Economic Analysis of the Effects of Winter Cover Crops on No-Tillage Corn Yield Response to Fertilizer Nitrogen

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Abstract

Winter cover crops can substitute for fertilizer nitrogen in no-tillage corn production. Tennessee data for 1986-95 were analyzed for profit-maximizing nitrogen rates. Vetch was $6 per acre more profitable than no cover when rainfall was average, but became less profitable than no cover when rainfall was 37.5 percent below average.

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Introduction

Corn production is an important source of income for farmers in West Tennessee (Tennessee Department of Agriculture). The corn plant uses fertilizer nitrogen intensively with high application rates relative to other crops required to maximize net revenue. However, the soils on which corn is row-cropped in West Tennessee are often highly erodible and susceptible to nitrate and pesticide run-off (Bradley and Tyler). The potential externalities of off-site pollution from agricultural production is a major concern of the general public. Farming is perceived as a major source of nitrate contamination in ground water, primarily from the use of fertilizer nitrogen by farmers (Chowdhury and Lacewell). Nitrates in groundwater used for drinking water have become a public concern because of the real or perceived risks to human health (Huang, Shank, and Hewitt). Economists have proposed standards and incentives, taxes based on ambient concentrations, liability rules, and firm-specific taxes and standards based on emissions as ways to reduce non-point pollutants such as nitrates (Chowdhury and Lacewell). The intended effect is to decrease fertilizer nitrogen usage by farmers in areas susceptible to groundwater contamination. Policy approaches, however, may be difficult to implement and costly to regulate.

An alternative to policy is encouraging farmers to use legume winter cover crops to provide part or all of the nitrogen requirements to the crop (Bradley and Tyler). Research indicates winter legume covers can provide 36 to 110 lb/ac of nitrogen to a crop (Decker

et al.). Combining legume winter cover crops with no-tillage production practices may also reduce soil erosion, increase organic matter, conserve soil moisture, and decrease runoff (Duck and Tyler). Non-legume cover crops, such as winter wheat, may have similar affects on soil.

Economic considerations influence the fertilizer nitrogen rate farmers apply following winter cover crops. Lichtenberg et al. determined that the profit-maximizing fertilizer nitrogen rate was reduced 5 percent for the hairy vetch cover and increased 2 percent for the winter wheat cover when compared with the no-cover situation. The objective of this study was to evaluate how alternative winter cover crops affect profit-maximizing fertilizer nitrogen rates, yields, and net revenues for no-tillage corn production in West Tennessee.

Data and Methods

The data used were for 1986-95 from a cover crop study for no-tillage corn at the Milan Experiment Station, Milan, TN. No-tillage corn was planted after hairy vetch, crimson clover, wheat, and no cover alternatives. Equal rates of burndown herbicide were used for each alternative. The cover crops were reestablished each season after corn harvest. Broadcast ammonium nitrate was the nitrogen source applied around May 30 about three weeks after planting. The experimental design was a randomized complete block with split-plots. Nitrogen rates of 0, 50, 100, 150, and 200 lb/ac were the main plots, while the winter cover crops were the split plots. The same plots received the same

treatments each year to evaluate the long-term effects of cover crops on soils. After corn plant emergence, plant populations were thinned to uniform adequate stands in all plots. Yields from four replications were averaged and used to estimate quadratic yield response functions for each cover crop alternative.

Profit-maximizing nitrogen rates, yields, and net revenues over nitrogen, nitrogen application, and cover crop establishment costs were calculated for corn prices averaging $2.39 per bushel (range $1.65 to $3.20) and ammonium nitrate prices averaging $0.271 per pound of nitrogen (range $0.228 to $0.324) (Tennessee Department of Agriculture). Break-even cover crop seed prices and rainfall amounts were calculated to equate net revenues from the cover crop alternatives with net revenue from the no cover alternative. Net revenues and nitrogen use required to achieve a target yield of 110 bushels per acre were also estimated.

