Evaluation of an Organic No–Till System for Organic Corn and Soybean Production–Agronomy Farm Trial, 2011

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Introduction

The Rodale Institute (Kutztown, PA) began experimenting with an Organic No–Till Plus system in 2004, where commercial crops (corn, soybean, pumpkin) were no-till drilled or planted into cover crops that were rolled with a roller/crimper. The roller consists of a large steel cylinder (10.5 ft. wide x 16 in. diameter) filled with water to provide 2,000 lb. of weight. The Rodale Institute supplied Iowa State University with a roller in 2005 for experimentation in Iowa.

Due to the fact that organic production of crops primarily relies on tillage for weed management, much attention has been focused on an organic no-till system. Tillage may be problematic for soil quality by increasing erosion and carbon loss, but also increasing labor and energy use (Pimentel et al., 2005). Mixed results have occurred in Iowa and across the nation since the inception of roller experimentation. In 2007, no-till organic soybeans were yielded 45 bu/acre, compared to 50 bu/acre in the tilled organic soybeans (Delate et al., 2007). Organic no-till corn in Iowa was not competitive in 2007 with yields as low as 10 bu/acre compared with a 124-bu/acre average for the tilled corn. In Pennsylvania, however, yields have been reported as high as 153 bu/acre after planting corn into a rolled hairy vetch cover crop (Mischler et al., 2010). In 2009, corn and soybeans were planted into hairy vetch and rye cover crops, respectively, in the Integrated Organic Program project (Delate et al., 2010). Corn yields in 2009 were 29.9 bu/acre in the no-till corn plots and 99.4 bu/acre in the tilled treatment. Organic no-till soybeans were much more competitive at 36.6 bu/acre compared to 42.6 bu/acre in tilled plots.

Materials and Methods

Soil samples were taken on August 26, 2010, in all plots to compare soil quality after the third year of the experiment. Soils were evaluated at the USDA-ARS National Laboratory for Agriculture and the Environment (Ames, IA).

Plots for the organic no–till experiment were laid out in a randomized complete block design of four treatments and four replications: a tilled (control) treatment for corn and soybean (cover crops tilled/tillage used after planting); a cover crop of rye (56 lb/acre) for soybeans; and a cover crop of hairy vetch (32 lb/acre) for the corn crop. Cover crops were planted on October 1, 2010. On May 24, 2011, cover crops were disked in the tilled treatment plots to allow decomposition prior to planting. In the no-till treatment, cover crops were rolled with a roller/crimper mounted on the rear of the tractor on June 2, 2011. Cover crops were crushed at anthesis (pollen shedding in the small grains). The corn and soybeans in the experiment were planted in the cover crop treatments on the same day as rolling in a two-pass operation in 30-inch rows: the soybeans (BR 34A7) at 200,000 seeds/acre and the corn (BR 63H07) at 30,000 seeds/acre. Corn and soybeans were planted at the same rates in the tilled plots. After planting, it was evident that the hairy vetch cover crop was not killed by the roller/crimper, so the hairy vetch cover crops were mowed on June 7 before the corn emerged.

Because of excessive rains in Spring 2011, corn and soybean tilled plots were not rotary hoed.

Row cultivations occurred on June 29, July 7 and 14.

Cover crop stands were determined on May 18 by counting the number of living plants per square foot in three randomly selected areas within each plot. Cover crop biomass and height were taken on May 18 and 24, respectively, by harvesting the biomass within three randomly selected square foot sections in each plot and drying until at a constant weight. Cover crop coverage compared to bare ground and weed cover was estimated on May 24 and June 20 by estimating percentage of cover for each component per square foot in three randomly selected areas within each plot. Corn and soybean plant populations were determined on June 27. Corn borer presence and damage was determined in each corn plot on July 13 by inspecting the whorl of 3 randomly selected corn plants in each plot and recording presence or absence of corn borer damage and counting number of live larvae. Plant height was taken in each plot on July 21. Weed density was determined in each plot on June 20 by counting the number of broadleaf and grass weeds per square foot in three randomly selected areas within each plot. Soil moisture differences were determined in 2011 by collecting five randomly located 1.3-in-diameter soil cores at a depth of 6 inches on 1 September 2011; weighing each sample; drying at 140° F until at a constant weight, and re-weighing to determine percent moisture. Soil samples were taken on August 26, 2010, in all plots to compare soil quality after the third year of the experiment. Soils were evaluated at the USDA-ARS National Laboratory for Agriculture and the Environment (Ames, IA) and at the USDA-ARS lab in Morris MN.

