AN AGRONOMIC AND ECONOMIC EVALUATION OF FERTILIZER N AND LEGUME COVER CROP MANAGEMENT FOR NO-TILL COTTON PRODUCTION

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Abstract

A field study was conducted from 1992 through 1995 to determine both the agronomic and economic effects of fertilizer and legume N in no-tillage cotton production on lint yield and net returns. Fertilizer N rates of 0, 40, 80, 120, and 160 lb/acre were applied in combination with winter fallow cover management using either broadcast ammonium nitrate (AN) or a subsurface banded urea-ammonium nitrate (UAN) solution. Additionally, there was a winter cover system using a hairy vetch cover crop in combination with all N rates used with winter fallow, except the highest. Agronomically, the use of hairy vetch was shown to increase soil productivity while decreasing the amount of UAN fertilizer needed to achieve predicted maximum yields. Economically, because the vetch system did not significantly increase the agronomic maximum lint yield over that of fertilizer N , the non-legume systems had net returns of $14 to 43/acre more depending on N source, N price, and lint price than the more expensive legume system. Average net returns in the vetch system were slightly improved with the use of UAN fertilizer. Broadcast ammonium nitrate had significantly greater average yields and net returns than the UAN system.

Introduction

The agronomic benefits associated with using leguminous cover crops in conservation tillage systems are many and well-documented. For many years research has shown how legumes can increase soil organic matter (Frye and Blevins, 1989), improve soil structure (Beale et al., 1955) and soil productivity (Frye et al. 1985). Moreover, the mulch effect of legumes has been shown to improve both the water holding capacity of the soil (Griffith et al., 1986) and infiltration (Touchton et al., 1984), while decreasing erosion (Frye et al., 1985) and runoff. Lastly, and perhaps the most important agronomic benefit of legumes is their ability to provide biologically fixed N which can decrease the fertilizer N requirement of the primary crop (Brown et al., 1985). Agronomically, the potential overall effect of these legume benefits is to increase the yield potential of a primary crop over that of fertilizer N alone (Touchton et al., 1984).

The economic benefits or effects, however, of using leguminous cover crops are not so clear or well-documented. The yearly cost of establishing the legume crop is usually high especially when considering that no direct profits will be obtained from planting it. Moreover, the profit risks associated with using cover crops can adversely affect their desirability to risk-averse producers. Reducing soil moisture before spring planting, the potential for winter kill in certain geographic locations, and the yield variability which affects the N supply for the following crop are three such risks that Allison and Ott (1987) discuss in their economic evaluation of leguminous cover crops. They go on to point out that because of their high costs and potential risks, desirability of legumes decreases when their primary value is simply to supply N to the following crop. At current N prices the savings from using legumes does not make them profitable unless they significantly increase the agronomic yield potential of the primary crop beyond that of fertilizer N alone. Frye and Blevins (1989) and Lichtenburg et al. (1994) have both demonstrated that grain yield potential in corn can increase using legumes and that these increases result in increased profitability.

Even though legume cover crops have been evaluated in no-till cotton production for their agronomic benefits, research or documentation of their economic benefits is lacking. Consequently, the objective of this study was to evaluate the agronomic and economic effects of fertilizer and legume N on lint yield and net returns in no-tillage cotton production.

Materials and Methods

Agronomic Procedures

A field experiment was conducted from 1992 through 1995 on a Marietta fine sandy loam (fine-loamy, mixed, thermic, siliceous Aquic Fluventic Eutrochrept) at the Plant Science Research Center at Mississippi State. A 3 x 5 factorial arrangement of cover-N source management systems and fertilizer N rates was used in a randomized complete block design with four replications. The winter cover-N source system evaluated was a hairy vetch (*Vicia villosa Roth.*)cover crop with subsurface banded UAN solution, while the winter fallow-N source systems included 32% subsurface banded urea-ammonium nitrate (UAN) solution or broadcast ammonium nitrate (AN). One-half of the fertilizer was applied shortly after planting with the remainder being applied at early square. Fertilizer N was applied on the AN and UAN plots at a rate of 0, 40, 80, 120 and 160 lb/acre, while the vetch-UAN plots received rates of only 0, 40, 80 and 120 lb/acre. Plot size was 12.67 ft. wide by 30 ft. long.

