AN ECONOMIC ANALYSIS OF CARRYOVER EFFECTS OF MANURE NITROGEN ON CORN SILAGE

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ABSTRACT

Results from a four year manure application on corn silage experiment were evaluated from an economic perspective. Four levels of manure applicatin were applied to corn silage land using a random block design from 1993 to 1996. The experiment was designed to evaluate carryover effects of the manure on corn silage.

Manure impact on soil was also evaluated in the study. Applications of manure add carbon as well as other nutrients to the soil. Soil organic C contents increased in the surface 7.5 cm of soil from approximately 1.2% to 1.7% after three years of manure application at the 336 kg manure-N/ha rate. Soil total N and Mehlich I extractable P have also increased in soils receiving manure results in carryover to succeeding crops.

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INTRODUCTION

Dairy production in Tennessee amounts to 14.7 per cent of the cash farm marketing in the state, second only to cattle and calves. The 196,000 cows in the state produce milk and meat which is sold for more than 300 million dollars per year. Further, as many as 97 per cent of the dairy farms have land within one mile of the facility that can utilize manure in crop production and help prevent water contamination (Montgomery and Hoppers, 1992). The significant changes in the dairy industry have led to increased confinement of cattle. As a result, the manure which was being distributed naturally when the animals were pastured on fields, is concentrated in the lots (Montgomery and Hoppers, 1992). One method of dairy waste disposal occurs when using manure as fertilizer in crop production. If done correctly, environmental impacts of the waste might be reduced through the avoidance in the loss of nutrients to surface and ground water (Van Horn et al., 1994). As many as 97 per cent of the dairy farms in the state have land within one mile of the facility that can utilize manure in crop production (Montgomery and Hoppers, 1992).

Sutton et al. (1978) found that maximum corn yield obtained from manure application was comparable to yields obtained with recommended levels of inorganic nitrogen. Safley et al. (1985), in their study comparing use of slurry dairy manure as a corn nutrient to application of commercial fertilizer at levels recommended by soil testing, found that manure supplied sufficient nutrients to produce comparable corn (Zea mays L.) silage and grain yields. Manure N must to be mineralized before it becomes for use: therefore, only a portion of it is available to the crop in the year of application, with remainder being carried over to subsequent years (Klausner et al.,1994). Effective utilization of feed lot waste in crop production should account for its nutrient content, mineralization rate as well as management, hauling and spreading costs (Araji and Stodick, 1990). Information is limited on the effect of nutrient carryover of different durations and application cost differences on the economically optimum levels of manure application.

This Tennessee study addresses these issues. The specific objectives of this study were to estimate yield response function for manure N applied to corn silage in the current and/or previous year(s) and to compare optimum returns above application cost for spreaders of different capacities used to apply manure. Additionally, we will discuss these findings relative to the environmental impacts of manure application.

MATERIALS AND METHODS

Experimental Site

Data were obtained from a four-year experiment at the Martin Agricultural Experiment Station in Martin, TN that began in 1993 and ended in 1996. The experiment was conducted to evaluate the carry-over effect of manure on corn silage yields and soil properties. Eighteen treatments in a randomized complete block design with 4 blocks were originally used in the study. For this paper, ten of the treatments were evaluated: application of no manure-N in any year; application of 112 kg ha^{-1} (100 lbs ac^{-1}), 224 kg ha^{-1} (200 lbs ac^{-1}), or 336 kg ha^{-1} (300 lbs ac^{-1}) of manure-N in 1993 only; application at these three levels in 1993 and 1994 and lastly, the same levels of application for three years, 1993-1995. The source of manure-N was dairy slurry from a concrete holding tank. Manure was analyzed for total N prior to application to determine application rates. The manure was applied to the soil surface as a slurry. No-tillage corn silage was grown on all plots during all the four years. Silage yields were recorded from each plot in August to September of each year. Because silage yields in 1993 were influenced by residual N from previous years (the area had previously had a cover of hairy vetch (*vicia villosa* Roth)), the yield observations for 1993 were excluded from the analysis.

Silage yield data and manure-N application rates were used to estimate yield response functions. The economic analysis of the carryover effect of manure required the estimation of yield response functions and the calculation of dairy slurry application costs for different capacity spreaders. To facilitate manure spreader capacity evaluations, an average slurry N content of 0.25% was used (average for manure applied over life of this study).

