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STAFF PAPER

AN ECONOMIC COMPARISON OF COMPOSTED MANURE AND COMMERCIAL NITROGEN WITH IMPERFECT INFORMATION

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ABSTRACT

The economic feasibility of fertilizing irrigated grain sorghum with composted manure is evaluated using net return budgeting and production function analysis. Although the use of compost is technically feasible, the economic analysis indicates that compost does not comprise a large percentage of the nitrogen source in the profit-maximizing combination with commercial fertilizer.

Key Words: Composted manure, commercial nitrogen, net returns budgeting, production function analysis, irrigated grain sorghum.

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INTRODUCTION

In recent years, increases in groundwater nitrate levels and decreases in soil organic matter have been attributed to the overuse of commercial fertilizers in crop production. The use of raw animal manures, instead of commercial fertilizers, presents another set of problems. Raw manure has little dry matter (<20%) and is expensive to transport. This encourages high application rates on cropland near the source, which may result in high nitrate levels in soil, runoff, leachate (Evans et al; Mathers et al.); odor; and transport of viable weed seeds. Composting manure before use may reduce these problems.

Composting raises the dry matter level of manure (20% to 80%), resulting in higher nutrient concentration per pound of manure. This reduces transportation and handling costs. Composted manure has less odor and better physical properties (loose, friable texture with uniform particle size) than fresh manure (Schlegel) and lessens weed seed viability (Wiese et al.). It may also increase soil organic matter. Although the use of composted cattle manure as an alternative nitrogen (N) source has potential benefits, it also involves management problems. Farmers located some distance from a source are at a disadvantage in terms of hauling costs. Also, the volume of compost needed to obtain similar yield results as provided by commercial fertilizers could be high.

Results from yield studies have not shown definite positive or negative impacts from use of composted manure. Brinton concluded that no significant difference in maize yields resulted from using compost as opposed to raw manure. Shapiro et al. reported that compost use increased soybean dry matter content, but differences in yields were not significant. Schlegel concluded that compost alone will increase grain sorghum yield, but larger increases occur when a combination of compost and commercial N is used. He found that 1 ton of compost and 12 pounds of commercial N produced the same yields. However, none of these studies provide an economic analysis of using composted manure and many of them are not appropriately designed to address this issue. Experimental designs have focused on determining the technical feasibility of compost as a N source rather than its economic feasibility.

The purposes of this study are to evaluate the economic feasibility of using composted manure and to recommend changes in the experimental designs typically used in field studies of compost, so that better economic decisions can be derived from the data. Data from a recently completed field study at the Southwest Kansas Research-Extension Center are used in this analysis. The field study provides agronomic results of 20 different combinations of composted manure and commercial N in the production of flood-irrigated grain sorghum.

DATA AND PROCEDURES

Yield data and cropping practices are from Schlegel's study performed at the Southwest Kansas Research-Extension Center in Tribune, Kansas, initiated in 1987 and completed in 1990. Twenty combinations of four rates of commercial N (0, 55, 110, and 165 pounds per acre) and five rates of composted feedlot manure (0, 0.9, 1.8, 3.6, and 7.2 tons per acre) were applied to irrigated grain sorghum. When composted manure or commercial N was individually applied, yields increased with each increase in application rate. Combinations of compost and commercial N generally increased yields as one or both components increased, except when commercial N increased from 110 to 165 pounds per acre. This additional increment reduced yields for three of the four strategies when compost was also used. The purpose of the field study was to examine feedlot manure compost as a N source for irrigated grain sorghum and the effects of annual compost and commercial N applications on soil chemical properties and yield.

Two methods of economic analysis are employed in this study. The first is a budgeting analysis based on the yield results from the field study. The second method uses the yield results to estimate a production function. Under each method of analysis, the most economic combination of compost and commercial fertilizer is found, based strictly on their contribution to crop yield and net return.

Budgeting Analysis

Net returns over variable cost for each of the 20 compost/commercial-N combinations are compared. Net returns over variable cost are used rather than returns over total cost, because fixed costs are assumed to be identical among all compost and commercial-N combinations. Individual farmers normally would not need to purchase additional equipment for composting and application, because the manure is composted at commercial feedlots and applied at delivery, using delivery equipment.