Each fall, after chopping the cotton stalks, vetch seed was inoculated with *Rhizobium leguminosarum* and broadcast at a rate of 25 lb/acre between mid-October and mid-November. At approximately 25 days prior to planting, 10.8 square feet of vetch was harvested from each plot to determine dry matter production. The samples were dried

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and ground and then analyzed using a Carlo Erba 1500 C:N dry combustion analyzer to determine aboveground N content. The remaining cover crop and any winter annual vegetation was desiccated with a 0.5 lb ai/acre Bladex and 0.625 lb ai/acre Gramoxone Extra mixture. Just prior to planting, a 1.0 lb ai/acre Roundup application was made for a final burn down. Cotton variety 'DES 119' was planted 13 May 1992, 17 May 1993, and 5 May 1994, while 'Suregrow 125' was planted 5 May 1995. Cotton was planted in 38" solid rows with postemergence and residual weed and insect control following recommended guidelines. The cotton was harvested at maturity and representative seed cotton samples were ginned to determine lint yields.

Economic Procedures

Each N system was evaluated by estimating and comparing the average net returns at the N rate that maximized the average lint yield over the four year period. A range of lint and fertilizer N prices was used to determine the sensitivity of the results to changes in these important variables. N-lint yield response functions were calculated for each N system using data from the four experimental years. The vetch-UAN function consisted of a weighted average in which the two years where lint response was somewhat quadratic to N rate were averaged with the vetch 0 N checks the 2 years where lint yield did not respond to N rate. Because of the possible discrepancies with this method the economic analysis was also performed using the 4 year lint yield average of the vetch plots with no UAN fertilizer. The functions for the UAN and ammonium nitrate systems were based solely on 4 year averages of significant quadratic equations except for the first year of UAN where the 0 check lint yield was used because there was no significant quadratic response to N rate.

Once calculated, these functions were used together with varied lint and N prices to determine economically optimal quantities of N fertilizer for each N system. At these optimal N rates, average lint yields for each N system and the vetch 0 N system across varied lint and N prices were calculated. Lastly, average net returns at the optimal N rates were determined for each N system and the vetch 0 N system. This calculation was made across varied lint and N prices using the following equation:

Avg. Net Return = (net lint price x avg. lint yield) -(N price x opt. N rate) - legume establishment and/or N appl. expense - all other prod. expenses.

The "legume establishment and/or N application expense" in this equation was calculated assuming that the producer owned the machinery, hired labor, bought fuel, paid interest on operating and investment capital, and had depreciation on big equipment. Those expenses were as follows: vetch with no fertilizer N cost $27.55/acre to plant 25 lb seed/acre at $0.80/lb seed; vetch with UAN band cost $34.47/acre for the same seeding rate plus liquid banding; UAN band cost $6.92/acre for liquid banding; and ammonium nitrate cost $10.62/acre for spin spreading. The "other production expenses" in this equation were based on all other operation costs associated with planting, growing, and picking cotton excluding land costs, general farm overhead, and a management charge for farm owners. These expenses were as follows: The total cost of operations was $261.40/acre; the interest on the operating capitol was $6.45/acre; and the cost of unallocated labor was $12.73/acre for a total specified cost of $280.68/acre. The varied lint prices were derived by assuming a lint percent of 36 and a seed percent of 60. The value of the seed was added to the lint value to obtain an adjusted price. Finally, the net lint price was obtained by subtracting $0.10/lb of lint for hauling and ginning expenses.

Results and Discussion

Agronomic Analysis

Cover crop yields and N content values averaged across N rates for each year are shown in Table 1. Legume yields ranged from 1262 to 1923 lb/acre containing from 47 to 80 lb N/acre. The four year average yield was 1593 lb/acre with a N content of 62 lb N/acre. Legume yields and N contents for 1993 and 1994 were similar, but those for 1995 were higher probably due to a mild winter that permitted extra vetch growth and biological N fixation. From 1992-1994, the four year vetch with no fertilizer N plots had an average N content of 61 lb/acre.

Yearly lint yield response to fertilizer N rates and N systems for 1992-1995 is shown in Figure 1. In 1992, the ammonium nitrate system had a quadratic response to N rate. The vetch-UAN plots, however, had an almost linear response in the downward direction to N rate. This is likely the result of high winds and rainfall produced by the remnants of hurricane Andrew in August which caused lodging of taller and more heavily fruited plants. In 1993, 1994, and 1995, both ammonium nitrate and UAN systems responded quadratically to N rate. Even though yield trends were inconsistent for the vetch-UAN system in these three years, the lint yield of the vetch 0 plots consistently increased over that of the 0 check plots. The yearly productivity increase due to vetch time is shown in Table 2. The lint yield difference between the vetch 0 plots and the 0 check plots increased from -68 lb/A in 1992 to 240 lb/acre in 1995. Each year the lint yield difference became more significant and increased linearly across years ($p=0.07$, $r^2=0.87$).