Results

Cover crop performance

In 2011, the germination and stand of the hairy vetch cover crop was greater than in 2009 (Table 1). Plant populations averaged 640,550 plants/acre over all hairy vetch plots on 18 May, compared to 135,036 plants/acre in 2009. Rye stands averaged 2,259,675 plants/acre, which were lower than 2009 stands of 2,408,868 plants/acre, but plant height of the rye cover crop height was 48 inches on 24 May prior to rolling/crimping. Hairy vetch plant height averaged 9 inches, which was similar to 2009. Despite a more extensive hairy vetch stand in 2011 than in 2009, cover crop ratings in no-till plots on 24 May determined that hairy vetch plots consisted of only 16% cover crop, with 83% of the plot in weeds, and 1% in bare ground (Table 1). This high proportion of weeds in hairy vetch plots led to extensive weed problems in corn plots throughout the growing season, particularly when hairy vetch was not suppressed by the roller/crimper. Rye plots, on the other hand, consisted of 93% cover crop, with only 6% in weeds and 1% in bare ground. Cover crop biomass was higher in the rye cover compared to the hairy vetch plots, averaging 3,525 lb/acre, with significantly greater amounts in the no-till plots (4,767 lb/acre) compared to the tilled plots (2,283 lb/acre) (Table 1). Hairy vetch biomass averaged 242 lb/acre, with no difference between tilled and no-till plots. Both cover crops yielded significantly less biomass than in 2009.

Soybean crop performance

Soybean plant populations were significantly higher in the no-till plots in 2011 compared to the tilled plots, with no-till plots averaging 129,667 plants/acre compared to 99,833 plants/acre in tilled plots (Table 2). Weed suppression in the no-till plots was satisfactory early in the season, with broadleaf and grass weed populations averaging <2 weeds/ft^2 on 20 June (Table 3). Broadleaf weeds were lower in the tilled plots but, with such low populations in all plots, biological differences were not recognized. Later in the season, however, volunteer rye plants, along with other grass and broadleaf weeds, emerged in no-till plots, leading to significantly greater populations of 5 broadleaf weeds/ft^2 and 37 grass weeds/ft^2 on 1 September compared to <1 broadleaf weed/ft^2 and 11 grasses/ft^2 in tilled plots.

Weed and volunteer rye competition again did not appear to adversely affect the soybean yield in no-till plots in 2011 (Table 2). Soybean yields in both no-till and tilled treatments were successful in 2011, averaging 28 bu/acre in the tilled plots and 31 bu/acre in no-till plots, which was considered an excellent yield for organic soybeans in 2011. Yields were not significantly different between treatments.

Soybean grain quality

Soybean grain quality was not significantly different between no-till and tilled treatments in 2011 (Table 6). Protein content averaged 36.7%, with 17.3% oil, and 23.2% carbohydrates. Soybean staining (percentage of soybeans stained from insect feeding/fungal infection) was low, at 1.31%, and no difference between treatments.

Soil moisture

Tilled plots averaged 18% soil moisture compared to 16% in no-till plots (Table 5). While significantly different, the 2% difference did not have an adverse effect on plant growth, since yields were equivalent between tillage treatments.

Corn crop performance

In 2011, as occurred in 2009, corn plants in the no-till treatments suffered from competition with hairy vetch re-growth and excessive weed populations. Plant populations in the no-till treatments averaged 21,167 plants/acre, which were significantly lower than the tilled treatments at 26,917 plants/acre (Table 2). Despite an increase of 1,250 plants/acre in no-till corn plant populations from the 2009 season, weed and hairy vetch competition prevented adequate corn growth. Broadleaf weed populations were low in tilled plots, averaging <1 broadleaf weed/ft^2 on 20 June and on 1 September (Table 3). Grass weeds in tilled plots averaged 4 grasses/ft^2 on 20 June and 14 grasses/ft^2 on 1 September. Weed populations in the no-till corn plots greatly exceeded those in tilled plots: on 1 September, there were 25 broadleaf weeds/ft^2 and 39 grass weeds/ft^2. In terms of weed biomass production, there were 723 lb/acre of annual grasses in no-till corn plots compared to 1,135 lb/acre in tilled plots, but because of high variability among plots, there was no statistical difference between treatments. Perennial broadleaf weeds totaled 225 lb/acre in no-till plots compared to none in tilled plots, where annual broadleaf weeds predominated.