Costs. Variable costs for grain sorghum production, with the exception of seed, chemicals, commercial N, compost, and application costs, are based upon budgets developed by Warmann and Schlender and Nelson and Dhuyvetter. Irrigation costs are estimated using a computer program developed by Williams et al. Seed and chemical costs are based upon the actual rates used in the experiment station field study. Fertilizer costs for commercial N are $0.23 per pound for solid ammonium nitrate and $0.15 per pound for anhydrous ammonia. Solid ammonium nitrate is the form of commercial N used in the field study. Compost costs of $6.00 per ton are based on the actual price charged to farmers in the area by a commercial compost dealer (Unruh). This compost price results in a value of $0.50 per pound of N in compost.

We assumed that all machinery and irrigation operations are performed by the farm operator except for applications of commercial-N, compost, and herbicide. These activities are assumed to be custom hired. Custom hire for compost application is $5.00 per 3 tons for cropland within 50 miles of a source (Unruh). Custom hire rates for commercial-N and herbicide applications were obtained from Kansas Agricultural Statistics.

Gross Returns. Gross returns are based on the market price for grain sorghum and government deficiency payment for a stated program yield. A market price of $1.50 per bushel is assumed. Most grain sorghum producers in western Kansas participate in the federal government's commodity program and receive deficiency payments. The deficiency payment is calculated using formulas from Berends et al. and is based upon 1991 commodity program values. The projected deficiency payment used in the analysis is $0.96 per bushel. The total amount of government payments (per acre) a producer can receive is equal to the deficiency payment (per bushel) multiplied by the program yield (bushels per acre). The program yield in this study is assumed to be 87 bushels (average yield with zero compost and 110 pounds per acre of commercial N). Gross return is the sum of market returns and government payments. In this study, government payments are the same for all treatments, because the program yield is currently fixed by farm program provisions.

Production Function Analysis

Although budgeting analysis can provide useful information as to the general profitability of inputs, it is constrained by the actual input levels used in the field study. Optimum levels of input use may be incorrectly identified because of this constraint. A production function approach allows an infinite number of input combinations and associated yields to be considered.

Based on production theory, net returns are maximized when the value of marginal product for an input (VMP_i) is equal to the input's cost (P_i):

$$VMP_i = P_i. \tag{1}$$

When more than one input is used the production process, equation (1) can be expanded to show:

$$VMP_i/VMP_j = P_i/P_j, \tag{2}$$

or,

$$MRTS_{i,j} = P_i/P_j. \tag{3}$$

This equality states that profits are maximized when the marginal rate of technical substitution (MRTS) for two inputs equals the inputs' price ratio. In this study, the inputs are commercial N and composted manure, and the price of each is known.

A quadratic production function is used to estimate the marginal products of the inputs. A quadratic function is estimated because the field study data exhibit both Stage II and Stage III of production. The model is defined as:

$$Y_i = \beta_0 + \beta_1 N_i + \beta_2 N_i^2 + \beta_3 C_i + \beta_4 C_i^2 + \beta_5 (N_i * C_i) + \beta_6 YR87_i + \beta_7 YR88_i + \beta_8 YR89_i + e_i \quad (4)$$

where,

- Y = bushels of irrigated grain sorghum produced,
- N = pounds of commercial nitrogen,
- C = tons of composted manure,
- YR87 = dummy variable for year 1987,
- YR88 = dummy variable for year 1988,
- YR89 = dummy variable for year 1989,
- e = error term, and
- β = parameters to be estimated.

The model is estimated using ordinary least squares (OLS). Years are included to capture general characteristics that may cause year to year fluctuations in yield (e.g., temperature). The base year is 1990. Although a Chi-Squared test showed little heteroscedasticity (P-value = .7114), White's estimator is used to adjust the standard errors of the parameters to provide more precise estimates.

RESULTS AND DISCUSSION

Budget Analysis

Table 1 presents the budgets for a grain sorghum producer. These budgets show that increases in net returns are not accompanied by increases in yields associated with higher compost levels. When compost is the only available N source, the most profitable return ($51.17 per acre) occurs at the zero compost level (Treatment 1, Table 1). When only commercial N is available, the largest return ($70.03 per acre) occurs at a N level of 55 pounds per acre (Treatment 2, Table 1).