Results and Discussion

The estimated quadratic yield response functions for each cover crop alternative are presented in Table 1. All coefficients are significantly different from zero at the 10 percent level, except the intercepts for no cover, wheat, and clover, and the quadratic coefficient for the clover cover. The intercepts for clover and vetch are significantly higher than the intercepts for both no cover and wheat, indicating that when no additional nitrogen is applied, the legume cover crops provide enough nitrogen to boost yields 37 and 30 bushels per acre compared to no cover and wheat, respectively. Furthermore, the linear

coefficients for clover and vetch are significantly different from the no cover alternative, which indicates different marginal physical products of applied nitrogen. The R^2s for the legume cover crops are lower than those for no cover and wheat, indicating that less variation in corn yield is explained by applied nitrogen for legume cover crops.

Figure 1A graphically depicts the estimated yield response functions and the corresponding profit-maximizing levels of applied nitrogen and yields for average corn and nitrogen prices. For profit maximization, the vetch cover system uses 19 (12 percent) and 36 (20 percent) pounds per acre less applied nitrogen than the no cover and wheat systems, respectively. Yields for vetch are 9 (8 percent) and 12 (10 percent) bushels per acre higher than no cover and wheat, respectively. Clover, on the other hand, uses 7 (4 percent) pounds per acre more applied nitrogen than the no cover system and 10 (6 percent) pounds per acre less nitrogen than wheat. Corn yields for the clover system are only 2 (2 percent) and 5 (4 percent) higher than for no cover and wheat, respectively. Thus, the vetch cover reduces profit-maximizing applied nitrogen rates substantially more than clover, compared to no cover or wheat. A similar result is found for increases in profit-maximizing corn yields.

Figure 1B shows the relationships among the value marginal products (VMP) for the four cover alternatives. Profit-maximizing levels of nitrogen use for average corn and nitrogen prices are also shown (same levels as in Figure 1A). These VMP curves indicate that the vetch cover uses less applied nitrogen than the other three cover alternatives at

any positive nitrogen price. As the price of nitrogen falls, the vetch cover increases the use of nitrogen more rapidly than no cover and wheat. This result indicates that the advantage vetch has in using less nitrogen than no cover and wheat decreases as the price of nitrogen falls. A similar, but more pronounced, result holds for the clover cover. Within the range of nitrogen prices observed between 1986 and 1995, clover actually requires more nitrogen to maximize profits than does the no cover alternative. In fact, the price of nitrogen would have to increase to $0.373 per pound (15 percent above the highest price observed during the period) before the clover cover would require less nitrogen than the no cover alternative. Clover uses less applied nitrogen than the wheat cover, except at nitrogen prices below $0.079 (65 percent below the lowest price observed during the period).

Table 2 contains estimates of net revenues over nitrogen, nitrogen application, and cover crop establishment cost for the range of nitrogen and corn prices. Break-even cover crop seed prices that equate net revenues from the cover crop alternatives to the no cover system are also given. For average corn and nitrogen prices, the vetch cover is $6 (3 percent) more profitable than the no cover alternative. Wheat and clover are $33 (15 percent) and $17 (8 percent) less profitable than the no cover alternative. Assuming a farmer plans for average nitrogen and corn prices, rainfall during the 75 days after fertilization would have to be 8.27 inches, or 2.32 (22 percent) inches below the average of 10.59 for 1986 through 1995, for net revenues for the vetch and no cover alternatives

to be equal. For rainfall below 8.27 inches, the no cover system would be more profitable than the vetch system. The probability of receiving rainfall of 8.27 inches or less during the 75 days after May 30 is 37.5 percent, based on rainfall data for 1951-90 at a nearby weather station.

The low corn price ($1.65/bushel) is 48 percent below the high corn price ($3.20/bushel) causing profit-maximizing nitrogen use to decrease by 14 (8 percent), 18 (10 percent), 28 (16 percent), and 24 (16 percent) pounds per acre for the no cover, wheat, clover, and vetch systems, respectively. Lower nitrogen use causes yields to decrease slightly by 2 (2 percent), 3 (3 percent), 4 (3 percent), and 3 (2 percent) bushels per acre, respectively. These results suggest that applied nitrogen use for the legume cover crops is slightly more responsive than no cover and wheat to changes in the price of corn, but that none of the cover alternative is greatly influenced by changes in the price of corn. Profit-maximizing yields are minimally responsive to changes in the price of corn.

