PROFIT MAXIMIZING WINTER COVER CROP, TILLAGE AND NITROGEN FERTILIZATION SYSTEMS FOR COTTON

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Abstract

Winter cover crops and conservation tillage can benefit soils in cotton production. This study evaluated how alternative winter cover crops and tillage affect profit maximizing nitrogen fertilization rates and net revenues for cotton production in West Tennessee. Net revenues for vetch and the other winter covers was less than for cotton with no cover. Consequently, producers may not adopt winter covers for conservation purposes because net revenues are lower with winter cover crops.

Introduction

Crop residue remaining after planting tilled cotton (*Gossypium hirsutum* L.) averages 3% compared with 29% for corn (*Zea mays* L.) (U.S. Department of Agriculture, 1997). The absence of crop residues on the soil surface may exacerbate soil erosion problems and the runoff of chemicals and nutrients. Incorporating winter cover crops and conservation tillage practices into cotton production may improve soil quality over time by reducing soil erosion, increasing soil organic matter and nutrient availability, and conserving soil moisture (Meisinger et al., 1991). These soil benefits are important in West Tennessee because the soils are often highly erodible and susceptible to nitrate runoff and leaching (Bradley and Tyler, 1996).

Besides soil benefits, profitability considerations influence farmer adoption of winter cover crop and conservation tillage practices in crop production. Higher yields or lower nitrogen fertilizer costs are needed to offset the seed, machinery, and labor expenses of establishing the winter cover. Studies by Frye et al. (1985), Lichtenberg et al. (1991), and Roberts et al. (1998) indicate that corn grown after a winter legume can be more profitable than corn produced without a winter cover. The legume winter cover provides nitrogen to the next crop while reducing the application of nitrogen fertilizer. Lichtenberg et al. determined that the profit maximizing applied nitrogen rate for corn after hairy vetch (*Vicia villosa* L.) was 5% lower than the rate for corn without a winter cover. Roberts et al. estimated an even greater reduction in the nitrogen fertilization rate required to maximize profit in the presence of legume. In their study, planting no tillage corn after a hairy vetch cover required 16% to 26% percent less nitrogen fertilizer when compared to the no winter cover alternative. In addition, improved soil quality with winter covers and conservation tillage may enhance productivity of nitrogen fertilizer over time.

Presently, there is little information on the profitability of conventional tillage or no tillage cotton grown after alternative winter cover crops. The objective of this study was to evaluate how alternative winter cover crops and tillage practices affect profit maximizing nitrogen fertilization rates, yields, and net revenues for cotton production in West Tennessee.

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Data and Methods

Cotton yield data for 1981 through 1999 were obtained from a winter cover crop experiment at the West Tennessee Experiment Station, Jackson, TN Tillage practices and nitrogen fertilizer were also varied in the study. The experimental design was a randomized complete block with split-plots and four replications per year. Nitrogen fertilizer was varied in the main plots with winter cover and tillage being varied in the split plots. The same plots received the same nitrogen fertilizer rate, cover crop, and tillage treatment each year. Individual plot sizes were 4 m (4 rows) wide and 9.1 m long.

Cotton was planted on conventional tillage and no tillage plots after winter wheat (*Triticum aestivum* L.), hairy vetch, crimson clover (*Trifolium incarnatum* L.), and no winter cover crop alternatives. A burn-down herbicide was used to kill the cover crop before planting cotton in the no tillage plots. Conventional tillage plots were disced to destroy the cover crop before planting. Winter covers were reestablished each season after cotton harvest with seeding rates of 100.8 kg ha^{1} for wheat, 22.4 kg ha^{1} for vetch, and 16.8 kg ha^{1} for clover. Broadcast ammonium nitrate was the nitrogen source applied after planting. Rates of nitrogen fertilizer applied to the plots were 0, 33.6, 67.2, and 100.8 kg ha^{1}.

Researchers who managed the experiment had to learn how to manage heavy crop residues with herbicides in cotton and which winter covers worked the best from an agronomic standpoint. The experiment started with rye (*Secale cereale* L.) and vetch-rye covers that were switched to wheat and crimson clover in the fourth year of the experiment. Therefore, the first three years of data from the experiment (1981-1983) were excluded from the analysis, leaving a total of 512 observations (128 for each cover).

Two important events in the experiment complicated the analysis of the yield data. Researchers experienced increasing difficulty with controlling weeds over time. Pigweed was especially prevalent in the no tillage and legume winter cover plots. Researchers were better able to control pigweed with the availability of prythiobac sodium (Staple) herbicide in 1995. Researchers also conducted a lime recommendation study. After letting pH deteriorate by delaying the regular application of lime for several years, they spit the plots and applied different lime rates in 1995; the full extension service recommended rate and half the recommended rate. Declining soil pH may have negatively impacted yields over time. Plots receiving half the recommended lime rate were excluded from this analysis.

