2007

Agronomic and Economic Performance Characteristics of Conventional and Low-External-Input Cropping Systems

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Abstract

A 22-acre field experiment was conducted in Boone, IA, from 2003–2006 to test the hypothesis that low-external-input(LEI) cropping systems can produce yields and profits that match or exceed those obtained from conventional systems. A conventionally managed 2-year rotation system [corn (*Zea mays* L.)/soybean (*Glycine max* (L.) Merr.)] was compared with a 3-year LEI rotation system [corn/soybean/small grain + red clover (*Trifolium pratense* L.)], and a 4-year LEI rotation system [corn/soybean/small grain + alfalfa (*Medicago sativa* L.)/alfalfa]. Triticale (× *Triticosecale* Wittmack) was used as the small grain in 2003–2005; oat (*Avena sativa* L.) was used in 2006. Over the period of 2003– 2006, synthetic N fertilizer use was 59% and 74% lower in the 3- and 4-year systems, respectively, compared with the 2-year system. Similarly, herbicide use was reduced 76% and 82% in the 3- and 4-year systems.

Keywords

Agronomy

Disciplines

Agricultural Science | Agriculture | Agronomy and Crop Sciences

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Introduction

A 22-acre field experiment was conducted in Boone, IA, from 2003–2006 to test the hypothesis that low-external-input (LEI) cropping systems can produce yields and profits that match or exceed those obtained from conventional systems. A conventionally managed 2-year rotation system [corn (*Zea mays* L.)/soybean (*Glycine max* (L.) Merr.)] was compared with a 3-year LEI rotation system [corn/soybean/small grain + red clover (*Trifolium pratense* L.)], and a 4-year LEI rotation system [corn/soybean/small grain + alfalfa (*Medicago sativa* L.)/alfalfa]. Triticale (× *Triticosecale* Wittmack) was used as the small grain in 2003–2005; oat (*Avena sativa* L.) was used in 2006. Over the period of 2003–2006, synthetic N fertilizer use was 59% and 74% lower in the 3- and 4-year systems, respectively, compared with the 2-year system. Similarly, herbicide use was reduced 76% and 82% in the 3- and 4-year systems.

Materials and Methods

Plots were 60 ft × 275 ft. The experiment was laid out as a randomized complete block design with four replications. Each entry point of each rotation system was present each year. Crop yields were determined from the central 12 rows of each plot. Small grain and alfalfa yields were determined from whole plots. Weed biomass was determined in late September or early October of each year from multiple sampling quadrats in each plot. Weed biomass was measured in a total of 200 sq ft in each corn and soybean plot, whereas sample area in small grain stubble and alfalfa hay plots was 22 sq ft. To determine rotation system effects on weed seed banks, a pulse of giant foxtail (*Setaria faberi* Herrm.) and velvetleaf (*Abutilon theophrasti* Medik.) seeds was placed in a 23 ft × 23 ft subplot in each main plot in November 2002 and tracked for the next four years. Giant foxtail was added at a density of 186 seeds/ft^2; velvetleaf was added at 46 seeds/ft^2. Soil from these subplots was sampled to a depth of 8 in. in April 2006, weed seeds were washed from soil, and numbers of viable giant foxtail and velvetleaf seeds were determined by direct germination and tetrazolium tests. These values were compared with initial seed densities.

Results and Discussion

Corn and soybean yields were as high (2003 and 2004) or higher (2005 and 2006) in the LEI systems as in the conventional system (Table 1). Weed biomass in corn and soybean did not differ among systems and was low (≤ 38 lb/acre) in all years (Table 2). Giant foxtail seed densities in the surface 8 in. (20 cm) of soil declined in all systems over the 4-year measurement period (Figure 1A); velvetleaf seed densities declined in the 2- and 4-year systems and remained unchanged in the 3-year system (Figure 1B).

Without subsidy payments, net returns were highest for the 4-year system ($202/acre/year), lowest for the 3-year system ($170/acre/year), and intermediate for the 2-year system ($173/acre/year) (Table 3). Higher profitability of the 4-year rotation as compared with the 2-year rotation derived from a 28% reduction in production costs (Table 3).