Corn borers were again observed in 2011 (Table 4). While censusing corn borer damage in the field, there was a trend towards greater damage in no-till plots, but since populations were so low, biological differences were insignificant between tillage treatments.

Because of limited N in all plots, tilled corn plots averaged 77 bu/acre (Table 2). No-till corn yields averaged only 10 bu/acre, due to both low N and high weed populations. Corn grain was not analyzed for grain quality in 2011 due to poor yields.

Soil quality

There was no difference in soil moisture in no-till or tilled corn plots, which averaged 16.3% across all plots (Table 5). Prior to cash crop planting in Spring 2009, soil quality analysis revealed no significant differences in any parameters between the no-till and the tilled treatments in samples taken in Fall 2008 (Delate et al., 2012). After the first corn and soybean season, in Fall 2009, soil microbial biomass carbon (MBC) values were significantly greater in no-till than in tilled plots (Weyers and Cambardella, 2011). Higher MBC and microbial biomass nitrogen (MBN) continued in no-till plots after the oat year in 2010. Additionally, residual soil nitrate-N, pH and electrical conductivity were greater under no-till than tilled plots. These findings were explained by Weyers and Cambardella (2011) as suggestive of MB-C and N quickly reacting to soil management changes as experienced with the no-till treatment. The reduced soil disturbance from no-till and higher available C and N concentration in the top soil layer may have led to increased microbial populations.

Discussion

Overall, the organic no-till system for organic soybeans was excellent in 2011, with no-till yields having numerically higher yields than the tilled system. The rolled winter rye cover crop provided acceptable weed control compared to the tilled treatment, and despite volunteer rye tillers later in the season, the soybean yields were not adversely affected. These results were similar to previous no-till experiments in Iowa. The largest impediment in an organic no-till system for organic corn utilizing hairy vetch as a cover crop appears to be thoroughly killing the cover crop with the roller-crimper. The rolled hairy vetch, which continued to grow, drastically reduced corn yields and provide did not provide adequate control of the weeds compared to the tilled control plots. Rolling the vetch at later dates in June has been shown to potentially alleviate both problems by allowing for larger biomass growth and better control of the hairy vetch, thus providing higher yields (Mischler et al., 2010); however, a much later planting date would result in drastically lower corn yields. Tilled corn also suffered from lack of supplemental nitrogen in this experiment, leading to the conclusion that cover crops should not be considered as a sole nutrient source in organic corn production.

As a result of these experiments, organic no-till corn is now considered too difficult for Midwest conditions, and a new crop rotation including alfalfa as a cover crop prior to the no-till segment of rye/soybean is currently under investigation. Based on the beneficial effects from increased carbon inputs in long-term organic no-till crop rotations, economic benefits could also be obtained from soil carbon enhancement and greenhouse gas reduction if Clean Energy legislation and carbon markets support such practices in the future.

Literature Cited

Delate, K., B. Burcham, and A. McKern. 2007. Evaluation of an Organic No-Till System for Organic Corn, Soybean and Tomato Production—Neely Kinyon Trial. 2007. Annual Research Reports-2007 Armstrong Research and Demonstration Farm, Iowa State University, Ames, IA. http://extension.agron.iastate.edu/organicag/researchreports/nk07notill.pdf

Delate, K., and D. Cwach. 2010. Evaluation of an organic no–till rotation for corn and soybean–Agronomy Farm Trial, 2009. Iowa State University Organic Agriculture Webpage, ISU, Ames, IA: http://extension.agron.iastate.edu/organicag/researchreports/agronomyfarmnotill09.pdf

Mischler, R., S.W. Duiker, W.S. Curran, K. Sinclair, D. Wilson. 2010. Hairy Vetch Management for No-Till Organic Corn Production. Agron. J. 102:355-362.

Pimentel, D., C. Harvey, P. Resosudarmo, K. Sinclair, D. Kurz, M. McNair, S. Crist, L. Shpritz, L. Fitton, R. Saffouri, and R. Blair. 1995. Environmental and economic cost of soil erosion and conservation benefits. Science 267:1117–1123.

Weyers, S.L. and C. Cambardella. 2011. Soil quality changes with organic no-till production. American Society of Agronomy Annual Meetings, San Antonio, TX, ASA Abstracts: http://a-c-s.confex.com/crops/2011am/webprogram/Paper66298.html.

