Agronomic, environmental, economic, and energetic characteristics of conventional and low-external-input cropping systems in the U.S. Corn Belt

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INTRODUCTION

Conventional cropping systems in the central U.S. have low levels of biological diversity and rely heavily on synthetic fertilizers and herbicides, which commonly contaminate water in this region. Ecological theory suggests that diversified cropping systems integrated with livestock should foster reduced reliance on agrichemicals and fossil fuels, and should lower production costs and pollution. Since 2002, we have conducted a 9-hectare experiment in Boone, Iowa, within the core area of the U.S. Corn Belt, to test this hypothesis. The experiment includes a conventionally managed 2-year rotation system (corn/soybean); a 3-year low-external-input (LEI) system (corn/soybean/small grain + red clover green manure); and a 4-year LEI system (corn/soybean/small grain + alfalfa/alfalfa hay).

WHAT WE'VE LEARNED

Averaged over the period of 2003-2008, synthetic N fertilizer use was 66% and 78% lower in the 3-year and 4-year LEI systems, respectively, than in the 2-year system (Figure 1, top); similarly, herbicide use was reduced 80% and 85% in the 3-year and 4-year LEI systems (Figure 1, bottom). Mean weed biomass in corn and soybean was low (<1 g m^{-2}) in all systems (Figure 2), despite the marked reduction in herbicide use in the 3-year and 4-year LEI systems. Weed biomass was greatest in the small grain crops grown in the 3-year system.

Corn and soybean yields were higher in the LEI systems than the conventional system (Figure 3). Corn, soybean, small grain, and alfalfa hay yields from the experimental plots (each 18 m x 85 m) matched or exceeded yields from commercial farms in the surrounding county.

Concentrations of particulate organic matter carbon in the surface 30 cm of soil were greater in the LEI systems than the conventional system (Table 1).

Nitrate-N concentrations of water leaching through the plots were lower in the 4-year system than in the 2-year and 3-year systems (Table 1). This effect derived from effective nutrient scavenging by alfalfa.

Labor requirements were higher in the LEI systems than the conventional system, but net returns to land and management, including labor costs, were equivalent among the three systems (Table 1).

Fossil energy use was markedly lower in the LEI systems than the conventional system (Table 1).

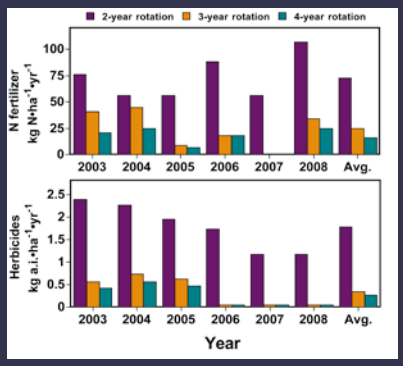


Figure 1. Synthetic N fertilizer (top) and herbicide (bottom) inputs for the three rotation systems, 2003-2008.

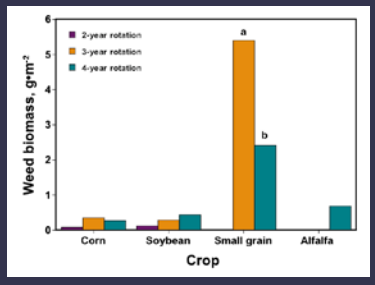


Figure 2. Weed biomass averaged across the period 2003-2008. Data were ln (x+1) transformed before analysis; back-transformed means are presented. Within crops, values followed by different letters are significantly different ($p<0.05$).

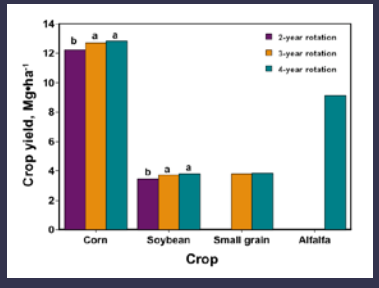
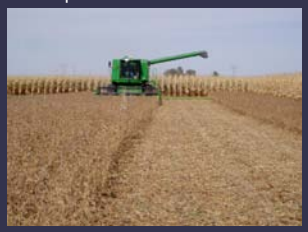


Figure 3. Crop yields averaged across the period 2003-2008. Triticale was used as the small grain in 2003-2005; oat was used in 2006-2008. Within crops, values followed by different letters are significantly different ($p<0.05$).

Performance characteristic	2-year rotation	3-year rotation	4-year rotation
Particulate organic matter-C, 2007 (g C • kg soil^{-1})			
— 0-15 cm soil layer	2.18 b	2.67 a	2.51 a
— 15-30 cm soil layer	0.93 b	1.78 a	1.43 a
Mean nitrate-N conc. in water, 2004-2007 (mg • L^{-1})	12.1 a	13.4 a	8.9 b
Labor requirement, 2003-2008 (hr • ha^{-1} • yr^{-1})	1.78 c	2.76 b	3.40 a
Net returns to land and management, 2003-2008 ($ • ha^{-1} • yr^{-1})	614 a	605 a	624 a
Fossil energy inputs, 2003-2008 (MJ • ha^{-1} • yr^{-1})	16,133 a	9,492 b	7,090 c

Table 1. Soil, water, economic, and energetic characteristics of the three rotation systems. Within rows, values followed by different letters are significantly different ($p<0.05$).

Each of the 36 experiment plots is 18 m x 85 m. Each entry point of each rotation system is present in four replicate blocks.



Corn and soybean yields in the LEI systems have matched or exceeded yields from the conventional system.

Photographs by P.R. Westerman and T. Blackmer

CONCLUSIONS

Data from this experiment indicate that cropping systems can be redesigned for productivity, profitability, improved environmental quality, and energy conservation. Diversification of cropping systems permits large reductions in agricultural chemical use without compromising productivity or weed suppression.

REFERENCES

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