The largest return ($72.60 per acre) for a combination of compost and commercial N is with Treatment 6, using 55 pounds per acre of commercial N and 0.9 tons per acre of composted manure. The lowest return ($13.24 per acre) is from Treatment 20, which has the highest application levels of both inputs. Although the net return of Treatment 6 suggests that use of compost is profitable, the additional 10.8 pounds per acre of N provided could be acquired at less cost from commercial N. Unfortunately, the field study design does not allow further economic analysis using budgets to be performed.

The field study design also does not allow economic comparisons of yields and net returns for equal amounts of available N from either source. Treatments do not represent this situation; instead the N sources were varied by regular increments, allowing the total amount of available N to vary across treatments. Therefore, individual budgets cannot be compared across treatments to determine the most profitable combination of inputs to use, but only to indicate which of the combinations studied are most profitable. This is often a limitation of experimental designs used in field studies of nutrient sources from which cursory economic results are obtained and used. Economic analysis using budgets to estimate net returns from such studies should be interpreted with caution.

Sensitivity analysis with respect to commercial nitrogen price is performed (Table 2). When the price of solid ammonium nitrate is doubled from $.23/lb. to $.46/lb. the strategy that uses 55 lbs. per acre of commercial N and 0.9 tons of compost has the highest net return. This is the same treatment that had the highest net returns under the previous prices.

Production Function Analysis

The OLS regression results are presented in Table 3. The coefficients on all variables and the overall model's explanatory power are significant. From the regression results, the VMPs for nitrogen (N) and compost (C) are calculated, and the profit-maximizing conditions of equation (3) are found. The VMPs are calculated as:

$$VMP_n = P_s*(\partial Y/\partial N) \quad (5)$$

and

$$VMP_c = P_s*(\partial Y/\partial C) \quad (6)$$

where, P_s is the price of grain sorghum, $2.46 per bushel ($1.50/bu. plus $.96/bu. deficiency payment). The price of commercial N (P_n), $0.284, and the price of compost-C (P_c), $9.31, include custom application changes. Levels of N = 97.11 pounds per acre and C = 2.30 tons per acre (27.7 lbs. of available N per acre) were found to satisfy equations (2) and (3) (Table 4). The price of compost ($9.31 per ton) is based on the mean application charge for compost. Two additional compost prices are included, because the application charge is per acre and, therefore, the input cost varies by tonnage applied. For purchasing and custom applying compost, $8.56 per ton is the lowest possible cost; $12.25 is the highest.

The costs of $12.25 per ton for compost and $.309/lb for N are equivalent to the actual costs including all application and opportunity cost charges under Treatment 6 in the budget analysis. Given these costs, the resulting profit-maximizing combination of inputs is 106.54 lbs. of commercial N and .04 tons of compost. The closest combination of inputs used in the actual field trial was 110 lbs of commercial N and 0.0 tons of compost. This input combination had the sixth highest net return. The production function is also used to estimate the yield for each combination of inputs from the field study. When the estimated yields are used in the budget analysis, the most profitable input combination is 110 lbs. of N and 0.0 tons of compost. Thus, the budgeting and production function results are in general agreement. The use of compost does not appear to be economically feasible.

An alternative commercial-N source is anhydrous ammonia at $0.178 per pound. The profit-maximizing combination of compost and anhydrous is included in Table 3 for comparison. The cheaper commercial-N source causes approximately a 20 percent decrease in the use of compost, when its cost is $9.31 per ton. If compost cost is $12.25 per ton, only anhydrous ammonia is selected.

The production function analysis provides a somewhat more accurate report of the profit-maximizing combination of compost and commercial-N. Although production function analysis can consider numerous input combinations, it has difficulty capturing the impacts of deficiency payments and drying costs on the VMP. This can be attributed to the fact that deficiency payments are not paid on all bushels, and net returns are a function of drying costs, which also vary with yield. The profit-maximizing input combinations from the production function estimation, like those from the budget analysis, utilize a comparatively large amount of commercial N and a small amount of compost, although the commercial-N price is lower. This indicates that yields may be affected by more than the N content of compost. Other nutrients and soil-building characteristics cannot be valued in this analysis, because of the field study design.

