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Rye Cover Crop Management Affects Grain Yield in a Soybean-Corn Rotation

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Abstract

Cover crops provide environmental benefits, yet their adoption into production agriculture has been limited. The objectives of this study were to determine how rye (*Secale cereale* L.) cover crop management affects yield of soybean [*Glycine max* (L.) Merr.] and corn (*Zea mays* L.) in a soybean-corn rotation. Field studies were conducted from 2001 to 2004 near Boone, IA. Prior to soybean, rye was controlled chemically and mechanically at Feeke's growth stages 7 (2nd node visible), 9.8 (boot), and 10.5.1 (flowering). Prior to corn, reseeded rye from mechanical control plots was chemically controlled. In 2002 and 2003, no soybean yield differences were detected among timing treatments in mechanical control, which yielded 21 and 29 compared to 52 and 42 bu/acre in the no-rye check. In the chemical control treatments, soybean yielded 30, 39, 43, and 50 bu/acre in the 2nd node, boot, flowering, and check in 2002 and 29, 30, 36, and 43 bu/acre in 2003. Corn yield following rye was lower than the check in 2003 (133 versus 153). In 2004, corn yield only differed between the flowering treatment and the check. These results indicate that alternative rye cover crop systems must be developed to protect soil and water resources and provide economic returns.

Introduction

Cover crops provide beneficial environmental functions, improve soil quality, and may positively impact crop production. Nevertheless, producers' reluctance to use cover crops in farming systems originates from unfavorable short-term economic return on investment and inconsistent information pertaining to cover crop effects on yield. Agricultural policy could play a role in addressing the economic aspect of cover crop implementation by providing cost-sharing to producers who want to deploy cover crops on their land to reduce soil erosion or other deleterious processes. However, more research is required to address producers' management concerns that arise when considering cover crops for their farming systems.

The dominant concern relates to yield suppression following certain cover crops. Johnson et al. (5) reported that corn following cereal rye had 17% lower yield than corn with no-rye cover crop. In their study, rye was controlled just prior to corn planting. Eckert (4), who described rye growth at planting to be 2 to 3 ft tall, used chemical control immediately after planting to kill rye. Continuous no-tillage corn yields were 11% lower in 2 of 4 years compared to the no-rye check, while no-tillage corn yield following soybean with rye was 15% lower in only 2 of 8 comparisons (4) compared to the no-rye treatment. Rye increased corn yield following soybean at one site in 1 year by 13% compared to the no-rye treatment (4).

Ebelhar et al. (3) reported similar no-tillage corn yields following rye or no-rye, averaged across five production seasons under Kentucky growing conditions, when rye was chemically killed immediately after planting. Clark et al. (2) observed similar corn yield following rye compared to the no-rye control in 3 site-years with N at 160 or 120 lb/acre using a late April cover crop kill date and an early May corn planting date. They concluded that the positive cover crop mulching effect on soil water conservation was greater than spring soil water depletion in determining final corn yield. In contrast, Munawar et al. (8)

reported that corn yield following early versus late killed rye, averaged across tillage system and 2 years, were 11% greater because of less soil water depletion due to the growing rye.

Reddy et al. (9) obtained similar soybean yield, averaged across 3 years and herbicide treatment, in rye and no-rye treatments under Mississippi conditions. Rye decreased continuous no-tillage soybean yield in 1 of 4 years by 10% and in 2 of 4 years following corn by 12% (4). Eckert (4) attributed the lower yields in corn and soybean to reduced stands. Mitchell and Teel (7) also reported that heavy growth of rye was associated with irregular and low corn populations. In Michigan under organic soybean production, Thelen et al. (13) reported that interseeded rye, which was planted the same day as soybean in 30-inch row widths, decreased soybean yield 23, 27, and 23% in their 3-year study and attributed the predominant factor for the yield reduction to water stress.

Producers using organic and low-input systems typically plant winter annuals in the fall and use mechanical control with and without herbicide application for cover crop control prior to planting the cash crop. Ashford and Reeves (1) examined the effectiveness of using mechanical control with various cover crops at different growth stages with and without herbicide. They found early control (flag leaf) of cover crops provided poor control (19%), while waiting until anthesis and using a half-rate of herbicide provided similar control compared to the herbicide only treatment. They concluded that mechanical control alone did not provide effective control until the soft dough growth stage. Published cover crop studies typically only report yield data for one main crop. The objectives of this study were to determine how rye management affects yield of soybean and corn in a soybean-corn rotation.

