COMBINING MANURE AND CONSERVATION TILLAGE FOR PROFITABLE YIELDS

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INTRODUCTION

Few studies have combined conservation tillage with manure use. Conservation tillage maintains crop residue at the soil surface to reduce erosion, yet most recommendations for surface application of manure on cropland suggest incorporating the manure as soon as possible to limit nutrient loss, especially volatilization of ammonia (Lauer et al., 1976). Additionally, the combination of conservation tillage and manure use may result in increased N losses due to denitrification in some soils (Pratt et al., 1976: Grove, 1992, unpublished data). Nitrogen losses may be especially dependent on the time of manure application, as the seasonal timing of manure application has been found to be important in nitrate leaching and the recovery of N in the target crop in European studies (Bertilsson, 1988). Thus it would appear that conservation tillage and manure use may not be compatible.

Kentucky has approximately 206,000 dairy cows that produce about 3.1 million wet tons of manure every year (KY Ag Stats., 1991). This results in the production of about 25 million pounds of nitrogen. Approximately one-half of this production is collected and applied to crop land in the fall or spring. Because Kentucky has relatively mild winter temperatures combined with abundant precipitation, the nitrogen from fall manure application may have little or no effect on the following seasons' crop yields.

No-tillage and other forms of conservation tillage systems are widely used in Kentucky; therefore, an experiment was initiated to observe the effects of combining conservation tillage methods (no-till or chiselldisk) with surface applied dairy manure on corn *(Zea mays,* L.) yields. The objectives of this study were to (a): examine the yield response of a continuous corn production system to manure application timing, tillage, and fertilizer N rate, and (b): determine the economic value of manure application.

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MATERIALS AND METHODS

This experiment was established in the fall of 1991 at the Kentucky Agricultural Experiment Station Farm in Lexington, KY. The soil is a Maury silt loam (fine, mixed mesic Typic Paleudalf), a well drained soil formed in the residuum of phosphatic Ordovician limestone. The area had been in blue grass pasture for several years prior to the initiation of this experiment. The experimental design is a randomized block split-plot with three replications. Treatment structure is a complete factorial with six manure-timing-tillage treatments and three nitrogen fertilizer rates. Main plots consist of 1) no-tillage, no manure: 2) no-tillage, fall manure: 3) no-tillage, spring manure; 4) no-tillage, fall plus spring manure: 5) chiselldisk, no manure; and 6) chiselldisk. spring manure. Subplot treatments are 0, 75, or 150 lb N A^{-1}, using ammonium nitrate as the N source. Subplot size is 12 ft wide (four rows) by 30 ft long.

Fresh dairy manure was surface applied with a commercial spreader to selected plots before planting in late April to early May for the spring manure treatments, and post harvest in early to mid-November for fall manure treatments. The manure source was a nearby dairy farm operated by the University of Kentucky. As such, no hauling costs were incurred during this experiment. The manure spreader was calibrated to deliver approximately 9000 lbs A^{-1} (dry weight) (30,000 lbs A^{-1} wet weight). As a check, 14" by 18" flat trays were randomly assigned throughout the plots before manure application for sample collection. After spreading, the sample trays were collected, dried, and weighed to determine the application rate. The dried manure was analyzed for % N to estimate the nitrogen application rate for each application. Nitrogen concentration and calculated application rates are listed in Table 1.

Immediately following spring manure application, chisel/disk treatments were implemented, chiseling and then disking twice to incorporate the manure over a depth of 0 to 6 inches. No cultivation was performed in the no-till system, including those that received manure.

Table 1. Average actual rate, %N, and calculated N rate for each manure application.

Date	avg. dry wt. lb A^{-1}	%N	SD[1] of %N	N rate lb A^{-1}
Fall 1991	8970	1.99	0.24	179
Spring 1992	6200	2.20	0.37	136
Fall 1992	8780	2.19	0.16	192
Spring 1993	18590	2.11	0.22	392

1. Standard deviation.

Table 2. Corn response to tillage, manure, and N fertilizer treatments for 1992 and 1993.

