Evaluation of an Organic No–Till System for Organic Corn Production–Neely-Kinyon Farm Trial, 2011

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Introduction

In addition to termination with herbicides, cover crops have been killed using a roller/crimper with steel blades welded onto a cylindrical drum in conservation tillage systems (Ashford and Reeves, 2003). 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/crimper 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.

Organic farming has been suggested as promoting poor soil stewardship because of the perception that intensive tillage practices are needed for weed control and contribute to excessive erosion and overall soil degradation (Kuepper, 2001). Conservation tillage, including no-till crop production, addresses the concerns of tillage and has improved soil quality (Uri, 2000); however, conventional no-till relies on herbicides as the primary form of weed management, which is not allowed in organic production. Due to these facts, much attention has been focused on an organic no-till system.

Mixed results have occurred in Iowa and across the nation since the inception of the roller/crimper. Organic no-till corn in Iowa has presented growers with the greatest challenge, with yields as low as 10 bu/acre compared with a 124 bu/acre average for the tilled corn in 2007 (Delate et al., 2007). In 2010, both the tilled and no-till corn were harvested as biomass due to the no-till corn plots lack of ear formation. The tilled corn yielded an average of 24 tons/acre biomass with the no-till corn averaging 6 tons/acre (Delate et al., 2010). Although yields in Iowa have been disappointing, Pennsylvania yields have been more successful, with reported yields as high as 153 bu/acre when planting corn into a rolled/crimped hairy vetch cover crop (Mischler et al., 2010).

Materials and Methods

Cover crops for the organic no–till corn experiment were planted on October 18, 2010, at the Iowa State University Neely-Kinyon Farm and consisted of two main treatments: no-till and conventional tillage. The six cover crop sub-treatments including hairy vetch (30 lb/acre), winter rye (240 lb/acre), winter triticale (240 lb/acre), Austrian winter peas (30 lb/acre), a combination of hairy vetch (20 lb/acre) and winter rye (180 lb/acre), and a control with no cover crop planted. The cover crops in the tilled treatment were disked on June 2 and June 6. In the no-till plots, cover crops were terminated with a roller/crimper mounted on the tractor on June 7. Corn (Blue River 45R37) was planted into both treatments on June 7 at 35,000 seeds/acre in 30-inch rows. The tilled corn plots were rotary hoed on June 24 and row cultivated on June 29, July 7 and July 15.

Visual percentage of cover crop, weed, and bare ground coverage was estimated in each plot from May 11 to 19, prior to termination. Cover crop biomass estimates were determined after coverage ratings by harvesting all biomass within three randomly selected square foot sections in each plot and drying until at a constant weight. Cover crop re-growth within no-till plots was estimated by rating three randomly selected square-foot areas within each plot for percentage of live cover crop plants three weeks after rolling/crimping. Corn stand and weed populations were determined on June 29 by counting the number of emerged plants in three randomly selected 17.4 ft. row lengths, and the number of grass and broadleaf weeds per square foot in three randomly selected areas within each plot. European corn borer damage was recorded on July 14 by counting the number of living corn borers per three plants and providing an overall estimation of the plants with corn borer damage in each plot. Soil samples were taken at a 6-inch depth in three randomly selected corn rows per plot on July 14. Corn height was measured on July 22 for three randomly selected plants in each plot. A Minolta SPAD reading was taken as an estimate of N content in leaves on September 28.

The tilled corn plots were harvested for grain with a combine on October 24. Due to minimal ear formation, corn in the no-till plots was harvested for silage with a forage biomass harvester on October 5. Soil samples were taken on November 3 to compare end-of-season differences between the two tillage treatments and cover crop sub-treatments.