DISCUSSION AND CONCLUSIONS

The field study data used in this study showed changes in yield due to the N provided by commercial N and compost. Results of the budgeting and production function analyses of those data are in general agreement that use of compost is not economically feasible. However, the field study design does not isolate other inputs from compost. Nutrients such as phosphorus, potassium, and micro-nutrients, as well as organic matter, affect the valuation of compost and economic results. This is a weakness of experimental design that should be addressed in future studies of alternative, sustainable, nutrient sources.

Traditional experimental designs of field studies of nutrients limit economic analysis in many ways. To analyze compost more formally as a N source, other nutrients should be held constant. If not, it is difficult to determine which nutrient affects yield and net returns. Also, equal amounts of available N from compost and commercial fertilizers are needed for effective comparisons. This would allow researchers to determine if any additional effects from compost are attributable to nutrients other than N. Ideally, the experimental design should control for all nutrient sources. Economic analysis could then determine the value of each compost component in addition to N. Compost should be studied as a multiple input rather than a N source alone. In the field study used in this analysis, no yield observations for comparable levels of available compost N were collected. In fact, only the compost application of 7.2 tons per acre (86.69 pounds of available N per acre) exceeds the 55 pounds per acre level of commercial N.

Further field investigations of compost, based on the more detailed experimental design suggested in this study, are needed to conduct a more complete economic evaluation of compost use in commercial agriculture.

Measurements of runoff and leaching potential of N from compost versus commercial sources would also be useful to determine the external impacts of compost versus commercial-N use on irrigated cropland.

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Table 1. Net Returns above Variable Costs for Twenty Different Combinations of Commercial Nitrogen and Composted Manure for Irrigated Grain Sorghum Production within 50 Miles of a Composted Manure Source in Western Kansas, 1987-1990.