Treatment		Fertilizer N, lb A^{-1}			
tillage[1]	manure	0	75	150	MEAN[2]
		------------- bu A^{-1}	-------------	-------------	-------------
			1992		
NT	none	174.5	192.0	186.1	184.2 c
NT	fall	184.3	197.1	196.1	192.8 ab
NT	spring	192.2	197.8	196.6	195.8 a
NT	fall+spring	194.4	191.4	183.5	189.8 abc
CD	none	175.8	196.0	184.0	185.3 bc
CD	spring	195.5	201.6	192.7	196.4 a
	MEAN[2]	186.2 b	195.9 a	190.0 ab	
			1993		
NT	none	89.6	149.1	167.4	135.3 cd
NT	fall	116.6	149.8	146.6	137.7 bc
NT	spring	145.4	147.6	159.1	150.7 ab
NT	fall+spring	137.5	161.7	147.9	149.0 ab
CD	none	89.0	129.8	145.5	121.4 d
CD	spring	153.9	156.4	148.2	152.8 a
	MEAN[2]	122.0 b	149.1 a	152.4 a	

1. NT = no-tillage CD = chisel/disk
2. Means followed by the same letter are not significantly different ($P \leq 0.1$).

Corn cultivar Pioneer 3140 was planted on 29 April, 1992 at 21,800 seeds A^{-1} in 36 inch rows with a ripple coulter no-till planter. Corn cultivar Pioneer 3279 was planted on 21 May 1993 at 23,100 seeds A^{-1}. Glyphosphate, 2,4-D atrazine, and alachlor were tank mixed with a non-ionic surfactant and water, at University of Kentucky Extension Service recommended rates, and applied at planting for weed control. Nitrogen fertilizer, as ammonium nitrate, was top-dressed by hand five to six weeks after planting. Corn yields were measured by hand harvesting 20 ft lengths from the middle two rows of each plot in mid-October in both 1992 and 1993. Yield data were corrected to 15.5% moisture.

Statistical analyses were performed with the use of the Statistical Analysis System (SAS Institute, 1989). The General Linear Model (GLM) procedure was used for the analysis of variance, and mean separations among treatments were determined by least significant difference (LSD 0.10).

RESULTS AND DISCUSSION

Corn grain yields for 1992 are presented separately from 1993 because of the large yield difference due to the growing season. Figure 1 illustrates the differences in precipitation and evaporation that occurred. including long-term average values for comparison. 1992 was a better growing season in Kentucky, with precipitation exceeding or matching evapotranspiration in July and August. Corn yields, averaged across all treatments, were 191 bu A^{-1}. 1993 was a fairly normal growing season, in that potential evaporation generally exceeded precipitation. Average corn yields were 141 bu A^{-1}.

Statistical analysis of 1992 and 1993 yield data showed significant differences ($P \leq 0.1$) to the main effect of manure-timing-tillage treatments and N fertilizer rate treatments. In 1993 the manure-timing-tillage by N rate interaction was also significant, but this was not the case in 1992. Tillage method alone (chisel/disc vs. no-tillage) did not have a significant effect on corn yield in either year.

The spring manure treatments resulted in significant ($P \leq 0.1$) average yield increases over the non-manured controls in both years (Table 2). In 1992 and 1993, no significant differences were found due to the timing (fall, spring, or fall plus spring) of manure application, though there was a trend for higher yields with the spring manure application. This is especially apparent in 1993 (Table 2). The no-tillage fall plus spring manure treatment was not significantly different from the fall only or spring only treatments in either year. Yields at 150 lb N A^{-1} were depressed more consistantly by the excessive fertilizer N availability in this system (Table 2). and this may account for the lower average yield in both seasons. This suggests that doubling up on manure in one season offered no added benefit to the corn crop.

Nitrogen fertilizer caused a significant ($P \leq 0.1$) average yield increase in both years, but the yields obtained at the 75 lb and 150 lb N A^{-1} rate were not significantly different from one another (Table 2). A significant N rate by manure interaction occurred in 1993. In that year, plots receiving manure showed very little response to fertilizer application, while unmanured plots did respond to fertilizer N. In 1992 the interaction was not significant, possibly because of the abundant precipitation in the summer and because this was the first year of the study and considerable N mineralization occurred when the killed grass sod decomposed. To illustrate the N rate by manure interaction, regression equations were calculated for the observed yield response in yield to fertilizer N in manured and non-manured plots (Table 3). Because neither tillage nor time of manure application had a significant effect in either year, only the manured and the non-manured yield responses are shown (Figure 2).

Based on the yield response curves shown in Figure *2*, maximum yields and the amount of fertilizer N needed to achieve maximum yields were calculated (Table 4). The nitrogen fertilizer equivalency (NFE) of the manure was estimated by determining the difference in the amount of N fertilizer needed to attain maximum yields with and without the manure application, as suggested by Smith et al. (1987). In 1992 and 1993, the NFE was 50 and 28 lb A^{-1}, respectively. The rather low NFE in 1993 is interesting in that the spring manure application that year had an estimated N content of 392 lb A^{-1} (Table 1). This suggests that a substantial loss of nitrogen occurred, probably through volatilization, denitrification. and/or leaching, before the corn was mature enough to utilize the extra nitrogen.