The data were used to estimate a quadratic yield response function for each winter cover crop alternative as follows:

$$y = a + bN_t + cN_t^2 + dTM_t + eT_t + fN_t \times TM_t$$
$$+ gN_t \times T_t + hTM_t \times T_t + ipH_t + u_t,$$

where Y_t is lint yield (kg ha^{1}) for cotton following one of the winter cover crop treatments in the experiment, N is the applied nitrogen rate (kg ha^{1}); TM is a tillage binary variable (no tillage=1, conventional tillage=0); T is a time trend index (1=1984, 2=1985,..,16=1999); N×TM, N×T, and TM×T are interactions between the respective variables; pH is a soil pH experiment binary variable where pH=1 for 1995 through 1999, 0 otherwise; t is a subscript indicating year of the experiment; a, b, c, d, e, f, g, h, and i are parameters to be estimated by regression; and u is a random error term.

The estimated yield response function for each winter cover was used to predict profit maximizing nitrogen fertilization rates, yields, costs, and net revenues above variable, fixed equipment, and overhead costs. Profit maximizing nitrogen fertilization rates for each winter cover and tillage alternate were calculated by taking the first derivative of the lint yield equation with respect to N, setting the first derivative equal to the ratio of nitrogen fertilizer price to lint price, and solving for N (Debertin, 1986).

Profit maximizing net revenues for each winter cover and tillage alternate was calculated as follows:

$$NR^* = P_{lint} \times Y^* - P_N \times N^* - Cost_{WC} - Cost_{TM},$$

where NR^* is the profit maximizing net revenue for a winter cover crop and tillage alternative (\$ ha^{1}); Y^* is the profit maximizing lint yield calculated using the estimated lint yield response equation and the profit maximizing nitrogen fertilizer rate N^*; $Cost_{WC}$ is the estimated materials, labor, equipment, and interest costs to establish the winter cover crop (\$ Ha^{1}); and $Cost_{TM}$ is the other expenses for conventional tillage or no tillage cotton production that did no vary in this analysis (\$ Ha^{1}).

Prices used to calculate profit maximizing values were \$1.58 kg^{1} for cotton lint and \$0.73 kg^{1} for nitrogen fertilizer. Average prices for 1984 through 1999 were used in these calculations (Tennessee Department of Agriculture, Various 1985 through 2000 Issues). These prices were inflated to 1999 dollars by the Implicit Gross Domestic Product Price Deflator before averaging (Congress of the U.S., Council of Economic Advisors, 2000). Cover crop costs include cover seed cost and the costs of machinery, labor, and interest on the variable costs of cover establishment. Cover seed costs were 100.8 kg ha^{1} multiplied by \$0.38 kg^{1} for wheat, 22.4 kg ha^{1} multiplied by \$2.69 kg^{1} for vetch, and 16.8 kg ha^{1} multiplied by \$2.34 kg^{1} for clover. Machinery and labor costs assume a 150-hp tractor and a 6.38 m drill with 17.8 cm row spacing requiring 0.27 hr ha^{1} plus labor at \$6.75 hr^{1} for 0.35 hr ha^{1} (Gerloff, 2000). Other costs of production that did not vary in this analysis were from extension service enterprise budgets for conventional tillage and no tillage cotton (Gerloff, 2000).

Results and Discussion

The estimated lint yield response functions for each winter cover crop are presented in Table 1. Several of the management variables were statistically significant in explaining lint yield response in each winter cover crop equation. Nitrogen fertilizer coefficients N and N^2 were significantly different from zero in the cotton after winter wheat and cotton after no winter cover equations ($p=0.05$) and had the hypothesized signs. The estimated TM coefficients were significant different from zero for cotton after winter wheat ($p=0.01$) and cotton after crimson clover ($p=0.05$). The interaction of nitrogen and no-tillage (N×TM) for cotton after wheat was statistically significant ($p=0.05$) and had the expected positive sign. The no tillage-time trend interaction term (TM×T) for cotton after wheat and cotton after clover had statistically significant ($p=0.05$) and positive coefficients. Coefficients for the time-trend variables in all four winter cover equations were statistically significant ($p=0.01$) and had a negative sign. As hypothesized, the signs on the estimate pH coefficients were positive and were statistically significant ($p=0.01$).

As indicated above, the estimated time-trend coefficients had negative signs that were statistically significant in each winter cover function. However, because of the interaction of time with other variables in the model, the net impact of time on yields was not clear. An evaluation of the lint yield with respect to the *T* and its interactions indicated that yields declined over time for all four cover crops. Problems controlling pigweed and deteriorating soil pH induced by delaying lime applications during a portion of the experiment likely caused the downward trend in yields. These negative influences on yields more than offset any positive long-term benefits of winter covers and no tillage on soil quality. With the availability of glyphosate (N-phosphonomethyl) glycine)-tolerant cotton and prythiobac sodium herbicide, weed control in no tillage cotton grown after a winter cover may be less of a problem for farmers.

