Comparison of Organic and Conventional Crops at the Neely-Kinyon Long-Term Agroecological Research Site

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Materials and Methods

The Neely-Kinyon Long-term Agroecological Research (LTAR) site was established in 1998 to study the long-term effects of organic production in Iowa. Treatments at the LTAR site, replicated four times in a completely randomized design, include the following rotations: conventional Corn-Soybean (C-S), organic Corn-Soybean-Oats/Alfalfa (C-S-O/A), organic Corn-Soybean-Oats/Alfalfa-Alfalfa (C-S-O/A-A) and organic Corn-Soybean-Corn-Oats/Alfalfa (C-SB-C-O/A).

Oat/alfalfa plots were field cultivated April 11, 2015, and Badger oats were underseeded with BlueJay 3HR alfalfa at a rate of 90 lb/acre and 15 lb/acre, respectively. Plots were cultipacked April 11 after planting. Following harvest of the organic corn plots in 2014, winter rye was no-till drilled at a rate of 75 lb/acre on November 7, 2014.

Conventional corn plots were injected with 32 percent UAN May 9, 2015, at 140 lb N/acre, disked May 13 and June 9, and field cultivated June 9. Chicken manure (SW Iowa Egg Cooperative, Massena, IA) was applied to organic corn plots at a rate of 6.9 tons/acre on April 11 in the organic C-S-O/A and C-S-O/A-A plots, and at a reduced rate of 2.9 tons/acre in the C-S-C-O/A plots the same day. Corn and soybean variety selection and planting methods in 2015 were as follows: Blue River 56M30 corn was planted at a depth of 2.5 in. as untreated seed at a rate of 35,000 seeds/acre in the organic plots and as treated seed in conventional plots, on June 9, 2015. Conventional soybean plots were disked May 13 and June 8, and field cultivated June 9. Blue River 24C3 soybeans were planted at a depth of 2 in. in organic and conventional plots at a rate of 175,000 seeds/acre on June 9, 2015. Conventional corn plots were sprayed June 10, 2015, with Outlook™ at 20 oz/acre and Round-Up™ at 1 qt/acre; and Choice™ at 1 qt/100 gal on June 10. Conventional corn plots were cultivated July 14 to deal with weed problems. Conventional soybeans received applications of Outlook™ at 20 oz/acre and Round-Up™ at 28 oz/acre; and Choice™ at 1 qt/100 gal on June 10. Conventional soybean plots were cultivated July 14 to deal with weeds still emerging after herbicides.

The alfalfa and compost applied in the organic corn plots were plowed under April 28, 2015. Plots were disked May 9 and June 9, and field cultivated June 9. Organic corn plots were rotary-hoed June 22 and row-cultivated June 29 — two cultivations less than in 2013, due to wet weather.

Rye was disked in organic soybean plots on May 13 and June 8, and field cultivated June 9, before soybean planting the same day. Organic soybean plots that were not too wet were rotary hoed June 19 and June 22, and row-cultivated June 29, July 8, and July 14. The length of time between planting and the first rotary hoeing (10 days) due to wet weather was damaging to weed management, and considerable time was invested in "walking" each organic soybean plot for large weeds above the canopy on August 9. There was a problem of weeds in conventional plots in 2015, even after repeated herbicide applications, but these were not “walked” in keeping with the protocol of herbicide applications only in conventional plots.

Oat and alfalfa plots were sampled for nutrient analysis May 18, 2015. Corn and soybean stands were counted June 29, and weeds were counted within square meter quadrats at three randomly selected areas within a plot. Soil nitrate tests were conducted July 31, due to wet weather at the beginning of the season, by sampling at a 6-in. depth in three randomly selected areas in each plot in the corn row. Corn borer sampling was conducted July 30 by sampling the whorl of three randomly selected corn plants/plot and counting incidence and numbers of corn borers. Corn stalk nitrate samples were collected October 9. All crop and soil analyses were conducted at the Iowa State University Soil and Plant Analysis Laboratory, Ames, Iowa, and nematode analysis was conducted at the ISU Plant Disease Clinic, Ames, Iowa.

Alfalfa was baled June 10, July 23, and September 14. Oat grain was harvested July 20. Soybean plots were harvested October 13, and corn plots were harvested October 26. Grain samples were collected from each corn and soybean plot for grain quality analysis, which was conducted at the ISU Grain Quality Laboratory, Ames, Iowa.