Results and Discussion

Cover crops

When germination and stand of cover crops was assessed in Spring 2011, cover crops that contained a cereal [rye, triticale, rye/hairy vetch (R/HV)] covered over 99% of sampled plot area, prior to termination in May (Table 1). The legume cover crops, hairy vetch (HV) and winter pea (WP), experienced lower germination rates and/or winter-kill, with only 24% and 55% ground cover, respectively, before termination (Table 1). Cereal cover crops alone or in a mixture (R/HV) yielded significantly greater amounts of biomass, averaging 3,201 lb/acre across all plots, compared to 277 lb/acre across all WP plots, and 608 lb/acre across all HV plots (Table 1). The average weed cover in the cereal cover crop plots was <1%, while legume cover crops averaged 16% weeds across all plots, compared to the control plots where 33% of the sampling area contained weeds. Bare ground (area other than cover crop plants or weeds) averaged 0% in plots containing cereal cover crops, 42% in legume cover crop plots, and 56% in control plots (Table 1). The roller/crimper adequately suppressed cereal cover crop re-growth, with less than 10% re-growth in these plots (Table 1). The HV and WP re-growth, however, averaged 100% and 97%, respectively (Table 1).

Corn

Corn stands were equivalent in the no-till plots, averaging 29,000 plants/acre, compared to 27,000 plants/acre in the tilled plots (Table 2). Lower stands were observed where cereal cover crops had been tilled under prior to corn planting, averaging 23,556 plants/acre, but in no-till plots, where cereal crops crops had been rolled/crimped, stands averaged 30,278 plants/acre (Table 2). Weeds were controlled in the no-till system, with grass and broadleaf weed populations averaging 1 plant/ft^2 three weeks after planting compared to an average of 8 grass weeds/ft^2 and 2 broadleaf weeds/ft^2 in the tilled plots (Table 2). Nitrogen limitations were observed in both systems, with soil nitrate content averaging 4 ppm NO_3 in tilled plots on July 14, and 1 ppm NO_3 in no-till plots (Table 2). On July 22, corn height was greater in the tilled system, averaging 51 inches, compared 34 inches in the no-till system (Table 2). Legume cover crop treatments in the tilled system were associated with taller plants, averaging 56 inches (Table 2). In the no-till plots, this pattern was not as apparent, except that the shortest corn plants were observed in the rolled/crimped triticale treatment (28 inches). SPAD readings were higher in the tilled plots (34) compared to a reading of 25 in the no-till plots (Table 2).

Corn borers were observed in 2011 (Table 2), with a trend towards greater damage in no-till plots, but no significant differences were obtained between tillage or cover crop treatments.

Yields in the tilled system ranged from 58 bushels/acre in the winter rye treatment to 144 bushels in the control treatment (Table 2). Corn in the legume cover crop treatments (HV and WP) averaged 120 bushels/acre compared to the cereal cover crop treatments averaging 57 bushels/acre. Corn silage biomass averaged 13.3 tons/acre, with no significant difference between cover crop treatments (Table 2).

<u>Soil fertility</u>

At the end of the season, soil nutrients (Ca, Mg, K, and Bray P) were not significantly different between cover crop treatments in the tilled plots (Table 3), but in the no-till plots, lower K concentrations were determined in the tritcale cover crop treatment compared to the legume cover crop treatments. Nitrate-N did not differ between tilled and no-till systems, averaging 2.8 ppm, but there was a trend towards greater nitrate-N in the no-till plots, which averaged 3.1 ppm, and had significantly lower nitrate-N in rye and triticale plots (Table 3). Total N, total C, and organic matter content were equivalent between tilled and no-till systems and cover cover sub-treatments, averaging 0.18 ppm, 2.6%, and 4.7%, respectively.

<u>Corn grain quality</u>

Corn grain quality was not significantly different between cover crop treatments in tilled plots (Table 4). Protein content averaged 7.1% across all treatments, with oil and starch content averaging 3.5% and 61.5%, respectively. Moisture content averaged 23% (Table 4).

Discussion

In 2011, cereal cover crops produced adequate biomass and ground coverage for the roller/crimper operation, while single legume cover crops (HV, WP) suffered from poor winter survival and low biomass in the spring. Although crop stands were equivalent in both tillage treatments, corn plants in the no-till treatments suffered from competition with cover crop re-growth and nitrogen shortages, as observed in SPAD leaf readings and in soil nitrate content. Although considerable silage biomass was obtained from the no-till corn, grain harvest was unobtainable in both years of this two-year study. Contrary to 2010 results, however, the rolled/crimped cover crops were associated with lower weed populations than those observed in tilled plots, which signified greater success with the roller/crimper in creating a thick cereal cover crop mulch where very little re-growth occurred.