Going from the low nitrogen price ($0.228/pound) to the high nitrogen price ($0.324/pound) increases the price by 42 percent causing profit-maximizing nitrogen use to decrease by 8 (5 percent), 9 (5 percent), 14 (8 percent), and12 (8 percent) pounds per acre for no cover, wheat, clover, and vetch covers, respectively. Lower applied nitrogen reduces profit-maximizing yields minimally by 1 (1 percent), 1 (1 percent), 2 (2 percent), and 2 (2 percent) bushels per acre, respectively. Again, vetch and clover appear to be more responsive to changes in the price of nitrogen than the no cover and wheat

alternatives, but no alternative is greatly responsive, and yields are fairly unresponsive to changes in the price of nitrogen.

Break-even cover crop seed prices (Table 2) for wheat and clover that make their net revenues equal to net revenue for the no cover alternative are negative, except for average corn and low nitrogen prices and average corn and high nitrogen prices, which had break-even wheat seed prices of $0.07 and $0.00 per pound, respectively. Thus, no reasonable seed price for wheat or clover would compensate for the higher net revenue for the no cover alternative. Vetch, on the other hand, has high break-even seed prices. The lowest break-even vetch seed price is $0.80 per pound for low corn and average nitrogen prices, and the highest is $1.45 for high corn and average nitrogen prices. These prices are 23 percent and 223 percent above the price of $0.65 per pound used in calculating cover establishment costs.

Table 3 presents the amounts of nitrogen required to reach a yield goal of 110 bushels per acre for the four cover alternatives. Net revenues and differences in applied nitrogen and net revenue from the no cover alternative are also presented. Wheat requires 29 (22 percent) more applied nitrogen than no cover to achieve a yield of 110 bushels per acre, while clover and vetch require 7 (5 percent) and 55 (42 percent) pounds per acre less nitrogen to reach the yield goal. The reduced nitrogen use for vetch compared to the no cover alternative does not offset the cost of establishment, causing net revenue to be $2 per acre less for vetch than no cover. The break-even nitrogen price that equates net

revenues from vetch with no cover is $0.309 per pound. This price is 14 percent higher than the average nitrogen price for 1986 through 1995, but 5 percent lower than the high price for the period. Assuming a farmer plans for average nitrogen and corn prices, rainfall during the 75 days after fertilization would have to be 11.36 inches, or 0.77 (7 percent) inches above the average of 10.59 inches for 1986 through 1995, for net revenues for the vetch and no cover alternatives to be equal. The probability of receiving rainfall of 11.36 inches or more during the 75 days after May 30 is 30 percent.

Conclusions

Legume winter cover crops, combined with no-tillage corn production practices, can reduce the amount of fertilizer nitrogen required for profit maximization while protecting the soil from erosion. Our results suggest that for average corn and nitrogen prices the hairy vetch cover system provided $6 per acre more revenue per acre than the no cover alternative, while using 12 percent less nitrogen for profit maximization. Crimson clover and wheat, on the other hand, required 4 and 10 percent more nitrogen and provided $22 and $37 per acre less net revenue per acre than the no cover alternative.

If a farmer had a yield goal of 110 bushels per acre rather than a profit-maximization goal, the no cover alternative would give higher net revenues than the other cover alternatives. Net revenue per acre would be $2 per acre less for the vetch alternative, but would require 55 pounds per acre less applied nitrogen (42 percent).