Results and Discussion

The weather in 2015 was extremely challenging, with a cool, wet May and 10 in. above normal rainfall in June. A very short window for planting was missed in May, pushing back planting dates to June. As a result of these extreme weather conditions and late planting, weed management and yields were affected in all plots. Oat and alfalfa stands also were affected by the poor weather, with N content in oat/alfalfa fields averaging 4.8 percent N and second-year alfalfa fields averaging 3.8 percent N (Table 1). Corn stands were similar between organic and conventional systems, averaging 34,110 plants/acre (Table 2). Organic soybean populations averaged 136,830 plants/acre, and conventional plots averaged 147,250 plants/acre, which was significantly higher than populations in the C-S-O/A-A plots (Table 3). Grass weed populations were highest in the organic corn plots, averaging 29 weeds/m^2, and broadleaf weeds averaged 14 weeds/m^2, compared with two broadleaf weeds in conventional plots (Table 2). In the soybean plots, the organic plots averaged 31 grass weeds/m^2, compared with <1 weed/m^2 in conventional plots (Table 3). Broadleaf weeds were not significantly different between organic and conventional soybean plots because of high variability, but the organic plots averaged 20 weeds/m^2, compared with 5 weeds/m^2 in conventional plots. Weeds in organic fields could be attributed to wet fields in spring, which created poor conditions leading to a delay of 10 days between planting and the first rotary hoeing in corn and soybean plots. For good weed management in organic crops, the first rotary hoeing should occur within 2–3 days after planting.

Corn borers were low in all fields, showing the high degree of tolerance or resistance in conventionally-bred (non-GMO) corn varieties. No corn borer damage was detected in any plants sampled in all corn plots (Table 4). Although there was no statistical difference between soil nitrate levels, conventional corn plots averaged 3.1 ppm NO_3-N, while organic soils averaged 2.6 ppm NO_3-N (Table 5), far below the recommended level of 25 ppm in all plots.

Several plots were re-planted on June 29 due to poor stands in wet fields, so silage samples were collected September 16 to decide if corn should be chopped or left for grain harvest in these plots. Chopped corn biomass averaged

12,098 lb/acre, which is a very good silage yield (Table 6). Nutrient analysis of the chopped corn averaged 42 percent carbon and 2.3 percent N (Table 7). Corn stalk nitrate levels averaged 1,004 ppm nitrate-N in conventional corn, and 2,398 ppm nitrate-N in the organic corn, with no statistical differences between systems (Table 8).

Soybean cyst nematode populations were low and similar between organic and conventional plots where the organic plots averaged 119 eggs/100 cc of soil, compared with 100 eggs/100 cc in the conventional plots (Table 9).

Oat yields were impacted by wet weather. There was no difference in oat yield between the three- and four-year rotations, averaging 75 bushels/acre (Table 10). We expected alfalfa growth to be impacted by the wet spring, but yields averaged 4.7 tons/acre, which was significantly higher than the 1.8 tons/acre yield of 2013, and similar to the 4.6 tons/acre yields in 2014 and 2015. Oat and alfalfa baleage in the O/A plots averaged 1.47 tons/acre.

Organic corn yields in the fields planted June 9 averaged 109 bushels/acre compared with conventional yields of 126 bushels/acre (Table 11), with no statistical differences between systems. The combination of late planting and excessive rains, which rapidly mineralized N from both synthetic fertilizer and compost, impacted yields in all plots, as demonstrated by the lack of soil N in July (Table 5). The numerically highest organic yield was in the C-S-O/A rotation, at 115 bushels/acre. Yields in the June 29 re-planted corn plots averaged 74 bushels/acre, which, based on November 25, 2015 prices, would have been worth $740/acre, compared with $271/acre for conventional corn. Despite insufficient mechanical weed management in organic soybean plots due to weather impacting field operations, the subsequent high weed populations in the organic soybeans were managed through manual removal ("walking") and yields were remarkably high, averaging 54 bushels/acre in both organic and conventional systems that received multiple herbicides (Table 12).

Corn grain quality remained acceptable for organic feed markets despite the extreme weather. Protein levels were higher in conventional corn, at 8.3 percent, compared with 7.7 percent in organic corn (Table 13). Corn density was equivalent between systems, at 1.25 percent. Moisture was high, averaging 20 percent in organic corn at harvest and also in the conventional corn (18.5%). Corn starch was equivalent in both systems, averaging 72 percent. Corn oil content was similar, at 4.2 percent, in both systems.

Soybean moisture levels were not different between systems, averaging 9.7 percent in organic soybeans and 9.5 percent in conventional soybeans (Table 14). Protein levels were equivalent between systems overall at 37 percent, but the C-S-O/A rotation had greater protein content than the conventional soybeans. Soybean carbohydrate levels averaged 22 percent, with only small differences between systems (e.g., conventional soybeans averaged 22% compared with 21.5% in C-S-O/A soybeans). Oil levels (18%) also were similar across all rotations.