The HV and WP cover crop treatments were associated with higher yields in the tilled plots, compared to the cereal cover crops, presumably due to the nitrogen added through nitrogen fixation from legume cover crops, and potential allelopathy from cereal cover crops. The allelopathy effect appeared to be more significant, given that yields in control plots (with no cover crop) were equivalent to legume cover crop treatments. These results were similar to previous no-till experiments in Iowa where leguminous cover crops were associated with greater yields (Delate et al., 2007).

Many modifications to the organic no-till system are needed before recommending as a broad-scale approach for organic growers in all regions. Rolling/crimping the HV cover crop in late June has been associated with greater biomass and less HV re-growth (Mischler et al., 2010), but later corn planting can lead to lower yields in the Midwest. The inability of legume cover crops to supply adequate amounts of N for the corn crop and/or limited nitrogen mineralization in spring was observed in both the no-till and tilled system; thus, in future experiments, we will add supplemental nitrogen (manure or compost) to provide adequate nutrients to support corn grain yields.

Although progress has been made for other crops in the organic no-till system, with organic no-till soybeans averaging 31 bu/acre in 2011 (Delate et al., 2012), organic no-till corn continues to be a more challenging system. Future projects will include a high-residue cultivator to assist with terminating cover crop re-growth or tillering in the rye cover crop.

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Table 1. Cover crop performance in the organic no-till corn experiment, Neely-Kinyon Farm, 2011.

Treatment	Cover crop biomass (ton/acre)	Cover crop cover (%)	Weed cover (%)	Bare ground (%)	Cover crop re-growth after rolling/ crimping (%)
Conventional Tillage					
Austrian winter pea	0.10c [z]	57.92b	9.92b	32.17b	---
Hairy vetch	0.54b	33.33c	14.17ab	52.50a	---
Rye	1.63a	99.67a	0.33c	0.00c	---
Rye/hairy vetch	1.67a	99.92a	0.08c	0.00c	---
Winter triticale	1.39a	99.42a	0.58c	0.00c	---
Control	N/A	22.50c	20.83a	56.67a	---
$LSD_{0.05}$	0.004	15.78	7.27	15.70	---
No-Till					
Austrian winter pea	0.18b	55.42b	20.00b	24.58b	96.67a
Hairy vetch	0.07b	23.75c	20.00b	56.25a	100.00a
Rye	1.80a	99.92a	0.08c	0.00c	9.17b
Rye/hairy vetch	1.57a	99.75a	0.25c	0.00c	6.67b
Winter triticale	1.55a	99.33a	0.67c	0.00c	7.08b
Control	---	---	45.00a	55.00a	---
$LSD_{0.05}$	0.25	6.87	9.71	10.82	4.37
Significance of interactions (p value: tillage x cover crop)	0.0392	NS	0.0004	NS	N/A

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

Table 2. Crop, soil, and weed outcomes in the organic no-till corn experiment, Neely-Kinyon Farm, 2011.