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Table 1. Hairy vetch and rye cover crop plant performance in Organic No-Till experiment, Agronomy Farm, 2011.

Treatment	Tillage	Biomass (lb/acre) 5/18/2011	Stand (plants/acre) 5/18/2011	Total cover (%) 5/24/2011	Height (inches) 5/24/2011	Weed cover (%) 5/24/2011	Bare ground (%) 5/24/2011
Hairy vetch	Conventional tillage	248.09	831,125	N/A	N/A	N/A	N/A
	No tillage	235.28	449,975	16.25	9.15	83.08	1.67
	$LSD_{0.05}$	NS[z]	NS	N/A	N/A	N/A	N/A
Rye	Conventional tillage	2283.19	2,105,255	N/A	N/A	N/A	N/A
	No tillage	4767.25	2,414,095	92.58	47.80	6.33	1.08
	$LSD_{0.05}$	868.14	NS	N/A	N/A	N/A	N/A

[z] Means within a column within each section are not significant (NS), or significant at $p \leq 0.05$ (Fisher's protected LSD test).

Table 2. Corn and soybean plant performance and yield in Organic No-Till experiment, Agronomy Farm, 2011.

Treatment	Tillage	Stand (plants/acre) 6/27/2011	Height (inches) 7/21/2011	Yield (bu/acre)
Corn	Conventional tillage	26,917	44.62	77.16a
	No tillage	21,167	27.13	10.04b
	$LSD_{0.05}$	4,660	4.93	5.89
Soybean	Conventional tillage	99,833	15.96	28.21
	No tillage	129,667	18.52	31.04
	$LSD_{0.05}$	21,680	1.27	NS

[z] Means within a column within each section are not significant (NS), or significant at $p \leq 0.05$ (Fisher's protected LSD test).

Table 3. Weed density and cover ratings in Organic No-Till experiment, Agronomy Farm, 2011.

Treatment	Tillage	Grass weeds (plants/ft²)	Broadleaf weeds (plants/ft²)	Grass weeds (plants/ft²)	Broadleaf weeds (plants/ft²)	Cover crop (%)	Weed cover (%)	Bare ground (%)
		6/20/2011	6/20/2011	9/1/2011	9/1/2011	6/20/2011	6/20/2011	6/20/2011
Corn	Conventional tillage	3.50	0.66	13.89b	0.87b	---	---	---
	No tillage	---	---	38.53a	24.6a	5.91	37.41	56.68
	$LSD_{0.05}$	---	---	18.19	17.65	---	---	---
Soybean	Conventional tillage	1.42	0.03b	0.11b	11.3b	---	---	---
	No tillage	1.08	1.57a	4.73a	37.1a	---	---	---
	$LSD_{0.05}$	NS [z]	0.65	4.20	20.02	---	---	---

[z] Means within a column within each section are not significant (NS), or significant at $p \leq 0.05$ (Fisher's protected LSD test).

Table 4. Corn borer in Organic No-Till experiment, Agronomy Farm, 2011.

Treatment	Tillage	Corn borer damage	Corn borer presence
		7/13/2011	7/13/2011
Corn	Conventional tillage	0	0
	No tillage	0.08	0
	$LSD_{0.05}$	NS[z]	NS

[z] Means within a column within each section are not significant (NS), or significant at $p \leq 0.05$ (Fisher's protected LSD test).

Table 5. Soil moisture in Organic No-Till experiment, Agronomy Farm, 2011.

		Soil moisture (%)
Corn	Conventional tillage	16.27
	No tillage	16.40
	LSD $_{0.05}$	NS[z]
Soybean	Conventional tillage	17.98
	No tillage	16.16
	LSD $_{0.05}$	1.42

[z] Means within a column within each section are not significant (NS), or significant at $p \leq 0.05$ (Fisher's protected LSD test).

Table 6. Soybean grain quality in Organic No-Till experiment, Agronomy Farm, 2011.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Fiber (%)	Carbohydrates (%)	Soybean staining (%)
Conventional tillage	11.05	36.60	17.48	4.76	23.16	1.24
No tillage	11.23	36.88	17.20	4.76	23.16	1.38
LSD $_{0.05}$	NS	NS	NS	NS	NS	NS

[z]Means within a column are not significantly different (NS), or significantly different at $p \leq 0.05$ (Fisher's protected LSD test).