Site Description and Experimental Design

Field studies were conducted at the Agricultural Engineering Research Center in Boone County, Iowa from October 2001 through October 2004. During 2001-2003, the soil was a Spillville loam (fine-loamy, mixed, superactive, mesic Cumulic Hapludolls), and during 2002-2004 a Clarion loam (fine-loamy, mixed, superactive, mesic Typic Hapludolls). 'Rymin' rye was planted at 1,752,288 seeds per acre with a Marliss (Sukup Manufacturing Company, Jonesboro, AR) drill in late September and early October of 2001 and 2002 following corn grain harvest.

The experimental design was a randomized complete block with treatments arranged in a split-plot with four replications. Main plots were mechanical or chemical rye control applied in the spring. Subplots were timing of rye control and were 5 rows (12.5 ft) wide by 95 ft and 40 ft long in 2002 and 2003, respectively. Rye was not planted after soybean harvest in the fall of 2002 and 2003 because we were interested in the reseeding potential of the different mechanical control timing treatments. Plot sizes for corn were similar to soybean each year. The chemical control was glyphosate (Roundup UltraMax) application at a rate of 1.26 lb a.i./acre. Mechanical control was achieved using a Buffalo (Fleischer Manufacturing Inc., Columbus, NE) stalk chopper, using one pass in 2002 and two passes in 2003, which left approximately 6 inches of rye stubble. Timing of rye control occurred at one of three growth stages: 2nd node visible (7), boot (9.8), or flowering (10.5.1), corresponding to Feeke's decimal code for cereals (16). Both control measures were implemented respectively on 7, 14, and 23 May 2002, and 12, 20, and 30 May 2003. Control subplots with no-rye within each main plot were established by killing rye with glyphosate (0.62 lb a.i./acre) in the spring approximately one week after green-up (16 April, 2002 and 15 April, 2003). Control plots were maintained vegetation free for the entire growing season with additional glyphosate and hand weeding as necessary. All other subplots received no additional vegetation control until soybean reached approximately R4 (11). All subplots were then sprayed with glyphosate (0.62 lb a.i./acre) to kill weeds to prevent seed production.

Experimental Protocol and Statistical Analysis

Pioneer Brand '92B84' soybean was planted using no-tillage techniques on 28 May and 5 June in 2002 and 2003 at 180,000 seeds per acre using 30-inch row widths. Dekalb 'DKC53-33' corn was planted in the previous soybean plots on 22 and 23 April 2003 and 2004 using no-tillage at 33,000 seeds per acre in 30-inch row widths. Pre- and post-plant applications of glyphosate were applied for weed control. Corn stand counts were collected when plants were at V2 (10) by counting all the plants in 25 ft of row from the three interior rows of each subplot. A spoke-wheel applicator injected N at 150 lb/acre as urea ammonium nitrate on 12 June 2003 and 20 May 2004. Interior rows were harvested for grain yield and all yield data were converted to 13.0 and 15.5% moisture for soybean and corn, respectively. Prior to soybean harvest, a dry matter sample was collected from 4.1 ft^2 of each subplot to determine pod density, seed number per pod, and seed weight. Soybean seed were collected from the dry matter sample to determine seed protein and oil content using near infra-red (NIR) techniques.

In the fall after soybean harvest, reseeded rye density was determined in the mechanical control timing treatments only by counting all rye tillers using three 2.7 ft^2 quadrats in each subplot. The same quadrats were used for spring biomass determination just prior to corn planting by clipping rye at the soil surface and drying all shoot material at 185°F in a forced-air oven until a constant weight was achieved.

Statistical analysis was conducted separately for each year. Response variables were analyzed as a split-plot using fixed effects ANOVA in SAS (12). All data were subjected to diagnostic analyses to confirm compliance with assumptions for ANOVA. Treatment means were separated using a protected LSD (6) at an $\alpha = 0.1$ when the F-test was significant ($P < 0.1$).