Using the N-lint yield response functions specified in the Economic Procedures, the four year average lint yield response to fertilizer N rates and N systems is shown in Fig. 2. All three N systems calculated had a quadratic response to N rate. The predicted maximum yields with corresponding N rates were as follows: broadcast AN - 962 lb lint/acre at 108 lb N/acre; banded UAN solution - 917 lb lint/acre at 102 lb N/acre; and vetch-UAN - 917 lb lint/acre at 61 lb/N acre. The legume UAN system was able to achieve the same yield with 40% less fertilizer N than the nonlegume UAN system. Vetch did not increase the agronomic maximum lint yield compared to fertilizer N. Broadcast ammonium nitrate required more fertilizer than either of the other two N systems, but resulted in a 45 lb/acre greater lint yield increase.

Economic Analysis

The results of the economic analysis are shown in Table 3. Lint yields at optimal economic N rates were similar to those obtained from the agronomic analysis and again showed that the vetch-UAN system could achieve comparable yields to the UAN band system, while requiring only half as much fertilizer N. Nevertheless, due to the high cost of establishing the legume, the vetch-UAN system had an average net return of $14 to 18/acre less depending on N fertilizer and lint prices than the UAN band system. Moreover, even though the vetch system with no N fertilizer had an average lint yield of 20 lb/acre less than the vetch-UAN system, the average net returns of the two systems were essentially the same due to the added expense associated with applying UAN fertilizer. Similarly, broadcast ammonium nitrate, while costing more per pound of N and requiring a greater optimal N rate, achieved net returns $15-20/acre more than UAN band because of the 44 lb/acre average lint yield increase associated with its use.

Conclusions

From an agronomic standpoint, this study has shown that hairy vetch can significantly improve soil productivity in no-till cotton while reducing the need for UAN fertilizer. In spite of these findings, however, the use of hairy vetch did not increase the agronomic maximum lint yield compared to fertilizer N. Because of this fact, economically speaking, non-legume systems had higher net returns than the more expensive legume system. Average net returns in the vetch system were only slightly improved with the use of inorganic fertilizers. The use of broadcast ammonium nitrate in no-till cotton shows good potential for achieving greater yields and net returns than UAN solution.

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Table 1. Hairy vetch yield and N content values for no-till cotton.

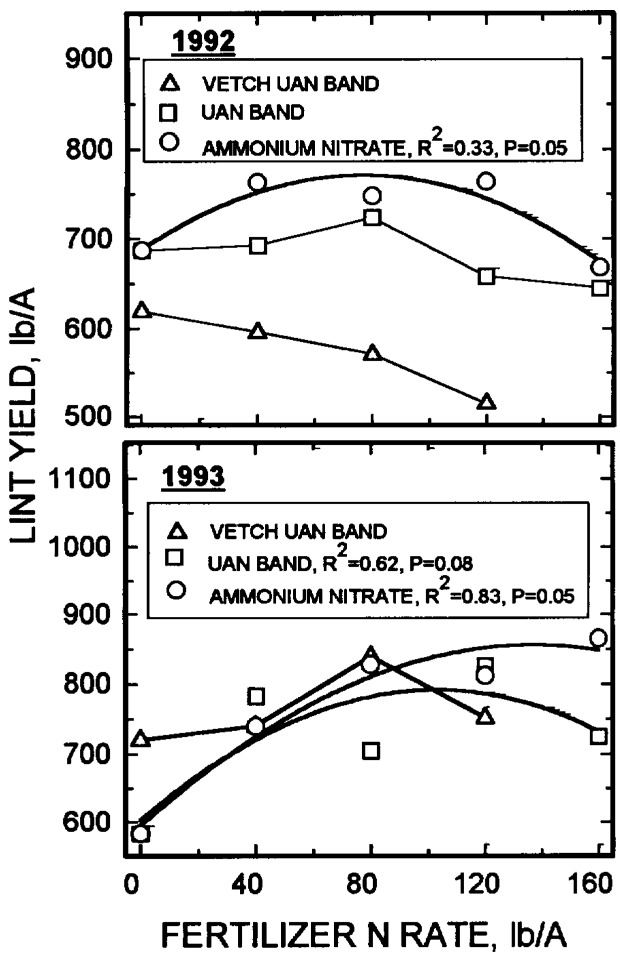
	1992	1993	1994	1995	Avg.
Legume Yield (lb/A)	1923	1310	1262	1879	1593
N Content (lb/A)	80	47	57	63	62

Table 2. Yearly lint yield increase due to vetch.