LTAR 2015 soil data summary. USDA-ARS (C. Cambardella) sampled LTAR plot by collecting five randomly-located soil cores (0-15 cm) from each plot in the fall after harvest but before any field operations (cover crop planting) in 2015. The cores were mixed together to produce one composite sample from each plot. Soil quality was higher in the organic rotations relative to the conventionally managed corn-soybean rotation in the fall of

2015. The organic soils had more microbial biomass C and N, higher P, K, Mg, and Ca concentrations, and lower soil acidity than conventional soils (Table 15). The long-term 4-yr organic rotation had more microbial biomass C and stable macroaggregates than the 3-yr organic rotation, although the effect was not statistically significant for macroaggregates. The results suggest the extra year of alfalfa increased the resilience of the 4-yr organic rotation through increased microbial biomass and more stabile soil structure.

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Table 1. Nutrient analysis of oat and alfalfa in LTAR experiment, Neely-Kinyon Farm, 5/18/2015.

Crop-treatment	Total carbon (%)	Total nitrogen (%)
Oat-Org C-SB-O/A[x]	41.74b[y]	4.85a
Oat-Org C-SB-O/A-A	41.79b	5.04a
Oat-Org C-SB-C-O/A	43.08a	4.49b
Alfalfa-Org C-SB-O/A-A	43.04a	3.78c
$LSD_{0.05}$	0.3167	0.2046
P value ($\alpha = 0.05$)	0.0005*	<.0001

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 2. Corn plant and weed populations in the LTAR experiment, Neely-Kinyon Farm, 6/29/15.

Treatment	Plant population (plants/acre)	Grass weed (plants/m^2)	Broadleaf weed (plants/m^2)
Conventional C-SB[x]	32,780	0.00c	2.44b
Org C-SB-O/A	32,330	-	-
Org C-SB-O/A-A	35,330	51.0a	18.67a
Org C-SB-C-O/A	34,670	7.67b	9.56ab
$LSD_{0.05}$	NS[y]	33.630	5.448
P value ($\alpha = 0.05$)	0.2134	<.0001	0.0145

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at $P \leq 0.05$ or not significant (NS) (Fisher's Protected LSD Test).

Table 3. Soybean plant and weed populations in the LTAR experiment, Neely-Kinyon Farm, 6/29/15.

Treatment	Plant population (plants/acre)	Grass weeds (plants/m^2)	Broadleaf weeds (plants/m^2)
Conventional C-SB[x]	147,250a [y]	0.50a	5.17
Org C-SB-O/A	141,080ab	26.33b	18.67
Org C-SB-O/A-A	132,580b	36.00b	20.67
$LSD_{0.05}$	3,849	21.038	NS
P value (α = 0.05)	0.0318	<.0001	0.0507

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 or not significant (NS) (Fisher's Protected LSD Test).

Table 4. Corn borer populations in LTAR experiment, Neely-Kinyon Farm, 7/30/2015.

Treatment	Corn borers
Conventional C-SB[x]	0
Org C-SB-O/A[x]	0
Org C-SB-O/A-A	0
Org C-SB-C-O/A	0
$LSD_{0.05}$	-

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.

Table 5. Soil nitrate analysis in the LTAR experiment, Neely-Kinyon Farm, 7/31/15.

Treatment	NO_3^--N (mg/kg)
Conventional C/S[x]	3.10
Org C-SB-C-O/A	2.68
Org C-SB-O/A	2.23
Org C-SB-O/A-A	3.03
$LSD_{0.05}$	NS[y]
Interaction P value (α = 0.05)	0.6538

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 or not significant (NS) (Fisher's Protected LSD Test).

Table 6. Chopped corn biomass weight in the LTAR experiment, Neely-Kinyon Farm, 9/16/15.

Treatment	Dry weight (g/0.5 m^2)	
	Leaves	Ears
Org C-SB-O/A[x]	221.60	392.26
Org C-SB-O/A-A	243.05	499.33
$LSD_{0.05}$	NS[y]	NS
P value (α = 0.05)	0.2392	0.1646

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).

Table 7. Corn leaf nutrient analysis in the LTAR experiment, Neely-Kinyon Farm, 9/16/15.

Treatment	Total carbon (%)	Total nitrogen (%)
Org C-SB-O/A[x]	42.38	2.23b
Org C-SB-O/A-A	42.00	2.42a
$LSD_{0.05}$	NS[y]	0.0827
P value (α = 0.05)	0.1662	0.0022

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).

Table 8. Corn stalk nitrate analysis in the LTAR experiment, Neely-Kinyon Farm, 10/9/15.