	TREATMENT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	N (lbs)	0	55	110	165	0	55	110	165	0	55	110	165	0	55	110	165	0	55	110	165
	Compost (tons)	0	0	0	0	0.9	0.9	0.9	0.9	1.8	1.8	1.8	1.8	3.6	3.6	3.6	3.6	7.2	7.2	7.2	7.2
	COSTS																				
1	Fertilizer	$0.00	$12.65	$25.30	$37.95	$0.00	$12.65	$25.30	$37.95	$0.00	$12.65	$25.30	$37.95	$0.00	$12.65	$25.30	$37.95	$0.00	$12.65	$25.30	$37.95
2	Compost	$0.00	$0.00	$0.00	$0.00	$5.40	$5.40	$5.40	$5.40	$10.80	$10.80	$10.80	$10.80	$21.60	$21.60	$21.60	$21.60	$43.20	$43.20	$43.20	$43.20
3	Drying ($.10/bu)																				
3.1	Drying -- 1987	$6.90	$7.20	$7.90	$7.70	$6.90	$8.60	$8.50	$7.80	$7.20	$8.10	$9.00	$8.40	$7.20	$8.30	$8.60	$8.90	$8.70	$9.50	$9.60	$8.50
3.2	Drying -- 1988	$5.80	$10.00	$10.10	$11.30	$6.40	$10.70	$11.10	$11.30	$7.00	$11.20	$11.80	$10.80	$8.70	$11.80	$12.50	$11.70	$9.50	$12.20	$13.40	$12.70
3.3	Drying -- 1989	$4.00	$7.90	$8.20	$9.00	$5.10	$8.60	$9.80	$9.70	$5.80	$8.80	$10.30	$9.60	$6.00	$9.70	$9.80	$10.70	$9.60	$10.70	$11.00	$10.40
3.4	Drying -- 1990	$5.90	$7.80	$8.60	$9.20	$6.60	$8.90	$10.20	$10.60	$6.70	$9.80	$10.70	$10.50	$7.90	$10.50	$10.20	$10.60	$8.50	$11.10	$10.70	$10.40
4.1	Custom Hire -- Fertil	$0.00	$3.42	$3.42	$3.42	$0.00	$3.42	$3.42	$3.42	$0.00	$3.42	$3.42	$3.42	$0.00	$3.42	$3.42	$3.42	$0.00	$3.42	$3.42	$3.42
4.2	Custom Hire -- Com	$0.00	$0.00	$0.00	$0.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$10.00	$10.00	$10.00	$10.00	$15.00	$15.00	$15.00	$15.00
5	All Other Variable C	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82	$104.82
6	Interest on 1/2 of Variable Costs @ 12%																				
6.1	Interest -- 1987	$6.70	$7.69	$8.49	$9.23	$7.33	$8.39	$9.15	$9.86	$7.67	$8.69	$9.50	$10.22	$8.62	$9.65	$10.42	$11.20	$10.30	$11.32	$12.08	$12.77
6.2	Interest -- 1988	$6.64	$7.85	$8.62	$9.45	$7.30	$8.52	$9.30	$10.07	$7.66	$8.87	$9.67	$10.37	$8.71	$9.86	$10.66	$11.37	$10.35	$11.48	$12.31	$13.03
6.3	Interest -- 1989	$6.53	$7.73	$8.50	$9.31	$7.22	$8.39	$9.22	$9.98	$7.59	$8.73	$9.58	$10.30	$8.55	$9.73	$10.50	$11.31	$10.36	$11.39	$12.16	$12.89
6.4	Interest -- 1990	$6.64	$7.72	$8.53	$9.32	$7.31	$8.41	$9.25	$10.03	$7.64	$8.79	$9.60	$10.35	$8.66	$9.78	$10.52	$11.30	$10.29	$11.41	$12.15	$12.89
7	Total Variable Costs																				
7.1	TVC -- 1987	$118.42	$135.78	$149.93	$163.12	$129.45	$148.28	$161.59	$174.25	$135.49	$153.48	$167.84	$180.61	$152.24	$170.44	$184.16	$197.89	$182.02	$199.91	$213.42	$225.66
7.2	TVC -- 1988	$117.26	$138.74	$152.26	$166.94	$128.92	$150.51	$164.34	$177.96	$135.28	$156.76	$170.81	$183.16	$153.83	$174.15	$188.30	$200.86	$182.87	$202.77	$217.45	$230.12
7.3	TVC -- 1989	$115.35	$136.52	$150.24	$164.50	$127.54	$148.28	$162.96	$176.27	$134.01	$154.22	$169.22	$181.89	$150.97	$171.92	$185.44	$199.80	$182.98	$201.18	$214.90	$227.68
7.4	TVC -- 1990	$117.36	$136.41	$150.67	$164.71	$129.13	$148.60	$163.39	$177.22	$134.96	$155.28	$169.64	$182.84	$152.98	$172.77	$185.86	$199.69	$181.81	$201.60	$214.59	$227.68
	RETURNS																				
A	Yield Per Acre																				
A.1	Yield -- 1987	69	72	79	77	69	86	85	78	72	81	90	84	72	83	86	89	87	95	96	85
A.2	Yield -- 1988	58	100	101	113	64	107	111	113	70	112	118	108	87	118	125	117	95	122	134	127
A.3	Yield -- 1989	40	79	82	90	51	86	98	97	58	88	103	96	60	97	98	107	96	107	110	104
A.4	Yield -- 1990	59	78	86	92	66	89	102	106	67	98	107	105	79	105	102	106	85	111	107	104
B	Price Per Bushel	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50	$1.50
C	Deficiency Payment	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96	$0.96
D	Total Returns																				
D.1	TR -- 1987	$187.02	$191.52	$202.02	$199.02	$187.02	$212.52	$211.02	$200.52	$191.52	$205.02	$218.52	$209.52	$191.52	$208.02	$212.52	$217.02	$214.02	$226.02	$227.52	$211.02
D.2	TR -- 1988	$170.52	$233.52	$235.02	$253.02	$179.52	$244.02	$250.02	$253.02	$188.52	$251.52	$260.52	$245.52	$214.02	$260.52	$271.02	$259.02	$226.02	$266.52	$284.52	$274.02
D.3	TR -- 1989	$143.52	$202.02	$206.52	$218.52	$160.02	$212.52	$230.52	$229.02	$170.52	$215.52	$238.02	$227.52	$173.52	$229.02	$230.52	$244.02	$227.52	$244.02	$248.52	$239.52
D.4	TR -- 1990	$172.02	$200.52	$212.52	$221.52	$182.52	$217.02	$236.52	$242.52	$184.02	$230.52	$244.02	$241.02	$202.02	$241.02	$236.52	$242.52	$211.02	$250.02	$244.02	$239.52
	NET RETURNS OVER VARIABLE COST																				
E.1	NR -- 1987	$68.60	$55.74	$52.09	$35.90	$57.57	$64.24	$49.43	$26.27	$56.03	$51.54	$50.68	$28.91	$39.28	$37.58	$28.36	$19.13	$32.00	$26.11	$14.10	($14.64)
E.2	NR -- 1988	$53.26	$94.78	$82.76	$86.08	$50.60	$93.51	$85.68	$75.06	$53.24	$94.76	$89.71	$62.36	$60.19	$86.37	$82.72	$58.16	$43.15	$63.75	$67.07	$43.90
E.3	NR -- 1989	$28.17	$65.50	$56.28	$54.02	$32.48	$64.24	$67.56	$52.75	$36.51	$61.30	$68.80	$45.63	$22.55	$57.10	$45.08	$44.22	$44.54	$42.84	$33.62	$11.84
E.4	NR -- 1990	$54.66	$64.11	$61.85	$56.81	$53.39	$68.42	$73.13	$65.30	$49.06	$75.24	$74.38	$58.18	$49.04	$68.25	$50.66	$42.83	$29.21	$48.42	$29.43	$11.84
	Net Returns Information																				
	Mean	$51.17	$70.03	$63.25	$58.20	$48.51	$72.60	$68.95	$54.84	$48.71	$70.71	$70.89	$48.77	$42.77	$62.33	$51.71	$41.08	$37.22	$45.28	$36.06	$13.24
	Std. Dev.	$14.57	$14.77	$11.79	$17.99	$9.58	$12.19	$13.04	$18.30	$7.47	$16.24	$13.96	$13.02	$13.82	$17.70	$19.70	$14.02	$6.71	$13.46	$19.33	$20.75
	C. V.	0.2847	0.2108	0.1864	0.3091	0.1975	0.1679	0.1891	0.3336	0.1533	0.2296	0.1969	0.2669	0.3231	0.2840	0.3810	0.3413	0.1803	0.2972	0.5360	1.5674

