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Agronomic and Economic Performance of Three Crop Rotation Systemsin Central Iowa

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Abstract

A 22-acre field experiment was established in 2001 at the Iowa State University Marsden Farm, in Boone, Iowa to test the hypothesis that diversifying a simple corn-soybean cropping system could allow for substantial reductions in nitrogen fertilizer and herbicide use without compromising crop productivity and profitability. The site lies within a region of intensive rain-fed corn and soybean production and is surrounded by farms with high levels of productivity. Soils at the site are fertile Mollisols: Clarion loam, Nicollet loam, and Webster silty clay loam. Three rotation systems have been evaluated intensively during 2003–2012; a 2-yr corn-soybean system, a 3-yr corn-soybean-small grain + red cloversystem, and a 4-yr corn-soybean-small grain + alfalfa-alfalfa system. The 2-yr rotation is representative of cash grain farming systems in the region, whereas the 3-yr and 4- yr rotations are representative of low-externalinput (LEI) farming systems in the region that include livestock.

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Agronomic and Economic Performance of Three Crop Rotation Systems in Central Iowa

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Introduction

A 22-acre field experiment was established in 2001 at the Iowa State University Marsden Farm, in Boone, Iowa to test the hypothesis that diversifying a simple corn-soybean cropping system could allow for substantial reductions in nitrogen fertilizer and herbicide use without compromising crop productivity and profitability. The site lies within a region of intensive rain-fed corn and soybean production and is surrounded by farms with high levels of productivity. Soils at the site are fertile Mollisols: Clarion loam, Nicollet loam, and Webster silty clay loam. Three rotation systems have been evaluated intensively during 2003–2012; a 2-yr corn-soybean system, a 3-yr corn-soybean-small grain + red clover system, and a 4-yr corn-soybean-small grain + alfalfa-alfalfa system. The 2-yr rotation is representative of cash grain farming systems in the region, whereas the 3-yr and 4-yr rotations are representative of low-external-input (LEI) farming systems in the region that include livestock.

Materials and Methods

The experiment used a randomized complete block design with each crop phase of each rotation system present every year in four replicate blocks. Plots were 0.4 acres and managed with conventional farm machinery. The site was uniformly cropped with oat in 2001 and the three rotation systems were initiated and tuned during 2002. Spring triticale was used as the small grain in 2003–2005, whereas oat was used in 2006–2012. During 2002–2012, solid pack manure was applied during the fall preceding corn production in the 3-yr and 4-yr rotations at a mean dry matter rate of 3.9 tons/acre, providing a mean of 104 lb total N/acre. Corn in the 2-yr rotation received 100 lb N/acre as fertilizer at planting, whereas corn in the 3-yr and 4-yr rotations did not. The late spring nitrate test was used to determine rates for post-emergence side-dress N applications (as urea ammonium nitrate) for corn in all rotation systems. Weed management in the 2-year rotation was based largely on herbicides applied at conventional rates. In the 3-yr and 4-yr systems, herbicides were applied in 15-in. bands over corn and soybean rows rather than broadcast, interrow areas of corn and soybean plots were cultivated, and no herbicides were applied in small grain and forage legume crops. Choices of herbicides used in each system were based on the identities, densities, and sizes of weed species observed in the plots. Sampling procedures and other details of farming practices used in the different cropping systems have been described by Davis et al. (2012, doi:10.1371/journal.pone.0047149).

Energetic and economic analyses were conducted using data obtained from logs describing all field operations, material inputs, and crop moisture characteristics for the experimental plots during the study period and data from sources provided in Davis et al. (2012, doi:10.1371/journal.pone.0047149). We focused the energetic and economic analyses on whole rotation systems and evaluated energy use and net returns to land and management on a unit land area basis, with land units divided in two equal portions for corn and soybean in the 2-yr rotation; three equal portions for corn, soybean, and oat with red clover in the 3-yr rotation; and four equal portions for corn, soybean, oat with alfalfa, and alfalfa in the 4-yr rotation. Net returns to land and management represented returns to a farm operation calculated without accounting for costs of land (e.g., rent or mortgage payments), management time (e.g., marketing), or possible federal subsidies.

Results and Discussion

Results for 2006–2012, after the rotation systems had been in place several years, are reported here; see Davis et al. (2012, doi:10.1371/journal.pone.0047149) for earlier results. Corn and soybean yields from the 3-yr and 4-yr systems were higher than those from the conventional 2-yr system, despite substantial reductions in the use of synthetic N fertilizer and herbicides (Table 1). Fossil energy use decreased with increases in crop diversity due to reductions in the use of fertilizers and pesticides, gas to dry grain, and liquid fuel to power farm machinery (Table 1). Weed suppression was highly effective in each of the three cropping systems, as reflected by the very small amounts of weed biomass found in corn and soybean phases of the rotations (Table 1). Although labor requirements were greater in the longer, more diverse rotation systems, net returns to land and management were statistically equivalent in all three cropping systems (Table 1).

The rotation systems and management practices used in the Marsden Farm experiment are well suited to investigations of crop performance, weed dynamics, and economic and energetic costs and returns, but they should not be construed to represent optimal systems. The experiment has not addressed the need for market development for diverse crops to be viable at a larger scale, nor has the experiment provided direct data concerning the impact of the contrasting cropping systems on nutrient and pesticide emissions. Nonetheless, results from the experiment indicate diversified systems for agronomic crops in the U.S. Corn Belt can be highly productive and economically viable, and that further research into their refinement and environmental impacts is warranted.

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Table 1. Mean inputs, net returns, crop yields, and weed biomass for the three cropping systems in the Marsden Farm rotation experiment, Boone, IA, 2006–2012, with the exception of fossil energy inputs, which are for 2006–2011.[a]

	Cropping system		
	2-yr rotation: Corn-soybean	**3-yr rotation: Corn-soybean-oat/red clover**	**4-yr rotation: Corn-soybean-oat/alfalfa-alfalfa**
Whole rotation:			
Fertilizer N inputs, lb N/acre per yr	71 a	8 b	6 c
Herbicide inputs, lb a.i./acre per yr	1.59 a	0.06 b	0.05 c
Fossil energy inputs, barrels of oil equivalent/acre per yr	0.58 a	0.25 b	0.25 b
Labor requirements, hr/acre per yr	0.70 c	1.13 b	1.47 a
Net returns to land and management[b], $/acre per yr	404	407	399
Crop yields:			
Corn, bu/acre	192.0 b	197.0 ab	198.9 a
Soybean, bu/acre	49.7 b	53.5 a	55.9 a
Oat grain, bu/acre	—	99.8 b	104.3 a
Alfalfa, tons/acre	—	—	4.2
Weed biomass:			
In corn, lb/acre	2.8	8.3	5.8
In soybean, lb/acre	0.7	6.8	2.9

[a]Within rows, means followed by different letters are significantly different ($P < 0.05$); means not followed by letters are statistically equivalent.
[b]Crop subsidy payments were not included as sources of revenue.