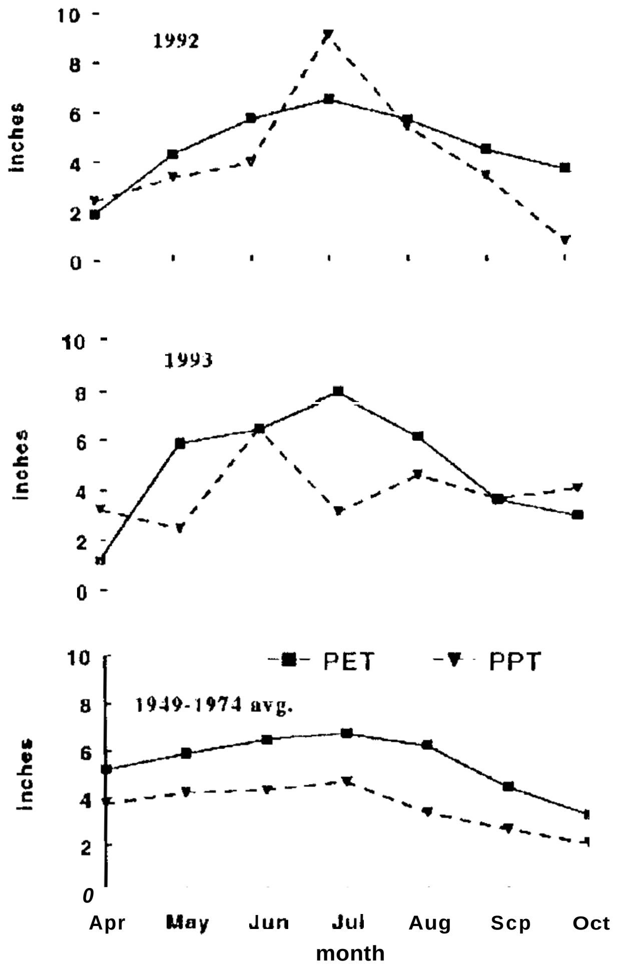

Figure 1. Average, 1992, and 1993 open pan potential evapotranspiration (PET,) and precipitation (PPT) for the Kentucky Agricultural Experiment Farm, Lexington, KY.