Treatment	Corn stand (plants/ acre)	Corn borer damage (%)	Corn borer presence (%)	Corn height (inches)	Grain yield (bu/acre)	Biomass harvest (tons/acre)	Soil NO_3-N (ppm)	SPAD reading	Grass weeds (plants/ft^2)	Broadleaf weeds (plants/ft^2)
Conventional Tillage										
Austrian winter pea	32,250a [z]	0.00	0.00	56.26a	123.26a	---	5.0	37.65ab	8.03	1.40bc
Hairy vetch	28,833ab	0.00	0.00	55.16a	118.36a	---	5.5	36.05bc	7.90	2.18ab
Rye	22,583c	0.00	0.08	45.12b	62.32b	---	4.8	30.15cd	4.07	0.90c
Rye/hairy vetch	22,917c	0.00	0.00	45.96b	52.69b	---	2.7	30.49cd	9.29	1.54bc
Winter triticale	25,167bc	0.08	0.00	45.06b	57.59b	---	2.6	23.59d	4.36	1.94bc
Control	31,000a	0.08	0.00	57.05a	144.32a	---	3.0	43.02a	11.53	3.20a
$LSD_{0.05}$	3,756	NS	NS	4.10	39.17	---	N/A	6.55	NS	1.19
No-Till										
Austrian winter pea	30,500ab	0.00	0.00	33.37ab	---	15.36	0.3	29.45a	0.88c	2.18a
Hairy vetch	28,167bc	0.00	0.00	32.34b	---	12.35	1.3	24.85abc	1.94b	1.13bc
Rye	32,833a	0.17	0.00	34.88ab	---	12.79	1.3	23.92bc	0.27cd	0.11d
Rye/hairy vetch	27,917bc	0.25	0.00	35.51a	---	13.52	0.5	22.18c	0.04d	0.20d
Winter triticale	30,083ab	0.08	0.00	28.43c	---	11.98	1.1	28.16ab	0.09cd	0.33cd
Control	25,231c	0.17	0.00	33.09ab	---	14.01	0.3	23.90bc	2.77a	1.87ab
$LSD_{0.05}$	3,895	NS	NS	2.62	---	NS	N/A	4.68	0.82	0.82
Significance of interaction (p value: tillage x cover crop)	NS	NS	NS	NS	---	---	---	<0.0001	NS	0.0174

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

Table 3. Soil parameters in the organic no-till corn experiment, Neely-Kinyon Farm, 2011.

Treatment	Ca (ppm)	Mg (ppm)	K (ppm)	Bray P (ppm)	NH_4 (ppm)	NO_3^- N (ppm)	Total N (%)	Total C (%)	Organic Matter (%)
Conventional Tillage									
Austrian winter pea	28.75 [z]	334.00	239.5	59.50	2.88	2.68	0.18	2.43	4.45
Hairy vetch	21.75	354.75	244.8	59.75	3.65	2.48	0.18	2.36	4.30
Rye	22.25	339.75	251.8	52.00	2.45	2.03	0.19	2.52	4.60
Rye/hairy vetch	35.50	339.25	260.0	55.00	2.60	2.35	0.19	2.46	4.53
Winter triticale	21.75	368.75	276.0	60.50	2.63	2.08	0.19	2.50	4.55
Control	17.50	338.75	231.5	56.75	2.83	2.63	0.18	2.39	4.35
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS	NS
No-Till									
Austrian winter pea	15.00	323.50	278.3a	56.50	2.53	4.43a	0.17	2.67	4.85
Hairy vetch	16.00	349.75	279.8a	55.25	2.95	3.60ab	0.18	2.63	4.80
Rye	19.00	366.50	270.5a	54.25	3.45	1.90c	0.17	2.58	4.70
Rye/hairy vetch	18.25	330.75	255.3ab	53.00	2.88	2.30bc	0.23	2.73	4.98
Winter triticale	22.25	335.50	215.3b	43.25	2.68	1.65c	0.18	2.76	5.05
Control	21.00	354.25	251.3ab	51.00	2.75	3.48ab	0.17	2.76	5.00
$LSD_{0.05}$	NS	NS	42.8	NS	NS	1.38	NS	NS	NS
Significance of interaction (p value: tillage x cover crop)	0.3180	0.6100	0.0250*	0.6884	0.1904	0.0811	0.6489	0.1567	0.1594

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

Table 4. Corn grain quality in the organic no-till corn experiment, Neely-Kinyon Farm, 2011.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Starch (%)	Density (g/cc)	Ethanol Yield (gal/bu)
Conventional Tillage						
Austrian winter pea	23.06 [z]	6.93	3.51	61.60	1.25	2.91
Hairy vetch	22.90	7.40	3.58	61.34	1.26	2.93
Rye	22.49	6.91	3.36	61.91	1.25	2.92
Rye/hairy vetch	23.33	7.18	3.45	61.60	1.26	2.90
Winter triticale	22.38	7.10	3.48	61.55	1.25	2.94
Control	21.06	7.04	3.43	61.68	1.26	2.91
$LSD_{0.05}$	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) if different letters.