Yield response functions

The residual effect of manure with the passage of time produced different yield response functions with different intercepts and slopes among the treatments. The following quadratic yield response model for manure N was derived.

$$Y = b_0 + b_1*N + b_2*N^2 + b_3*M_1 + b_4*M_2 + b_5*M_3 + b_6*M_4 + b_7*M_5 + b_8*M_6 + b_9*M_7 + b_{10}*N*M_1 + b_{11}*N^2*M_1 + b_{12}*N*M_2 + b_{13}*N^2*M_2 + b_{14}*N*M_3 + b_{15}*N^2*M_3 + b_{16}*N*M_4 + b_{17}*N^2*M_4 + b_{18}*N*M_5 + b_{19}*N^2*M_5 + b_{20}*N*M_6 + b_{21}*N^2*M_6 + b_{22}*N*M_7 + b_{23}*N^2*M_7 + b_{24}*W + b_{25}*W*N + b_{26}*W*N^2 + U \quad [1]$$

Where Y = corn silage yield in tons per acre; N = manure nitrogen applied in pounds per acre; M_1 = 1 if the crop was harvested in 1994 with manure application in 1993 and 1994 and 0 otherwise; M_2 = 1 if the crop was harvested in 1995 with manure application in 1993 and 0 otherwise; M_3 = 1 if the crop was harvested in 1995 with manure application in 1993 and 1994 and 0 otherwise; M_4 = 1 if the crop was harvested in grown in 1995 with manure application in 1993,1994 and 1995 and 0 otherwise; M_5 = 1 if the crop was grown in 1996 with manure application in 1993 and 0 otherwise; M_6 = 1 if the crop was grown in 1996 with manure application in 1993 and 1994 and 0 otherwise; M_7 = 1 if the crop was grown in 1996 with manure application in 1993, 1994 and 1995 and 0 otherwise; W = total rainfall in August of the harvest year in inches; U is a random error term; and b_0-b_{26} are parameters to be estimated by regression.

The dummy variables M_1 to M_7 generate different intercepts for the response model and the interaction terms M_1*N, M_1*N^2...M_7*N^2 allow the response model to have different slopes depending upon the duration of the nutrient carryover. The interaction term $W*N$ and $W*N^2$ cause a change in the slope depending upon August rainfall.

Cost of application of dairy slurry

For the purpose of comparison, five spreader types with different capacities – 3.6, 4.9, 6.2, 6.8, and 9.2 metric tons -- along with the tractors of appropriate horsepower were considered (John Deere Agricultural Equipment Sales Manual, 1994). Using the APAC Budgeting System (Slinsky et al., 1996), the total cost of covering an acre of land with a single load of manure was estimated for each capacity spreader. Using this information along with the information on the total quantity of N that can be applied with dairy slurry (at 0.25% N), in a single pass, the cost of applying N was calculated. The assumptions made were: (i) a spreader width of 50 feet and an operating speed of 4 miles per hour (ii) availability of manure on the farm where it is applied and (iii) zero price for slurry.

Optimum level of manure N application

Using the estimated response functions, economically optimum levels of manure N applications for i) 1993; ii) 1993 and 1994; and iii) 1993, 1994 and 1995 were calculated. These optimum N applications were defined as the ones that would yield the maximum returns above application cost, in terms of 1993 dollars, from silage production during the three consecutive years, 1994-1996. The returns were maximized using the following equation:

$$Z_{k,j} = Max \left| \sum_{i=1994}^{1996} (p * Y_{k,i}) / (1+r)^{i-1993} - \sum_{n=0}^{k-1} C_j / (1+r)^n \right| \quad (2)$$

where $Z_{k,j}$ = optimum returns above application cost, in 1993 dollars, from the crop grown in 1994, 1995 and 1996 using the jth spreader to apply manure for k number of year(s); j = 1 to 5 for different spreader capacities; k = the number of years of N application which could be 1 (if N is applied in 1993), 2 (if applied in 1993 and 1994) or 3 (if applied in 1993, 1994, and 1995); $Y_{k,i}$ = corn silage production in the year i, as a function of N applied in k number of year(s). C_j = cost of N application associated with the use of jth spreader type; P = price of silage and r = the rate of interest used to discount the returns to the 1993 level. This analysis assumes P (corn silage price)[1] = $ 27 per ton and r (the interest rate) = 8.5%.

It may be noted that C_j does not change in a continuous manner with the change in the level of N application. In other words, for the application of any quantity of N up to the maximum quantity that can be carried in a single load with a given capacity spreader, the cost of application equals the total cost of using that spreader for making a single pass. For the application at any level above the full capacity of the spreader up to two times its capacity, the cost would be two times the cost for a single pass and so on..