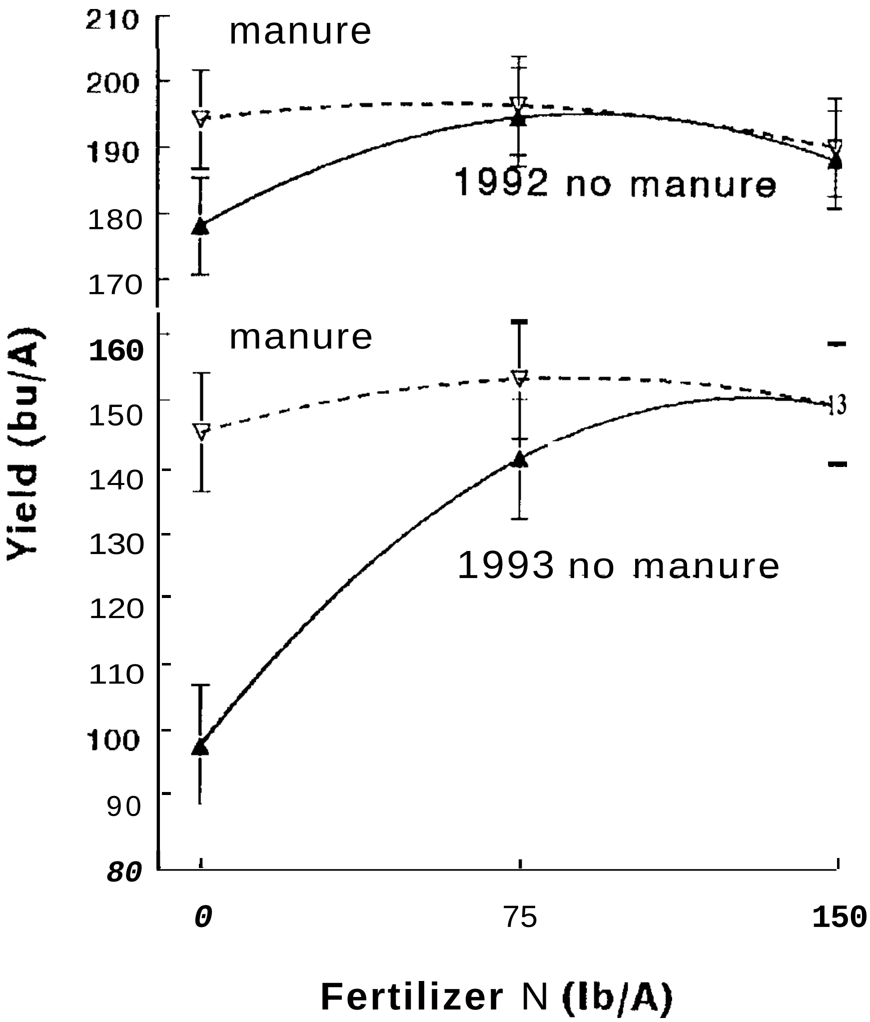

Figure 2. Corn grain yield response for manured and non-manured treatments. Error bars are ± one standard error.

Table 3. Regression equations for corn grain yield (y) as a function of fertilizer N rate (X) for manured and non-manured treatments for each year.

Year	Manure	Equation	R	CV[1] (for y)
1992	none	$y = 178.2 + 0.38x - 0.002x^2$	0.52*	6.5
	yes	$y = 194.3 + 0.09x - 0.001x^2$	0.22	5.5
1993	none	$y = 98.4 + 0.83x - 0.003x^2$	0.80**	14.2
	yes	$y = 145.6 + 0.22x - 0.001x^2$	0.28	9.7

*,** Significant at 0.05 and 0.01 probability levels, respectively.
1. CV = coefficient of variation.

Table 4. Maximum yields and N fertilizer levels calculated to achieve optimum economic returns.

Year	treatment	Max yld[1] bu A^{-1}	N rate[2] lb A^{-1}	PI[3] Py/Px	Max N[4] lb A^{-1}	Savings[5] \$ A^{-1}
1992	manure	196	45	0.10	0	15.48
1992	none	196	95	0.10	70	
1993	manure	158	110	0.10	60	13.64
1993	none	155	138	0.10	122	

1. Maximum yields calculated from regression equations.
2. Pounds of N per acre needed to achieve maximum yields.
3. PI = price index. Py = $2.20 per bushel and Px = cost of urea fertilizer at $199 per ton ($ 0.221 per lb N). ***Source:*** Ky *Ag. Stats.*, 1992.
4. Pounds of N per acre needed to achieve maximum economic yields.
5. Savings per acre from using manure based on maximum economic yields and urea as the N source. Does not include hauling and spreading costs.

To determine the fertilizer N rate to achieve maximum economic yields, a price index was calculated by dividing the cost of N (per pound) by the selling price of corn (per bushel) and setting this index equal to the first derivative of the regression equations for manured and non-manured plots:

$$Py/Px = B + 2Cx$$

where B and C are constants in the regression equation ($Y = A + Bx + Cx^2$), Py is \$0.221 lb^{-1} using urea as the N source. and Px is \$2.20 bu^{-1} of corn (KY Ag Stats., 1992). Urea was used for the price of N in the fertilizer (as opposed to the ammonium nitrate used in this study) because urea is the most common N fertilizer used on corn in the state of Kentucky. The 1992 price index was also used for 1993 because this is the most recent data available. The fertilizer rates calculated to achieve maximum economic returns are presented in Table 4. The amount of N fertilizer needed to achieve maximum economic yields was substantially reduced in the manured plots. Nitrogen fertilizer was not needed in 1992, probably due to the optimal growing season and abundant N mineralization that may have occurred. By reducing rates of fertilizer N to compensate for inputs from the manure, the average nitrogen equivalent value from manure was \$15.48 A^{-1} in 1992, and \$13.64 A^{-1} in 1993.

CONCLUSIONS

This experiment was conducted to observe the effects of tillage, nitrogen fertilizer, and timing of manure application had on continuous corn yields. No differences were found between no-tillage and chisel/disk tillage treatments in either year. Application of manure resulted in significantly greater yields in both years, but the timing of manure application had no significant effect. There was a tendency, however, for spring manure treatments to have higher yields, especially on chisel/disked plots. The lack of response to tillage method and manure timing may be partly explained by the fact that 1992 was the first year of the study and enough sod mineralization occurred, along with abundant precipitation, to mask treatment effects.

Nitrogen fertilizer inputs resulted in significant yield increases up to the 75 **lb** A^{-1} rate in unmanured plots in both years. However, in manured plots there was little response to N rate. Based on regression equations for corn yields as a function of fertilizer N rate and using urea as the fertilizer N source, manure's monetary contribution was calculated to average \$14.56 per acre. The results from this study show that manure does significantly increase yields in conservation tillage systems while allowing for a reduction in the fertilizer N required. The results also suggest that spring is a better time to apply manure than in the fall.

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