These results indicate that yields and weed suppression of certain LEI systems can match or exceed levels achieved in conventional systems. In the absence of crop subsidy payments, certain LEI systems can exceed the profitability of conventionally managed corn-soybean rotation systems.

Acknowledgments

Funding was provided by the USDA National Research Initiative, the Leopold Center for Sustainable Agriculture, and the ISU Agronomy Endowment. Special thanks are expressed to Mike Fiscus and the Ag Engineering/Agronomy Farm crew for expert assistance with field operations.

Table 1. Yields of corn, soybean, triticale and oat grain, and alfalfa hay from experimental plots, and from commercial farms in Boone Co., IA, 2003–2006.

		Rotation system					Contrasts	
Crop	Year	2-yr	3-yr	4-yr	SE	Boone Co. mean yield†	2-yr vs. (3-yr + 4-yr)/2	3-yr vs. 4-yr
		bushels/acre					P	
Corn	2003	191	187	183	4.9	170	0.3010	0.5115
Corn	2004	204	205	211	8.1	192	0.7352	0.6210
Corn	2005	198	227	225	5.9	192	0.0085	0.7988
Corn	2006	203	207	213	1.7	173	0.0156	0.0533
		bushels/acre						
Soybean	2003	44	43	44	1.9	35	0.6665	0.7348
Soybean	2004	54	60	59	2.1	52	0.0674	0.7988
Soybean	2005	59	64	64	1.3	56	0.0277	0.8526
Soybean	2006	44	50	50	1.0	50	0.0049	0.8032
		lb/acre						
Triticale‡	2003	—	4,600	4,460	45	na	—	0.0997
Triticale‡	2004	—	2,290	2,290	70	na	—	0.9900
Triticale‡	2005	—	3,650	3,940	150	na	—	0.2736
Oat‡	2006	—	4,270	4,240	125	3,080	—	0.8803
		tons/acre						
Alfalfa§	2003	—	—	3.8	0.05	3.7	—	—
Alfalfa§	2004	—	—	4.0	0.31	4.0	—	—
Alfalfa§	2005	—	—	4.5	0.16	3.8	—	—
Alfalfa§	2006	—	—	4.9	0.23	na	—	—

†Data from National Agricultural Statistics Service (2007); na=not available.

‡Mean yield of harvested triticale and oat straw in the 3- and 4-year rotations was 0.4 tons/acre in 2003, 0.7 tons/acre in 2004, 1.2 tons/acre in 2005, and 1.0 tons/acre in 2006.

§Total alfalfa hay yield for second-year stands. Mean first-year yield was 0 tons/acre in 2003, 0.5 tons/acre in 2004, 0.4 tons/acre in 2005, and 1.2 tons/acre in 2006.

Table 2. Weed biomass in different crops and rotations in 2003–2006.

