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Agronomic, ecological and economic comparisons of conventional and low-external-input cropping systems

Matthew Z. Liebman
Iowa State University, mliebman@iastate.edu

Craig Chase
Iowa State University, cchase@iastate.edu

Michelle Wander
University of Illinois

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Abstract
Low-external-input cropping systems were compared to conventional practices over several years with contrasting weather conditions. The results offer several potential options for farmers in times of rising fossil fuel costs. Diversified low-external input systems consistently outperform conventional systems on a number of important measures.

Keywords
Corn-soybean cropping systems, Multi-year rotations low-external input

Disciplines
Agronomy and Crop Sciences

LEOPOLD CENTER
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Principal Investigator:

Matt Liebman
Wallace Chair for Sustainable Agriculture

Co-investigators:
Craig Chase
ISU Extension
Iowa State University

Michelle Wander
University of Illinois

Budget:
$40,162 for year one
$38,500 for year two
$39,600 for year three

ECOLOGY

Q How can Iowa farmers produce sufficient amounts of food and farm income while protecting environmental quality?

A This project compared the agronomic, ecological and economic performance characteristics of three cropping systems: a conventionally managed corn-soybean rotation and two more diverse rotations (corn-soybean-oat/red clover and corn-soybean-oat/alfalfa-alfalfa) receiving much smaller quantities of nitrogen fertilizer and herbicides. Measurements included crop yields, weed dry matter production, weed seed densities in soil, economic costs and returns, fossil energy use, and soil organic matter concentrations. The experiment has been in place since 2001; this project covered the years 2007-2010.

Background

Synthetic fertilizers and pesticides are major expenses in Iowa farming systems and often are linked to environmental damage. If farmers can learn how to reduce reliance on these materials without compromising farm productivity and profitability, agricultural sustainability could be enhanced in Iowa and the U.S. Corn Belt. Fossil energy costs associated with farming have increased over the last decade and reducing reliance on non-renewable energy sources also is critical to improving agricultural sustainability.

Results of previous research at Iowa State University's Marsden Farm, in Boone County, indicated that small grains and perennial forage legumes added to conventional row-crop systems help to maintain crop yields, minimize requirements for synthetic fertilizers and herbicides, reduce production costs, and maintain or increase net returns. The Marsden Farm experiment was used to generate and extend additional information about the agronomic, ecological and economic characteristics of conventional and low-external-input (LEI) cropping systems. Specific objectives were to:

(1) Measure crop yields, weed growth and weed seed densities in a conventional and two LEI crop rotation systems.
(2) Determine the survival and fungal infection characteristics of weed seeds in the conventional and LEI systems.
(3) Determine the impacts of the conventional and LEI systems on soil organic matter and fertility.
(4) Assess labor requirements, input costs, and net returns for the conventional and LEI systems.
(5) Determine fossil energy use and energetic efficiencies for the conventional and LEI systems.

(6) Distribute key findings and insights to farmers, agricultural industry professionals, extension personnel, scientists and policy makers, giving particular emphasis to information related to weed management, soil management and profitability.

Approach and methods

The research team conducted a 9-hectare (22 acre) field experiment in Boone County to test the hypothesis that yield, weed suppression, and profit characteristics of low-external-input (LEI) cropping systems can match or exceed those of conventional systems. Over a four-year period (2007-2010), they compared a conventionally managed 2-year rotation system (corn/soybean) with two more diverse LEI systems: a 3-year corn/soybean/oat + red clover rotation, and a 4-year corn/soybean/oat + alfalfa/alfalfa rotation.