Treatment	NO_3^-N (mg/kg)
Conventional C-SB[x]	1,004
Org C-SB-O/A	2,900
Org C-SB-O/A-A	1,691
C-SB-C-O/A	2,603
$LSD_{0.05}$	NS [y]
P value (α = 0.05)	0.6501

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).

Table 9. Soybean cyst nematode in the LTAR experiment, Neely-Kinyon Farm, 10/12/15.

Treatment	Nematode population (eggs/100 cc)
Conventional C/SB	100.00
Org C-SB-O/A	150.00
Org C-SB-O/A-A	87.50
$LSD_{0.05}$	NS
P value (α = 0.05)	0.4257

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).

Table 10. Oat harvest in the LTAR experiment, Neely-Kinyon Farm, 7/31/2015.

Treatment	Bu/acre
Org C-SB-O/A[x]	71.70
Org C-SB-O/A-A	76.37
Org C-SB-C-O/A	76.03
$LSD_{0.05}$	NS [y]
P value (α = 0.05)	0.8722

[x]Org = organic, C = corn, SB = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 or not significant (NS) (Fisher's Protected LSD Test).

Table 11. Corn harvest from June 9 planting in the LTAR experiment, Neely-Kinyon Farm, 10/26/15.

Treatment	Bu/acre
Conventional C-SB[x]	125.78
Org. C-SB-O/A	115.15
Org. C-SB-O/A-A	102.41
Org. C-SB-C-O/A	110.73
$LSD_{0.05}$	NS[y]
P value (α=0.05)	0.2102

[x]C = corn, S = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).

Table 12. Soybean harvest in the LTAR experiment, Neely-Kinyon Farm, 2015.

Treatment	Bu/ac
Conventional C-SB[x]	54.90
Org C-SB-O/A	53.38
Org C-SB-O/A-A	56.11
$LSD_{0.05}$	NS
Interaction P value[y] (α=0.05)	0.7008

[x]C = corn, S = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).

Table 13. Corn grain quality analysis in the LTAR experiment, Neely-Kinyon Farm, 11/5/15.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Starch (%)	Density (g/cc)	Ethanol yield (gal/bu)
Conventional C/S[x]	18.50	8.33a	4.08	71.80	1.24	2.80
Org C-S-O/A	20.10	7.60b	4.25	72.23	1.25	2.84
Org C-S-O/A-A	22.00	7.83b	4.30	71.60	1.25	2.83
Org C-S-C-O/A	17.18	7.75b	4.10	72.35	1.24	2.83
$LSD_{0.05}$	NS[y]	0.04973	NS	NS	NS	0.01493
P value (α = 0.05)	0.2780	0.0226	0.1116	0.1026	0.2785	0.0187

[x]C = corn, S = soybeans, O = oats, A = alfalfa
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).

Table 14. Soybean grain quality in the LTAR experiment, Neely-Kinyon Farm, 11/5/15.

Treatment	Moisture (%)	Protein (%)	Oil (%)	Fiber (%)	Carbohydrates (%)
Conventional C-S	9.50	36.05b	16.73	4.63	22.10a
Organic C-SB-O/A	9.68	36.83a	19.15	4.53	21.55b
Organic C-SB-O/A-A	9.75	36.58ab	19.13	4.58	21.73ab
$LSD_{0.05}$	NS	0.18486	NS	NS	0.16643
P value (α = 0.05)	0.1742	0.0421	0.4227	0.0572	0.0276

[x]C = corn, S = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).

Table 15. Neely-Kinyon LTAR soil quality analysis, Fall 2015 (depth 0-15 cm).

Tmnt	MBC $mgkg^{-1}$	MBN $mgkg^{-1}$	NO_3-N $mgkg^{-1}$	P $mgkg^{-1}$	K $mgkg^{-1}$	Mg $mgkg^{-1}$	Ca $mgkg^{-1}$	EcμS cm^{-1}	pH	Aggs %	BD gcm^{-3}
Conv C-S[x]	282b[y]	12.8b	6.29	23.3b	221b	353c	3333b	173b	6.22a	26.3	1.20
Organic C-S-O/A	280b	14.7ab	5.88	99.7a	285a	415b	4079a	227a	7.21c	26.3	1.17
Organic C-S-O/A-A	316a	17.7a	5.60	63.7ab	245ab	421b	4006a	216a	7.02b	32.0	1.19
Organic C-S-C-O/A	320a	14.5ab	4.18	48.0ab	208b	490a	4051a	225a	6.97b	34.1	1.18
$LSD_{0.05}$	28	4.3	NS	20.1	44	51	139	26	0.11	NS	NS

[x]C = corn, S = soybeans, O = oats, A = alfalfa.
[y]Means followed by the same letter down the column are not significantly different at P ≤ 0.05 (Fisher's Protected LSD Test).