47.3abc	502.9ab
	Tilled	5c	21a	7.3b	8.7	4.3c	16.7	8.0a	4.7	85.6a	845.6a
	Mowed average	69.0B	16.0B	17.8A	8.0	22.9	11.5	2.4	6.4	44.8	418.1
Significance											
Species		<.0001	<.0001	<.0001	ns[e]	<.0001	ns	.0001	<.0001	<.0001	<.0001
Treatment		0.0137	<.0001	0.0107	ns	ns	ns	ns	ns	ns	ns
S × T		ns	<.0001	ns	ns	ns	ns	ns	ns	ns	ns

[a]Weed densities were determined in each of the plots in 2010 and 2011 by counting all emerged weeds in three 0.5-m^{-2} quadrats per plot.

[b]Weed biomass was determined by harvesting all weeds at ground level within three 0.5-m^{-2} quadrats and dried at 50°C to constant weight.

[c]Numbers in columns within a mode of termination treatment followed by different lowercase letters were significantly different at $P < 0.05$ according to an analysis of variance; means were compared through the Tukey-Kramer procedure.

[d]Numbers in columns followed by a different uppercase letter were significantly different at $P < 0.05$ according to an analysis of variance; means were compared through the Tukey-Kramer procedure.

[e]ns = nonsignificant at the $P = 0.05$ level.

Soil Moisture

Soil volumetric water content varied with the different cover crop species treatments at the 7.6 and 20 cm depths in 2010 and 2011 (Table 4) Soil volumetric water content varied by termination treatment only in 2011 at the 20 cm depth; thus, results from the two termination treatments are combined for 2010 in Table 5. In May of 2010, at the time of termination, soil volumetric water content (VWC) in the legume cover crop plots were greater than the small grain cover crop plots at the 7.6 cm depth, and soil VWC was lower in the tilled plot (Table 5). These differences were not observed in 2011 (Table 6). Within-season trends in soil moisture between cover crop types and depths were inconsistent during both years. In 2010, with above-average precipitation, soil moisture was near or exceeded field capacity (35% VWC) for much of the growing season. In 2011, with below-average precipitation, overall soil moisture at both depths was less than in the previous season,

TABLE 4 Results of repeated measures MANOVA examining the variation in soil volumetric water content (%) at two soil depths. Data sampled at the University of Wisconsin-Arlington Agricultural Research Station, 2010 and 2011

	2010		2011	
	7.6 cm	20 cm	7.6 cm	20 cm
Between-subjects		P>F		
Cover crop species	0.0013	<.0001	<.0001	0.0216
Treatment	0.8008	0.8037	0.0460	<.0001
Species × treatment	0.9871	0.7510	0.4014	0.7753
Within-subjects				
Month	<.0001	<.0001	<.0001	<.0001
Species × month	<.0001	<.0001	<.0001	<.0001
Treatment × month	0.7740	0.8914	0.2971	<.0001
Treatment × month × species	0.9706	0.9844	0.2650	0.7657

TABLE 5 Soil volumetric water content[a] (VWC, %) measured throughout the growing season, University of Wisconsin-Arlington Agricultural Research Station, 2010

	May (pretreatment)		June		July		August		September	
	7.6 cm	20 cm	7.6 cm	20 cm	7.6 cm	20 cm	7.6 cm	20 cm	7.6 cm	20 cm
Barley	20.8	27.0	22.9	26.4	23.9	34.7	29.0	27.9	31.7	30.9
Rye	22.6	25.6	34.4	27.7	22.6	37.2	29.9	25.1	31.1	29.6
Triticale	23.9	26.3	34.6	25.1	22.2	34.9	28.9	25.6	30.8	30.4
Vetch	30.1	27.5	29.8	28.7	23.9	36.7	30.5	26.2	32.8	28.7
AWP	29.9	30.7	26.7	26.4	23.8	35.7	30.7	27.1	30.1	30.5
Tilled	18.4	30.1	15.6	26.2	21.9	36.6	30.5	26.6	30.0	28.6

[a]Volumetric soil moisture content was measured approximately every 30 days during May–September at 7.6- and 20-cm depths at three locations in each plot with a FieldScout TDR300 soil moisture meter (Spectrum Technologies, Plainfield, IL).