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Table 1. Estimated yield response functions for various no-tillage corn cover crops, Milan, TN, 1986-95

Variable[a]	No Cover	Wheat	Clover	Vetch
Intercept	-11.08	-10.67	18.99[de]	26.44[cde]
	(-0.76)[b]	(-0.75)	(1.17)	(1.96)
N	1.00[c]	0.90[c]	0.60[cd]	0.59[cd]
	(5.73)	(5.32)	(3.10)	(3.67)
N^2	-0.0027[c]	-0.0022[c]	-0.0014	-0.0017[c]
	(-3.28)	(-2.71)	(-1.55)	(-2.16)
RAIN	3.49[c]	3.13[c]	3.67[c]	4.58[c]
	(2.93)	(2.71)	(2.78)	(4.16)
R^2	0.69	0.70	0.48	0.54

[a]Corn yield (bu/ac) is the dependent variable, N is applied ammonium nitrate (N lb/ac), and RAIN is cumulative rainfall 75 days after fertilization (inches).
[b]The t-statistics are in parenthesis.
[c]Significantly different from zero at the 10% level.
[d]Significantly different from no cover at the 10% level (test not shown).
[e]Significantly different from wheat cover at the 10% level (test not shown).

Table 2. Profit-maximizing levels of applied nitrogen, yields, total revenue, cover establishment costs, and net revenue for various cover-crop systems and prices on no-tillage corn, Milan, TN, 1986-95

Cover system	N lb/ac	Yield bu/ac	Total revenue[a]/ ac	Cost/ac of			Net revenue[e]/ ac	Break-even cover seed price[f]
				N[b]	Cover seed[c]	Cover mach. & labor[d]		
Average corn ($2.39) and N ($0.271) prices:								
No cover	162	116	277	44	0	0	237	-
Wheat	179	113	270	49	17	4	200	-0.22
Clover	169	118	282	46	17	4	215	-0.33
Vetch	143	125	299	39	13	4	243	0.95
Low corn ($1.65) and average N ($0.271) prices:								
No cover	153	115	190	41	0	0	149	-
Wheat	167	111	183	45	17	4	117	-0.17
Clover	151	115	190	41	17	4	128	-0.27
Vetch	127	123	203	34	13	4	152	0.80
High corn ($3.20) and average N ($0.271) prices:								
No cover	167	117	374	45	0	0	329	-
Wheat	185	114	365	50	17	4	294	-0.20
Clover	179	119	381	49	17	4	311	-0.07
Vetch	151	126	403	41	13	4	345	1.45
Average corn ($2.39) and low N ($0.228) prices:								
No cover	165	116	277	38	0	0	239	1
Wheat	183	113	270	42	17	4	207	-0.17
Clover	175	119	284	40	17	4	223	-0.07
Vetch	148	126	301	34	13	4	250	1.20
Average corn ($2.39) and high N ($0.324) prices:								
No cover	157	115	275	51	0	0	224	-
Wheat	174	112	268	56	17	4	191	-0.18
Clover	161	117	280	52	17	4	207	0.00
Vetch	136	124	206	44	13	4	235	1.20

[a]1986-95 average corn price ($2.39/bu) times profit-maximizing yield.
[b]1986-95 avg. nitrogen price for ammonium nitrate ($0.271/lb nitrogen) times profit-max. applied nitrogen.
[c]Wheat (90 lb/ac times $0.185/lb), clover (15 lb/ac times $1.10/lb), vetch (20 lb/ac times $0.65/lb).
[d]Assumes 80-hp tractor & a 14 x 7" grain drill requiring 0.17 hrs/ac plus labor at $5.85/hr for 0.21 hrs/ac.
[e]Total revenue minus costs of nitrogen and cover establishment.

Table 3. Amount of nitrogen required to achieve a no-tillage corn yield of 119 bu/ac for various cover systems and prices, Milan, TN 1986-95

Cover system	N lb/ac	Difference from no cover N lb/ac	Total revenue/ ac	Cost/ac of N	Cost/ac of Cover Estab.	Net revenue/ ac	Difference in net revenue/ ac from no cover
No cover	131	-	263	36	0	227	-
Wheat	160	29	263	43	21	199	-28
Clover	124	-7	263	34	21	208	-19
Vetch	76	-55	263	21	17	225	-2

Figure 1
Estimated No-Tillage Corn Yield Response Functions, Value Marginal Product Curves, and Profit-Maximizing Corn Yields and Applied Nitrogen Rates for Average Corn and Nitrogen Prices, 1986-95