RESULTS AND DISCUSSION

The preliminary analysis showed that the slopes of the response functions (Eq.1) for nutrient carryover scenarios of different durations, were not significantly different (Table 1). The estimated equation yields different response functions for different carry-over scenarios; one for each of the dummy variables, M_0, M_1Y..M_7. When $M_1 = M_2$ = Y.= $M_7 = 0$, M_0 takes on the value 1 and the resulting response function represents the case of crop production in 1994 with manure application in 1993.

The carry-over effect of manure applied in 1993 and 1994 showed that yield per acre decreased by 1.5 tons in 1995 and 1.9 tons in 1996 compared to 1994 yields. Similarly, application for three years, from 1993 to 1995, produced 0.9 ton less silage per acre in 1996 compared to 1995 yields. The carry-over effect of manure applied in 1993, however, showed a different trend. It is also evident from the Table 3 that as the number of applications increases, the larger is the carryover effect on the crop in any given year, and hence the higher the production per acre. For example, manure application in three consecutive years, 1993-1995 produced 1.4 ton more silage per acre in 1996 compared to manure application in only two years, 1993 and 1994 and 1.5 ton more silage per acre compared to the application only in 1993[2].

Table 4 presents the cost of application of a full load of dairy slurry over an acre of land in a single pass with different capacity spreaders. It can be seen from the table that the cost of making a single pass increases as the capacity of the spreader increases. However, as the capacity increases, the total amount of nitrogen from slurry that can be applied on an acre of land in a single pass also increases. As a result, the cost of applying a pound of nitrogen, in a given pass, decreases with an increase in the spreader capacity.

Table 5 shows the economically optimum levels of manure-N application as well as

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[1]Information on silage price was obtained from personal communication with Dr. Montgomery, Head Dairy Extension, University of Tennessee.

[2] Rainfall was placed in the model to tract different yearly growth potentials that occur as a result of changes in moisture. In one case, it appears that this variable was not sufficient as a higher yield occurred on plots with 2 years of no application when compared to plots with only one year of no application.

the optimum returns above the N application cost associated with the use of different spreaders under different application scenarios. The data indicate that application of 240 lbs of N per acre in 1993, using a 4 ton capacity spreader, and producing corn silage during the next three years, will yield a return of $261.45 per acre above application cost, in 1993 dollars. It can also be seen that the optimum quantities of applied manure-N change and the returns increase as one uses a larger capacity spreader under any scenario of manure application. However, the increase in returns will be most evident when increasing spreader capacity from four to 10.1 tons.

Comparing the economic outcomes of applying manure-N under the three scenarios, two things can be noticed. First, with the use of any capacity spreader, returns can be significantly increased by applying N more often. For example, a farmer applying N only in the current year, using a 4-ton capacity spreader, can increase his returns by about $55 by applying N in the current as well as the next year; returns can be increased by $111 by choosing to apply in the current and the next two years. Second, the difference in the returns due to spreader capacity will become more pronounced with multiple applications. For example, the difference in the returns from a 4-ton capacity spreader and a 10.1-ton capacity spreader is $8.28 per acre when manure is applied only in the current year and $18.79 when it is applied for three years. The analysis shows that while the application of 240 pounds of nitrogen (48 tons of slurry) with a 4 ton capacity spreader in the current year brings the lowest return of $261.45 per acre in the current dollars, applying at the rate of 202 pounds of nitrogen (40.4 tons of manure) in the current and the next two years with a 10.1 ton capacity spreader, will bring the highest returns of $ 391.24 per acre.

The economic analyses done here indicate that the application of manure-N ranges from approximately 200 to 260 lbs acre^{-1}, depending on the number of applications and spreader size. Water quality monitoring on adjacent plots at the Martin location (Mullen et al., 1993) indicate that the impacts of approximately 250 lbs of manure-N acre^{-1} on subsurface losses of NO_3-N towards shallow groundwater are less than those from inorganic N at recommended application rates. Figure 2 shows the cumulative loss of nitrate-N for 1997 from plots receiving four different rates of manure. Data for 1992 through 1996 are similar to 1997 (data not shown). The 113 lbs of manure-N acre^{-1} rate has resulted in significantly lower N losses than the195 lbs N acre^{-1} as ammonium nitrate treatment. Applications of 225 and 338 lbs manure-N acre^{-1} generally result in N losses no different than those from the inorganic N treatment.

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