Year	Vetch 0 Lint Yield (lb/acre)	0 Check Lint Yield (lb/acre)	Lint Yield Diff. (lb./acre)	Sign.
92	619	687	-68	p = 0.312
93	720	583	137	p = 0.166
94	1147	985	162	p = 0.033
95	1048	808	240	p = 0.016

Table 3. Results of economic analysis.

		Optimal N Rates, lb N/A	**Avg. Lint Yields at Opt. N Rates, lb/A**	**Avg. Net Returns at Opt. N Rates, $/A**
N System	Lint Price $/lb	[N price, $/lb N]	[N price, $/lb N]	[N price, $/lb N]
Vetch - no N	0.6 0.8	**0** **0**	**884** **884**	**222** **399**
Vetch - UAN	 0.6 0.8	[0.22] [0.30] **42 35** **47 42**	[0.22] [0.30] **914 911** **915 914**	[0.22] [0.30] **224 221** **407 403**
UAN	 0.6 0.8	[0.22] [0.30] **89 84** **92 89**	[0.22] [0.30] **915 913** **916 915**	[0.22] [0.30] **242 235** **425 418**
Amm. Nit.	 0.6 0.8	[0.28] [0.36] **94 90** **98 95**	[0.28] [0.36] **959 957** **960 959**	[0.28] [0.36] **258 250** **450 442**



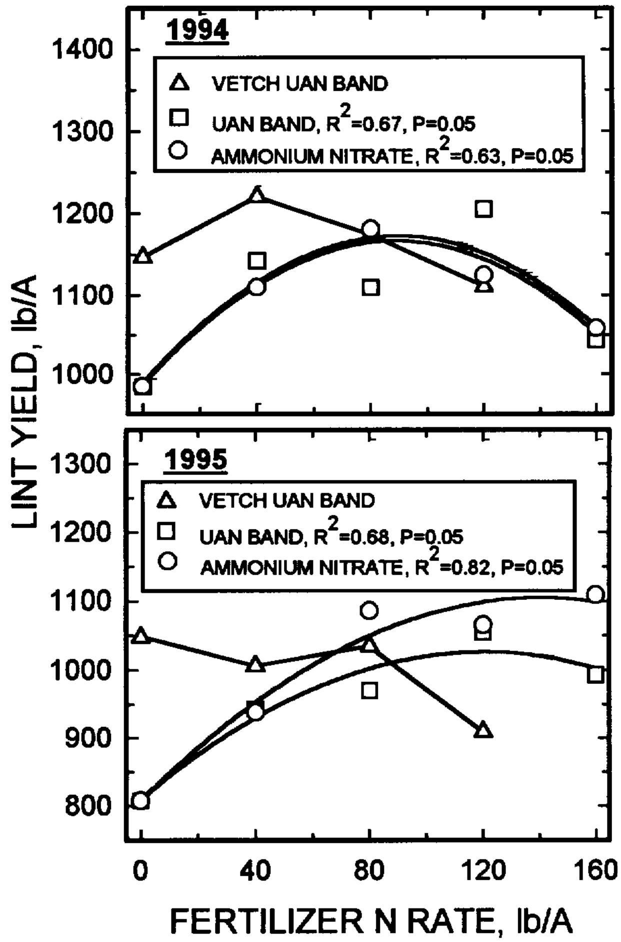


Figure 1. N system and fertilizer N rate effects on no-till cotton lint yield for the years 1992-1995.

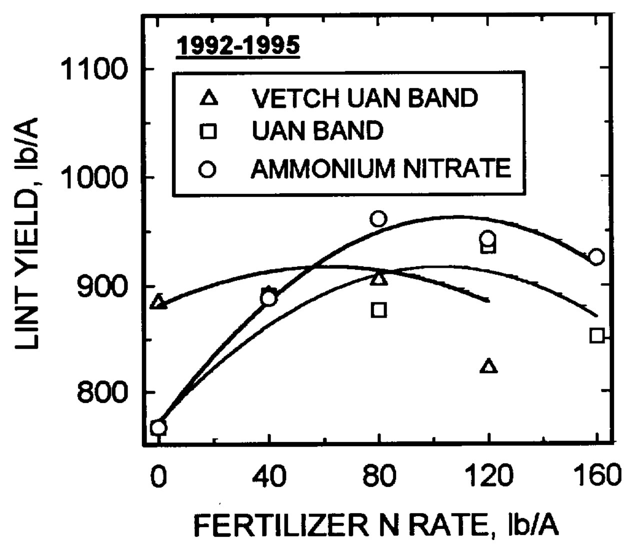


Figure 2. Averate N system and fertilizer N rate effects on no-till cotton lint yield for the years 1992-1995.