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FOR SUSTAINABLE AGRICULTURE

Impacts of conventional and diversified rotation systems on crop yields, profitability, soil functions, and environmental quality

Abstract: New questions and technologies are considered in a long-running ISU crop rotations study. The results continue to show remarkable adaptability exhibited by rotations that are more diverse and spread out over longer periods of time.

Principal Investigator:

Matt Liebman
Agronomy
Iowa State University

Co-investigators:
Craig Chase
ISU Extension
Ames

Michelle Wander
University of Illinois
Urbana, Illinois

Tom Sauer
Mark Tomer
USDA-ARS National Laboratory for Agriculture and the Environment
Ames

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Q How do cropping system diversity and contrasting technology packages of crop genetics and herbicide inputs affect agrichemical use, crop performance, weeds, soil quality and function, and profitability?

ECOLOGY

A Comparisons were made among contrasting cropping systems within a long-term, large-scale field experiment in Boone County, Iowa. Combining crop diversity with lower herbicide inputs and non-transgenic crops was effective in reducing requirements for nitrogen fertilizer; maintaining or improving weed suppression, grain yields, and profits; and increasing several soil quality indicators.

Background

Past research has shown that multi-year crop rotation systems, which include perennial legume species and organic matter amendments (such as manure) applied to soil, can enhance crop yields and soil quality, while reducing costs and negative environmental impacts. However, most Iowa farms do not use extended rotations and organic matter amendments. This project sought to better understand and demonstrate potential agronomic, economic and environmental benefits of lengthening conventional corn-soybean rotation sequences with oat and perennial forage legumes, in combination with applying manure.

Since 2002, a research team led by ISU agronomist Matt Liebman has conducted a 9-hectare (22-acre) field experiment at Iowa State University's Marsden Farm in Boone County, Iowa. The study is assessing agrichemical input use, yields, weed dynamics, economic characteristics and soil functions of diversified and simpler crop rotation systems. Funding to establish and maintain the plots has come from the Leopold Center and the USDA's National Research Initiative and Agriculture and Food Research Initiative.

Objectives for this project were to:

1. Measure crop yields, weed growth, and weed seed densities in conventional and more diverse cropping systems, including sub-plots in each rotation system containing transgenic and non-transgenic corn and soybean genotypes treated with contrasting herbicide regimes
2. Assess labor requirements, input costs, and net returns for conventional and more diverse cropping systems and for different technology packages of crop genetics and herbicides
3. Determine the impacts of conventional and more diverse cropping systems on soil functions and concomitant impacts on soil carbon storage, nitrogen transformation, nitrate leaching and carbon dioxide and nitrous oxide emissions

A4 harvest, 2012. (Photo by David N. Sundberg.)

4. Distribute results and insights from this project to farmers, agricultural industry professionals, extension personnel, scientists, policy makers and members of the general public through scientific and extension publications, field days, winter meetings, news articles and websites.

Approach and methods

Starting in 2008, two contrasting technology packages were inserted into each of three Marsden Farm rotation systems to create a 3x2 factorial set of treatments. The rotations selected were a 2-year corn-soybean system, a 3-year corn-soybean-oat + red clover system, and a 4-year corn-soybean-oat + alfalfa-alfalfa system. The technology packages embedded within the rotation systems featured different crop genetics and herbicide use regimes. One technology package used transgenic corn and soybean genotypes and high herbicide inputs, while the second technology package did not use transgenic crops and sought to minimize herbicide use by relying on band applications of herbicides, inter-row cultivation and mowing.

Results and discussion

Between 2008 and 2012, synthetic N fertilizer use was 91 percent lower in the 3-year rotation and 94 percent lower in the 4-year (94 percent) rotation compared with the 2-year rotation. Reductions in N fertilizer use were made possible through N fixation by legumes and N recycling in manure applications. Increases in rotation system diversity and use of the non-transgenic technology package led to marked reductions in herbicide use. For example, the 4-year rotation system managed with the non-transgenic approach received 96 percent less herbicide during 2008-2012 than did the 2-year rotation system managed with the transgenic approach.

Despite reductions in agrichemical use, corn and soybean yields were 4 to 20 percent higher in the more diverse 3-year and 4-year systems than in the conventional 2-year system. Corn yields were unaffected by the technology package used, but soybean yields were higher with the transgenic package, especially in the 2-year rotation.

Weed biomass in corn and soybean was low in all rotation systems and with both technology packages. Measurements of weed seed densities indicated that soil seed banks were neither increasing nor decreasing in any of the rotation systems and were unaffected by technology package.