Crop(s)	Year	Rotation				Contrasts	
		2-year	3-year	4-year	SE	2-year vs. (3-year + 4-year)/2	3-year vs. 4-year
		lb/acre				p	
Corn	2003	0.9 (0.9) †	14.2 (6.0)	0.9 (0.8)	(2.1)	0.3736	0.1280
Corn	2004	0.9 (0.9)	1.8 (1.3)	0.3 (0.3)	(0.9)	0.9192	0.4435
Corn	2005	0.9 (0.4)	0.9 (0.4)	0.9 (1.1)	(0.4)	0.4720	0.2418
Corn	2006	0.9 (1.0)	0.4 (0.4)	0.2 (0.2)	(0.4)	0.2819	0.7574
Soybean	2003	0.4 (0.4)	18.7 (6.9)	37.5 (9.3)	(3.2)	0.0940	0.6175
Soybean	2004	5.3 (3.4)	10.7 (3.9)	3.6 (2.1)	(3.2)	0.9337	0.7070
Soybean	2005	2.7 (2.1)	0.9 (0.7)	0.0 (0.0)	(0.8)	0.1359	0.5952
Soybean	2006	0.0 (0.0)	0.0 (0.0)	7.1 (3.3)	(1.7)	0.4657	0.2261
Triticale	2003	———	134.8 (23.1)	285.8 (29.9)	(4.4)	———	0.3578
Triticale	2004	———	15.1 (4.7)	2.7 (1.9)	(3.8)	———	0.6227
Triticale	2005	———	117.0 (21.8)	4.5 (3.4)	(2.3)	———	0.0118
Oat	2006	———	39.3 (15.1)	15.2 (8.0)	(1.5)	———	0.0453
Alfalfa	2003	———	———	28.6 (8.8)	(5.2)	———	———
Alfalfa	2004	———	———	2.7 (2.1)	(1.3)	———	———
Alfalfa	2005	———	———	0.1 (0.1)	(0.1)	———	———
Alfalfa	2006	———	———	6.3 (4.6)	(1.2)	———	———
Rotation avg	2003	0.9 (0.6)	55.4 (12.0)	88.4 (12.1)	(1.3)	0.0003	0.9221
Rotation avg	2004	3.6 (2.1)	11.6 (3.3)	1.8 (1.6)	(1.9)	0.8952	0.5405
Rotation avg	2005	1.8 (0.1)	39.3 (7.6)	1.8 (1.2)	(0.5)	0.0040	0.0002
Rotation avg	2006	5.4 (0.4)	13.4 (5.2)	7.1 (4.0)	(0.4)	0.0002	0.0939

† Means and standard errors of $\log_e(x+1)$ transformed data are presented in parentheses.

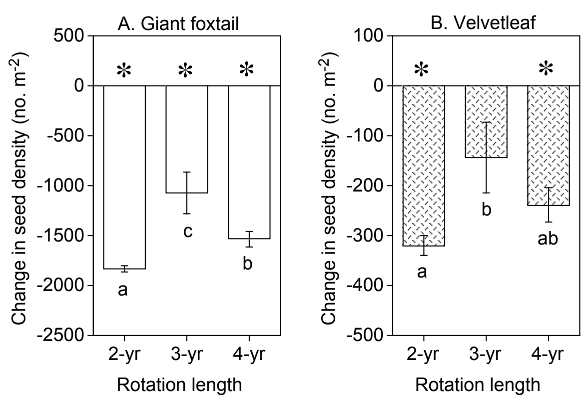

Figure 1. Changes from November 2002 to April 2006 in viable seed densities of giant foxtail (A) and velvetleaf (B) in soil to a depth of 8 in. (20 cm). Data are averaged over all crops within each rotation system. Asterisks indicate significant differences between dates. For each species, columns not underwritten by the same lowercase letter are different (P<0.05).

Table 3. Gross revenues, production costs, labor requirements, and returns to land and management for contrasting rotation systems, 2003–2006.

	Gross revenue†	Production cost‡	Labor requirement	Return to land and management§
	$/acre/yr	$ acre/yr	Hr/acre/yr	$/acre/yr
2-year rotation				
Corn	430	236	0.65	187
Soybean	300	134	0.82	158
Rotation avg.	365	185	0.73	173
3-year rotation				
Corn	445	203	1.72	225
Soybean	325	118	1.02	197
Small grain/clover	198	102	0.77	88
Rotation avg.	323	141	1.17	170
4-year rotation				
Corn	448	196	1.73	235
Soybean	328	118	1.02	200
Small grain/alfalfa	245	142	1.08	92
Alfalfa	376	79	1.69	281
Rotation avg.	349	134	1.38	202

†Crop prices used in the calculations were $2.15/bushel for corn; $6.00/bushel for soybean; $2.05/bushel for triticale grain (56 lb/bushel); $1.60/bushel for oat grain; $60.00/ton for triticale and oat straw; and $85.00/ton for alfalfa hay.

‡Corn costs include field operations, drying, handling, and hauling. Costs for other crops include field operations, handling, and hauling. Land and labor costs are not included in these figures.

§Labor charges are included in these figures; labor charge was set at $10/hr.