Table 2 provides estimates of profit maximizing nitrogen fertilizer rates, total costs of production, and net revenues. The estimated yield response functions were used "as is" to estimate profit maximizing fertilizer nitrogen rates and yields even though the fertilizer nitrogen coefficients were not significant for clover or vetch (with T held at its mean value of 8 and the pH variable set at 1). However, if the profit maximizing fertilizer nitrogen rate predicted by the model was negative, then the lowest nitrogen rate in the experiment of 0 kg ha^{1} was used to predict lint yield.

Cotton after the vetch cover provided the highest profit maximizing yield, while cotton after clover provided the lowest yield under both tillage and no tillage. However, the yield gain for cotton after vetch over cotton without a winter cover was small. Cotton after wheat required the most nitrogen fertilizer for profit maximization while cotton grown after the nitrogen fixing vetch and clover covers essentially required no fertilizer nitrogen. For wheat and no cover, profit maximizing nitrogen fertilizer rates for conventional tillage cotton were lower than for no tillage cotton. The profit maximizing nitrogen fertilization rate for cotton following wheat was 63 kg ha^{1} under conventional tillage compared with 89 kg ha^{1} under no tillage. The profit maximizing fertilizer nitrogen rate for cotton grown without a winter cover was 62 kg ha^{1} with conventional tillage and 76 kg ha^{1} with no tillage.

Cotton grown without a winter cover had the lowest production cost because the higher cost of nitrogen fertilizer compared with vetch or clover was more than offset by the lack of a cover crop establishment cost. Its high nitrogen fertilizer rate and cover establishment cost gave cotton following wheat the highest cost of production. Consequently, conventional tillage cotton grown after no winter cover produced the largest net revenue of \$1,221 \$ ha^{1}. The next highest net revenue of \$1,179 \$ ha^{1} was produced using a vetch cover followed by conventional tillage cotton. In general, net revenues for no cover and wheat under no tillage were lower because of smaller lint yields and higher nitrogen fertilization costs. No tillage cotton grown after no winter cover or a vetch cover produced the largest net revenues of \$1,142 \$ ha^{1} and \$1,125\$ ha^{1}, respectively. The smallest net revenues were produced by clover followed by no tillage cotton.

Conclusions

Winter cover crops and no tillage practices can benefit soils by reducing soil erosion, improving soil physical characteristics, and conserving soil moisture. Farmers interested in adopting winter cover crops and no tillage practices need information about nitrogen fertilization rates in cotton. This study evaluated profit maximizing nitrogen fertilization rates and net revenues for cotton grown after no winter cover, a winter wheat cover, a hairy vetch cover, and a crimson clover cover.

Results indicated that the hairy vetch winter cover provided yields similar to cotton grown without a winter cover. Analysis of profit maximizing nitrogen fertilization rates with winter legumes indicates that supplemental nitrogen fertilization is not necessary. However, total production costs with winter legumes is higher even though fertilizer cost is lower because of cover crop establishment costs. Because of higher production costs, the net revenues for vetch and the other winter covers were less than the net revenues for cotton with no cover. Farmers may be reluctant to adopt winter covers for conservation purposes because net revenues are lower with winter cover crops.

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Table 1. Estimated cotton lint yield response functions for alternative winter cover crop systems.

Variable[†]	**No Cover**	**Winter Wheat**	**Hairy Vetch**	**Crimson Clover**
Intercept	1178.32***	1190.58***	1319.53***	1275.00***
N	4.34**	4.23**	0.41	-1.45×10^{-03}***
N2	-0.03**	-0.03	-0.01	-0.01
TM	-183.01**	-264.76	-144.52	-192.73***
T	-72.27***	-66.27***	-70.35***	-69.12***
NHTM	0.91	1.51*	-0.89	0.23
NHT	0.03	-0.03	0.07	0.04
TMHT	7.10	17.11***	12.76	21.24***
pH	515.75***	412.97***	509.47***	424.71***

[†] Cotton lint yield (kg ha^{1}) is the dependent variable, *N*=applied ammonium nitrate (kg ha^{1}), *TM*=tillage method binary variable (no tillage=1, conventional tillage=0), *T*=time trend index (1=1984 to 16=1999), and *pH*=soil ph experiment binary variable where *pH*=1 if year of experiment>1995, 0 otherwise.

***,**, * Significantly different from zero at the 1, 5, or 10 percent level, respectively.

Table 2. Profit maximizing nitrogen fertilizer rates, winter cover establishment costs, total production costs, and net revenues.

Winter Cover Crop	**Tillage**	**Nitrogen Fertilizer Rate (kg ha^{1})**	**Winter Cover Establish-ment ($ ha^{1})**	**Total Costs ($ ha^{1})**	**Net Revenue ($ ha^{1})**
None	Tillage	62	0	790	1221
	No Tillage	76	0	780	1142
Wheat	Tillage	63	61	850	1068
	No Tillage	89	61	850	1068
Vetch	Tillage	19	85	843	1179
	No Tillage	0	85	809	1125
Clover	Tillage	0	62	806	1006
	No Tillage	7	62	791	990