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The Long-Term Agro-ecological Research (LTAR) experiment: Ecological benefits of organic crop rotations in terms of crop yields, soil quality, economic performance and potential global climate change mitigation

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Abstract
Work continues in Year 16 of a long-term experiment comparing organic and conventional crop rotations. Adverse weather conditions in 2013 affected the production and performance of several crops in the rotations being studied. As a consequence of extended wet weather in spring, poor stands, delayed weed management and subsequent high weed populations, organic soybean yields were 26 percent lower than 2012. Organic corn yields were, however, greater than conventional corn, even when re-planting occurred on June 8.

Keywords
Agronomy, Horticulture, Organic production practices and comparisons

Disciplines
Agronomy and Crop Sciences | Horticulture

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Budget:
$50,000 for year one
$50,000 for year two
$50,000 for year three

Q How can we gauge the viability of organic cropping systems in relation to the agronomic, economic and soil quality effects in conventional cropping systems?

A The project measured various parameters and determined that, even with reduced yields, organic crops were more lucrative because of lower costs of production coupled with higher premium prices compared to conventional crops. Soil quality effects were evaluated every fall after harvest by quantifying a suite of biological, chemical and physical soil properties. Researchers measured soil organic C, total soil N, microbial biomass C, N mineralization, macroaggregation, extractable NO_3-N, NH_4-N, P, K, Mg, and Ca, electrical conductivity, and bulk density.

Background

The Neely-Kinyon Long-Term Agroecological Research (LTAR) experiment site was established in 1998 to study the extended effects of organic production in Iowa. The plots are located at an Iowa State University Research Farm near Greenfield. Treatments at the LTAR site, replicated four times in a completely randomized design, include these 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 Corn-Soybean-Corn-Oats/Alfalfa (C-SB-C-O/A).

Approach and methods

On April 29, 2013, ‘Badger’ oats were underseeded with ‘BR Raven’ alfalfa at a rate of 90 lbs/acre and 15 lbs/acre, respectively. Following harvest of the organic corn plots in 2012 winter rye was no-till drilled at a rate of 75 lbs/acre on October 29.

Conventional corn plots were injected with 32 percent UAN on May 14, 2013, at 140 lbs N/acre, disked on May 16, and field cultivated on May 24. Chicken manure (from S.W. Iowa Egg Cooperative, Massena, Iowa) was applied to organic corn plots at a rate of 4.6 tons/acre on April 2 in the organic C-S-O/A and C-S-O/A-A plots and at a reduced rate of 1.9 tons/acre in the C-S-C-O/A plots on April 29.

The alfalfa and compost applied in the organic corn plots were plowed under on May 12, 2013. Organic corn plots had to be replanted on June 8 with BR 40R73. Organic corn plots were rotary-hoed twice and row-cultivated three times.

Rye was disked in organic soybean plots three times before soybean planting on May 24. All organic soybean plots were rotary hoed on June 2 before emergence and on June 12, and row-cultivated three times. Each organic soybean plot was “walked” twice for large weeds. Weeds were a problem in conventional plots in 2013, even after repeated herbicide applications, but these were not “walked” in keeping with the

Kathleen Delate at LTAR field day.

protocol of herbicide applications only in conventional plots. Corn and soybean stands were counted on July 5, and weeds were counted within square meter quadrants at three randomly selected areas within a plot. Soybean plots were sampled for insects on July 19. Late-spring soil nitrate tests were conducted on July 5 by sampling at a 6-inch depth in three randomly selected areas within each plot in the corn row. Corn borer sampling was conducted on July 23 by sampling the whorl of three randomly selected corn plants per plot and counting incidence and numbers of corn borers. Corn stalk nitrate samples were collected on September 19, and soybean cyst nematode sampling was completed on October 11.

Alfalfa was baled three times. Oat grain was harvested on July 23, and straw was baled on July 26. Soybean plots were harvested on October 13 while corn plots were not harvested until November 2. Grain samples were collected from each corn and soybean plot for grain quality analysis.

Results and discussion

Oat and alfalfa stands were affected by excessive rains in May, when oat biomass averaged 578 lb/acre on May 29, and alfalfa averaged 3,374 lb/acre. Plant populations in the organic grain crop plots also suffered from wet fields. Seed corn maggots infested the manure-applied corn fields because there were only twelve days between plowing and planting. This led to the decision to replant in June. On July 5, corn stands were similar between re-planted organic C-SB-O/A and conventional plots at 27,455 plants/acre, compared to higher populations in the other two organic rotations at 30,625 plants/acre. Organic soybean populations were some of the lowest ever recorded at the LTAR, averaging only 52,920 plants/acre, less than half of planted seed, compared to 121,080 plants/acre in the conventional plots. Weed populations were highest in the organic C-S-O/A corn plots; similar in the C-S-O/A-A and C-S-C-O/A plots; and lowest in the conventional corn plots.

In the soybean plots, the organic C-S-C-O/A rotation had the highest amount of weeds, with no difference in weeds between the organic C-S-O/A and C-S-O/A-A plots and the conventional plots. Weeds in general were greater in organic plots, averaging 11 weeds/sq. meter, compared to <1/sq. meter in conventional corn plots, and 15 weeds/sq. meter in organic soybean plots compared to 2 weeds/sq. meter in conventional soybean plots. This difference could be attributed to wet fields in spring, which created poor conditions leading to delays of seven and nine days between planting and the first rotary-hoeing in corn and soybeans, respectively. For good weed management in organic crops, the first rotary-hoeing should occur within two to three days after planting.