Results and discussion

Synthetic N fertilizer use was 89 and 93 percent lower in the 3-year and 4-year systems, respectively, than in the 2-year system. Herbicide use was reduced 96 and 97 percent in the 3-year and 4-year systems. Despite these input reductions, corn and soybean yields were higher in the LEI systems than in the conventional system, and weed biomass in corn and soybean was low in all systems. Measurements of weed seed densities indicated that soil seed banks were neither increasing nor decreasing in any of the rotation systems. Observed decay rates for giant foxtail and velvetleaf seeds buried in the soil were very low or nil and were not affected by rotation system, though fungi in the genera Alternaria, Fusarium, Pythium, Cladosporium, and Trichoderma were found on seeds of both weed species.

Soil particulate organic matter carbon (POM-C) concentrations were significantly greater in the LEI 3-year and 4-year rotation systems than in the conventional 2-year system, suggesting that soil organic carbon is increasing in the more diverse LEI systems. Potentially mineralizable nitrogen (PMN) levels in the soil also were higher in the 3-year and 4-year rotations than in the 2-year rotation, indicating that the more diverse LEI rotations had greater capacity to supply crops with N.

Net returns to land and management for 2007-2010 were highest for the 3-year rotation ($966 ha-1 yr-1), lowest for the 4-year rotation ($884 ha-1 yr-1) and intermediate for the 2-year rotation ($911 ha-1 yr-1). Labor requirements increased as rotation length increased, but labor costs were only a small fraction of total production costs. The conventional 2-year system used the largest amount of fossil fuel energy, the 4-year system used the least and the 3-year system was in between. Energy gain in crop products per unit of fossil fuel energy invested and net economic returns per unit of fossil energy input was greatest in the 4-year system, least in the 2-year system and intermediate in the 3-year system.

Conclusions

Results of this study indicate that diversified crop rotation systems can produce high yields of corn and soybean, suppress weeds effectively, and improve soil quality, while substantially reducing requirements for synthetic N fertilizer, herbicides, and

fossil energy inputs. Despite historically high market incentives for corn and soybean throughout the period of study (2007-2010), the LEI 3-year rotation system was 6 percent more profitable than the conventionally managed 2-year system. The LEI 4-year system was slightly (3 percent) less profitable than the conventional 2-year system.

Impact of results

This project was successful in documenting and extending information about the impacts of conventional and diversified LEI crop rotation systems on crop yields, weed dynamics, soil quality, energy use efficiency and profitability. Today's high prices for corn and soybeans and minimal incentives and regulations to promote environmental protection discourage widespread adoption of diversified LEI systems in Iowa and much of the central Corn Belt. However, if fossil energy costs increase substantially relative to crop prices, the diversified LEI systems tested in this project could serve as models for the types of cropping systems that will have to be considered if Iowa agriculture is to remain productive and profitable. Should environmental regulations force farmers to reduce their reliance on synthetic fertilizers and pesticides, results of this project indicate that diversified crop rotation systems offer agronomically and economically viable options.

Education and outreach

Seventeen public presentations were made about the project in the United States and overseas. Media coverage of the program was offered in Progressive Farmer, Corn and Soybean Digest, Crops, Soils, and Agronomy News; National Geographic News; Voice of America; AgWeb.com; Nature Biotechnology; The Furrow; Mother Jones; and the American Society of Agronomy. An ISU Extension publication (PMR-1001) by Liebman, Chase and Kelvin Leibold presented an "Economic analysis of three Iowa rotations."

A number of peer-reviewed research papers and book chapters were inspired by this project:

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- Westerman, P.R., J.K. Borza, J. Andjelkovic, M. Liebman, and B. Danielson. 2008. Density-dependent predation of weed seeds in Iowa maize fields. *Journal of Applied Ecology* 45: 1612-1620.

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• Williams, C.L., M. Liebman, P.R. Westerman, J. Borza, D. Sundberg, and B. Danielson. 2009. Over-winter predation of Abutilon theophrasti and Setaria faberi seeds in arable land. *Weed Research* 49: 439–447.

Leveraged funds

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For more information, contact:
Matt Liebman
1401 Agronomy
Iowa State University
Ames, Iowa 50011
(515) 294-7486
e-mail:
mliebman@iastate.edu