Net returns to land and management for 2008-2012 were highest for the 3-year rotation managed with the non-transgenic approach ($1101 ha-1 yr-1; $446 acre-1 yr-1), lowest for the 2-year rotation managed with the non-transgenic approach ($1031 ha-1 yr-1; $417 acre-1 yr-1), and intermediate for the other rotation system x technology package combinations. Labor requirements increased with increases in rotation length, but labor costs were only a small fraction of total production costs.

Patterns of CO_2 flux among treatments suggested that there was greater decomposable substrate in the soil in the longer rotations leading to higher carbon fluxes. Nitrous oxide fluxes were generally quite low in all rotations. Mean NO_3-N concentrations

Oat harvest, 2012. (Photo courtesy David N. Sundberg.)

in water beneath the plots were highest in the 2-year and 3-year rotations, and significantly lower in the 4-year rotation. The proportion of samples with detectable levels of PO4-P was lower under alfalfa in the 4-year rotation and corn crops than all crop phase x rotation system combinations.

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

Conclusions

Results of this study indicate that diversified crop rotation systems produced high yields of corn and soybean and suppressed weeds effectively, while receiving only a fraction of the synthetic N fertilizer and herbicides used for a conventionally managed corn-soybean rotation. Among the six rotation system and technology package combinations evaluated during 2008-2012, the highest level of profitability ($1101 ha-1 yr-1, $446 acre-1 yr-1) was obtained from the 3-year corn-soybean-oat/red clover rotation that did not employ transgenic crops.

Certain components of soil quality, such as particulate organic matter carbon and bulk density, were better in the more diverse rotation systems. Nitrate concentration of soil water beneath the 4-year corn-soybean-oat/alfalfa-alfalfa rotation was lower than for the 2-year and 3-year rotations. These results indicate that substantial improvements in the environmental sustainability of Iowa agriculture are achievable now, without sacrificing food production levels or farmer livelihoods.

This project successfully documented and shared information concerning the impacts of conventional and diversified crop rotation systems on crop yields, weed dynamics, fertilizer and herbicide use, profitability and soil quality indicators. Current high prices for corn and soybean and a lack of incentives and regulations to promote environmental protection create strong counterincentives to the widespread adoption of diversified, low-external-input cropping systems in Iowa in the near future. However, in the event that environmental regulations force farmers to reduce their reliance on synthetic fertilizers and pesticides, results of this project indicate that diversified crop rotation systems offer biologically and economically viable approaches for doing so.

Impact of results

The research team evaluated the impacts of the project by taking stock of (1) contacts with farmers, agricultural professionals, extension personnel, scientists, policy makers, media professionals through meetings, workshops, discussions, field days, lectures, and interviews; and (2) the impressive collection of extension, popular, and scientific publications that reported results from the project. Based on this evidence of public and professional recognition of the project, the team believes it had a significant impact in increasing public and academic awareness and knowledge of diversified, low-external-input cropping systems.

Education and outreach

The project was featured in 36 presentations to scientific, farm and student audiences; at least 37 stories presented in the popular press, agricultural magazines and radio; one extension booklet; two scientific conference proceedings papers; two published scientific abstracts; and eight peer-reviewed scientific journal papers and book chapters. The 2012 technical article on the project by Davis et al. that appeared in the scientific journal *PLoS ONE* has been viewed or downloaded more than 29,000 times.

Leveraged funds

The University of Illinois at Urbana-Champaign contributed three years of stipend, fringe benefits and tuition support for Patricia Lazicki, an M.S. student in soil science at that institution. The ISU Department of Agronomy and the ISU Graduate College made a commitment in 2012 for three years of funding to cover stipend support, tuition, and fees for Ph.D. student Will Osterholz.

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- Bi-national Agriculture Research and Development Fund. 2012-2015. $341,580.
- Iowa State University Plant Sciences Institute. 2013-2014. $250,000.
- U.S. Department of Agriculture, Agriculture and Food Research Initiative. 2014-2017. $499,873.
- Iowa Soybean Association. 2011-2013. $346,262.
- Iowa Soybean Association. 2013-2016. $104,601.
- U.S. Department of Agriculture, Agriculture and Food Research Initiative, 2014-2016. $499,836.

***For more information, contact**:*
Matt Liebman, 1401 Agronomy Hall, ISU, Ames, IA 50011; (515) 294-7486, e-mail mliebman@iastate.edu