Although there was no statistical difference between late-spring soil nitrate levels, conventional corn plots averaged 33 ppm NO3-N, while organic soils averaged 15 ppm NO3-N. Corn borers again were low in all fields, showing the high degree of tolerance/resistance in conventionally-bred (non-GMO) corn varieties. Incidence of corn borer damage and presence averaged less than 1 percent of plants sampled. Corn stalk nitrate levels were high at harvest, reflecting a crop with green leaves. The highest levels were in the organic C-S-O/A-A corn.

LTAR plots

Oat yields averaged 97 bu/acre and oat straw averaged 3 tons/acre. There was no difference in oat yield between the three- and four-year rotations.

Organic corn yields averaged 143 bu/acre compared to conventional yields of 135 bu/acre. Statistical differences were observed with the highest corn yield in the organic four-year rotation (C-S-O/A-A) at 159 bu/care, compared to the lower yields in the three-year rotation (C-S-O/A) at 143 bu/acre, the conventional rotation (135 bu/acre), and the rotation with two years of corn within three years (C-S-C-O/A) at 127 bu/acre. The poor stands, delayed weed management and subsequent high weed populations, along with drought in July and August, affected organic soybean yields, which averaged 31 bu/acre compared to 40 bu/acre in the conventional plots which received four different herbicides. The C-S-C-O/A soybean yield was significantly lower at 28 bu/acre, while the other organic three- and four-year rotations soybean yields averaged 33 bu/acre. The organic soybean yields were 26 percent lower than the 2012 average organic soybean yields after a more severe drought, highlighting the importance of weed management over dry weather for organic soybean yields.

Alfalfa growth was impacted by the wet spring followed by drought, yielding an average of 1.8 tons/acre, down from 4.3 tons/acre in 2011, but more than the 2012 drought, when alfalfa plots only yielded 0.77 tons/acre.

Corn grain quality remained high despite the drought. Protein levels were equivalent between conventional and organic C-S-O/A-A corn (averaging 8.8 percent), with the organic rotation containing two years of corn among the lowest, at 7.7 percent protein Corn density was greater (1.26 percent) in the organic rotations compared to 1.24 percent in the conventional. Moisture was high, 18.6 percent at harvest, with no difference between systems. Corn starch was greater in the organic rotations (73 percent) compared to 71 percent in the conventional corn. Corn oil content was greater, at 4.3 percent, in conventional corn compared to an average of 4.2 percent across all organic rotations.

Soybean moisture levels were not different among systems, averaging 11 percent. Protein levels also were equivalent among all rotations at 35 percent. Soybean carbohydrate levels averaged 23 percent, with no differences between systems. Oil levels (19 percent) also were similar across all rotations.

Soil quality remained high in the organic systems in 2011 and in 2012 even with multiple tillage operations for cover crop incorporation and for weed management. In the fall of 2011-2013 organic soils had more soil organic carbon, total N, microbial biomass C, labile organic N, higher P, K, Mg and Ca concentrations, and lower soil acidity than conventional soils. At the end of the 2012 growing season, particulate organic matter C also was higher in the organic soils than the conventional, likely because of altered rates of decomposition of new residue C inputs during this especially dry year. The four-year organic rotation had higher microbial biomass C and more stable macroaggregates than the three-year organic rotation in the fall of 2013, suggesting the extra year of alfalfa increased the resilience of the four-year organic rotation to extreme drought encountered in the summer of 2013.

Soil quality enhancement was evident particularly for labile soil C and N pools, which are critical for maintenance of N fertility in organic systems, and for basic cation concentrations, which control nutrient availability through the relationship with cation exchange capacity. Despite the serious drought conditions during the growing season in 2012 and 2013, organic management enhanced agroecosystem resilience and maintained a critical soil function, the capacity to supply nutrients to the crops.

Impact of results

Impacts of this research include an expanded suite of best management practices for organic and transitioning farmers, including the need to apply manure at least three weeks before planting to avoid seed corn maggot problems and the importance of timely weed management for achieving the highest organic yields. These recommendations were discussed, along with new government support for incorporating cover crops to improve soil quality, at the Neely-Kinyon Field Day on August 20, 2013, with 62 producers and ag agency staff present.

Education and outreach

Delate, K., C. Cambardella, C. Chase, A. Johanns, and R. Turnbull. 2013. The Long-Term Agroecological Research (LTAR) experiment supports organic yields, soil quality, and economic performance in Iowa. *Crop Management* doi: 10.1094/CM-2013-0429-02-RS.

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Leveraged funds

Results from the LTAR experiment have been used as background and supporting evidence for other organic research that examines the effects of organic practices (compost, cover crops, crop rotations, no-tillage) on yields, soil quality and water quality in farming systems. These include the following USDA grants that have been awarded to the LTAR research team of Delate, Cambardella and Chase:

1. USDA-NIFA-Organic Transitions Program: "Effect of Cover Crops, Soil Amendments and Reduced Tillage on Carbon Sequestration and Soil Health in a Long-Term Organic Vegetable System from Transition to Certified Organic Status" (with University of Florida) 2010-2013: $691,969
2. CERES Foundation: "Improving Organic No-Till Systems for Enhanced Soil Quality and Weed Management in Organic Vegetable and Grain/Forage Systems" 2013-2015: $176,000
3. USDA, Cooperative State Research, Education and Extension Service (CSREES), Organic Research and Extension Initiative & Water Quality Programs, "Enhancing Farmland Water Quality and Availability through Soil-Building Crop Rotations and Organic Practices" 2009-2013: $599,142.
4. USDA-NRI-Integrated Organic Program: "Developing Carbon-Positive Organic Systems through Reduced Tillage and Cover Crop-Intensive Crop Rotation Schemes" 2008-2013: $855,629
5. State Soil Conservation Committee, IDALS: "Improving Soil Conservation through Reduced Tillage and Cover-Crop-Based Rotations in Organic Production" 2012-2015: $69,984

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