Soybean Yield and Yield Component Response

Soybean yield exhibited a method by timing interaction in both years. In 2002, no differences were detected among timing treatments in mechanical control, which yielded 21 compared to 52 bu/acre in the check (Table 1). Among chemical timing treatments, control at 2nd node reduced yield (30 bu/acre) compared to control at boot and flowering (39 and 43 bu/acre), while all treatments were lower than the check (50 bu/acre). In 2003, mechanical timing treatments yielded 29 compared to 42 bu/acre in the check (Table 2). In chemical control, similar yields were obtained when rye was controlled at 2nd node and boot (29 and 30 bu/acre), which were lower than control at flowering (36 bu/acre). All timing treatments were lower than the check (43 bu/acre). Westgate et al. (14) reported that weed competition and rye regrowth reduced light interception by soybean in chemical and mechanical control treatments, which lowered yield. Using chemical control, Eckert (4) reported a 3% soybean yield reduction in rye compared to no-rye treatments averaged across 4 years in a soybean-corn rotation when rye was 2 to 3 ft tall at the time of control. Our last timing treatment had similar rye growth (14), but yielded 15% lower averaged across the 2 years. Eckert (4) reported 10 and 13% lower yields in 2 years when treatments were significant, which is closer to the yield depression we observed in our study.

The primary yield component responsible for the yield reduction was pod density (Table 1). In 2002, pod density in chemical control averaged 93 pods per ft^2 for the 2nd node and boot growth stages compared to 123 pods per ft^2 for the flowering and check treatments. In mechanical control, pod density averaged 69 pods per ft^2 for all timing treatments compared to 125 pods per ft^2 in the check. Differences in seed weight were also observed, but pod density differences were more pronounced. In 2002, oil content was lower in all treatments compared to the checks in both chemical and mechanical control, but no differences were detected in 2003.

Table 1. Least squares means and ANOVA results for different methods and timing of rye control prior to soybean planting in 2002 for yield and yield components near Boone, IA.

Method	**Timing**	**Yield** (bu/acre)	**Pod** (no./ft^2)	**Seed** (no./ft^2)	**Seed wt.** (g/100 seed)	**Protein** (%)	**Oil** (%)
Chemical	2nd node	30	85	1.86	14.3	38.1	18.1
	boot	39	101	1.93	14.7	38.1	18.3
	flowering	43	120	1.82	14.8	38.9	17.9
	check	50	125	1.87	13.6	36.4	18.9
Mechanical	2nd node	18	70	1.70	12.7	38.4	17.8
	boot	22	65	1.54	13.2	39.0	18.4
	flowering	22	73	1.63	13.1	39.1	18.2
	check	52	125	1.86	13.4	36.5	19.2
	LSD (0.1)*	5	19	NS	0.7	NS	0.3
ANOVA		P > *F*					
	Method (M)	0.004	0.007	0.060	0.057	0.338	0.157
	Timing (T)	0.000	0.000	0.331	0.243	0.000	0.000
	M x T	0.000	0.027	0.159	0.065	0.523	0.043

* LSD compares timing means for the same method.

Table 2. Least squares means and ANOVA results for different methods and timing of rye control prior to soybean planting in 2003 for yield and yield components near Boone, IA.

Method	**Timing**	**Yield** (bu/acre)	**Pods** (no./ft^2)	**Seeds** (no./pod)	**Seed wt.** (g/100 seed)	**Protein** (%)	**Oil** (%)
Chemical	2nd node	29	83	1.90	11.0	36.6	19.4
	boot	30	105	2.00	10.8	36.2	19.2
	flowering	36	93	1.84	11.1	36.8	19.0
	check	43	99	1.94	11.6	36.3	19.5
Mechanical	2nd node	31	84	1.86	11.2	36.0	19.4
	boot	28	79	1.94	10.7	37.0	18.9
	flowering	29	78	1.92	11.1	36.3	19.1
	check	42	100	2.03	11.3	35.6	19.7
	LSD (0.1)*	4	NS	NS	NS	NS	NS
ANOVA		P > *F*					
	Method (M)	0.281	0.091	0.649	0.826	0.385	0.755
	Timing (T)	0.000	0.191	0.219	0.134	0.442	0.023
	M x T	0.062	0.282	0.478	0.837	0.261	0.767

* LSD compares timing means for the same method.