TABLE 6 Soil volumetric water content[a] (VWC, %) measured throughout the growing season in crimped and mowed termination treatments, University of Wisconsin-Arlington Agricultural Research Station, 2011

			June		July		August		September	
		May (pretreatment)	Crimped	Mowed	Crimped	Mowed	Crimped	Mowed	Crimped	Mowed
7.6 cm	AWP	19.1	13.0	12.4	16.9	17.8	19.5	19.8	18.4	18.8
	Barley	14.1	15.2	21.6	14.1	14.9	17.6	18.1	23.2	23.4
	Rye	19.2	22.5	22.4	15.3	16.6	19.0	20.1	22.5	21.2
	Triticale	18.1	18.4	20.4	13.9	15.5	16.2	19.1	21.1	21.7
	Vetch	26.1	24.6	23.6	18.5	16.0	18.5	20.5	23.4	24.7
	Tilled	18.3	13.3	12.5	16.9	19.3	18.9	20.7	19.6	17.8
20 cm	AWP	27.2	12.4	25.3	24.6	23.0	14.2	15.1	29.3	30.0
	Barley	26.3	21.6	28.3	19.2	19.5	14.7	17.2	29.2	29.6
	Rye	24.1	22.4	33.9	23.0	23.2	14.0	15.2	30.5	30.7
	Triticale	26.3	20.4	27.3	19.5	20.8	14.9	15.3	30.4	29.5
	Vetch	24.5	23.6	30.1	23.8	24.9	15.0	15.7	29.8	30.5
	Tilled	27.2	12.6	26.1	21.7	23.4	14.7	15.8	29.2	28.2

[a]Volumetric soil moisture content was measured approximately every 30 days during May–September at 7.6- and 20-cm depths at three locations in each plot with a FieldScout TDR300 soil moisture meter (Spectrum Technologies, Plainfield, IL).

with values approaching the permanent wilting point (15% VWC) at certain times of the season. Effects of termination treatments on soil volumetric water content at the 20-cm sampling depth were observed during this drier year, with crimped treatments exhibiting less soil moisture at the 20 cm depth than mowed treatments immediately after termination (Table 6).

DISCUSSION

Many production questions remain as to the best management approaches for the successful implementation of cover crop-based organic no-till systems, Several studies estimate the amount of cover crop biomass required to consistently and reliably suppress weeds ranges from 3.4 Mg DM ha^{-1} to 9 Mg DM ha^{-1} (Doll and Mueller 2005; Smith et al. 2011). The data collected in this study indicate that the higher end of this range may be necessary in order to successfully implement an organic cover crop-based no-till system. This amount of cover crop growth is achievable in southern Wisconsin with fall-planted, overwintering, small grain cover crops but not with hairy vetch, as previously reported (Teasdale 2012). Biomass production exceeding 9 Mg DM ha^{-1} was achieved consistently over both years with two small grain cover crops, winter rye and winter barley. Even with the relatively heavy seeding rate used in this experiment, the biomass produced was not significantly greater than 9 Mg DM ha^{-1}. Similar to the conclusions of Teasdale and Mohler (2000), which indicated that differences of 1–2 Mg DM ha^{-1} of cover crop biomass strongly impacts season-long weed suppression, this study indicates a similarly strong relationship between mulch biomass and weed suppression.

The development best management practices for cover crop-based no-till production include questions related to the choice of cover crops to be used and the best termination strategies for those crops. The methodology of this study did not include an initial evaluate of the weed seed bank pressure; however, with this caveat, a discussion of the overall weed suppression of the various treatments can be initiated from the observations of this study. Adequate weed suppression by rye was particularly evident in 2011 with almost complete suppression of annual broadleaf weeds. Differences in weed suppression between rye and other cereal grain cover crops within a year were influenced by other factors apart from initial biomass, as initial rye biomass did not differ from winter barley in 2011. Biomass persistence or allelopathy of the cover crop mulch may have varied over years, resulting in the observed differences in weed suppression. Termination treatments (sickle-bar mowed vs. roll-crimped treatments) led to similar levels of weed suppression. This is consistent with results of Smith et al. (2011) comparing the weed suppression of flail-mowed versus rolled-crimped rye, showing differences in weed density and weed coverage in mode of kill in only one of four site years. Greater flexibility in mode of termination allows for more flexibility in sourcing appropriate equipment to employ this practice as part of an agronomic management plan. Flail mowers and sickle bar mowers are relatively common on farms across the upper Midwestern United States, presenting opportunities for farmers to experiment with the technique without the investment in new rolling-crimping equipment. However, soil volumetric water content data from 2011 suggests that crimping cover crops to initiate cover crop termination may lead to a transient depletion of soil moisture at deeper depths as compared to mowing. This is most likely due to continued transpiration of the flattened cover crop for several days subsequent to imposing the rolling-crimping treatment.

CONCLUSIONS

Incorporating cover crop-based no-till phases into the organic row crop rotation in Wisconsin may be an alternative management strategy for organic producers. Of the cover crops tested, winter rye may have the greatest potential for successful incorporation into the organic system. Over the two years of this study, rye exhibited sufficient winter hardiness and consistently produced high biomass in southern Wisconsin. Despite higher weed populations versus the tilled treatment in 2010, rye mulch suppressed weeds more consistently than other cover crop species treatments. Management questions remain for the use of each of the cover crops tested, including optimizing the system with alterations of planting dates, seeding rates, and variety selection.

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