Rye Reseeding

Reseeding densities of rye in the fall of 2002 were not affected by previous mechanical timing treatments prior to soybean planting (Table 3). Averaged across timing, 23 rye tillers per ft^2 were present in November in the different treatments heading into winter. Tiller number in the fall of 2003 was affected by timing treatment. An incremental decline in tiller number was observed as timing of control was delayed. Wilkins and Bellinder (15) reported incrementally less biomass 8 weeks after mowing rye for similar timing treatments. Although we measured fall tiller number not regrowth biomass, the two are probably highly correlated. In the spring of 2003, no differences were detected for rye biomass prior to corn planting. Rye was chemically controlled on 19 April. Averaged across timing treatment, 248 lb/acre dry matter had accumulated prior to corn planting. This is considerably lower than the biomass accumulation (1,666 lb/acre) reported by Johnson et al. (5), but can be partially explained by their mid-May rather than our late-April corn planting date and the reseeded rather than seeded nature of the rye stand. The driving factor for the differences we observed in the 2 years was the level of mechanical rye control. In 2002, only one pass occurred with the rolling stalk chopper compared to two passes in 2003. In 2003, we also added 528 lb to the toolbar for more effective control.

Table 3. Least squares means for treatments comparing timing of mechanical rye control prior to soybean planting in 2002 and 2003 for fall 2002 and 2003 reseeded rye density and spring biomass in 2003 and 2004 prior to corn planting near Boone, IA.

	Fall rye density (tillers per ft^2)		**Spring rye biomass** (lb/acre)	
Timing	**2002**	**2003**	**2003**	**2004**
2nd node	24	11	250	464
boot	27	8	254	245
flowering	18	4	240	160
check	--	--	--	--
LSD (0.1)	NS	2	NS	31

Corn Plant Density and Yield

Corn plant densities in 2003 were similar among all timing treatments (Table 4), and were on average 16% lower than the check. Similarly, no yield difference was detected among timing treatments, which on average were 20 bu/acre lower (133 versus 153 bu/acre) than the check. In contrast, in 2004 corn plant densities were similar across timing treatments and the check and only the flowering timing treatment yielded lower than the check.

Table 4. Least squares means for corn plant density and yield in 2003 and 2004 following mechanical timing treatments prior to soybean planting in 2002 and 2003 near Boone, IA in a soybean-corn rotation. Rye reseeded in mechanical control timing treatments after soybean harvest each year and was chemically controlled prior to corn planting.

	Plant density (plants per acre)		**Grain yield** (bu/acre)	
Timing	**2003**	**2004**	**2003**	**2004**
2nd node	26600b*	24742a	133b	199ab
boot	24974b	26368a	137b	206a
flowering	25439b	26077a	128b	192b
check	30666a	26136a	153a	207a

* Means in the same column followed by the same letter are not significantly different.

Reductions in corn yield in 2003 were probably related to differences in stand density, although we are unable to rule out differences in corn yield components because they were not measured. We hypothesize that rye shoot biomass was not directly responsible for the reduction in corn density because shoot biomass at planting was quite low. Eckert (4) described rye growth at planting to be 2 to 3 ft tall, while rye shoot height in our study was closer to 4 to 6 inches. Eckert (4) and Mitchell and Teel (7) both reported problems with seed-to-soil contact because of pressing rye shoot material into the seed furrow during the planting process. Eckert (4) also reported that corn seedling desiccation was observed in their rye plots because the growing rye depleted soil water. Our observations do not support this conclusion.

Additionally, the relationship between rye biomass prior to corn planting and corn yield is unclear. In 2004, the flowering treatment had the lowest quantity of biomass and the lowest corn yield. This treatment had the greatest quantity of biomass prior to soybean in 2003, but it is unclear how long the residual effect of rye persists. Previous research has reported yield responses to rye ranging from 12% higher to 17% lower compared to no-rye controls under non-limiting N conditions (3,4,2,5). Our results fall within this range and are similar to the majority of papers that report yield depression in corn when using rye as a cover crop.

Conclusions

Cover crops provide environmental and soil quality benefits. However, producers must weigh the potential benefits with the outcomes of implementing these practices in their farming systems because of the potential for lower economic returns. Rye cover crop management similar to practices used in this study will decrease soybean yield in both chemical and mechanical systems. Corn yield may also decline following a rye cover crop. Consequently, producers who select rye must either identify alternative management systems that do not depress yield or participate in programs that offer cost-sharing to offset lower returns.

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