Table 2. Sensitivity of Net Returns over Variable Costs ($/Acre) to a Doubling of the Price of Commercial Nitrogen Using Budget Analysis.

Rank	Price of Commercial N					
	$0.23/lb			$0.46/lb		
	N(lbs)	Compost (tons)	Net Return	N(lbs)	Compost (tons)	Net Return
1	55	0.9	$72.60	55	0.9	$59.19
2	110	1.8	$70.89	55	1.8	$57.30
3	55	1.8	$70.71	55	0.0	$56.62
4	55	0.0	$70.03	0	0.0	$51.17
5	110	0.9	$68.95	55	3.6	$48.92
6	110	0.0	$63.25	0	1.8	$48.71
7	55	3.6	$62.33	0	0.9	$48.51
8	165	0.0	$58.20	110	1.8	$44.07
9	165	0.9	$54.84	0	3.6	$42.77
10	110	3.6	$51.71	110	0.9	$42.13
11	0	0.0	$51.17	0	7.2	$37.22
12	165	1.8	$48.77	110	0.0	$36.43
13	0	1.8	$48.71	55	7.2	$31.87
14	0	0.9	$48.51	110	3.6	$24.89
15	55	7.2	$45.26	165	0.0	$17.97
16	0	3.6	$42.77	165	0.9	$14.62
17	165	3.6	$41.08	110	7.2	$ 9.24
18	0	7.2	$37.22	165	1.8	$ 8.54
19	110	7.2	$36.06	165	3.6	$ 0.86
20	165	7.2	$13.24	165	7.2	($26.99)

Table 3. Ordinary Least Squares Regression Results of Regressing Irrigated Grain Sorghum Yield on Commercial Nitrogen, Composted Manure, and Year with a Quadratic Functional Form.

Variable	Parameter Estimate	Standard Error	T-Statistic
Constant	57.8592	1.0552	54.8324[a]
N	0.5725	0.0567	10.1057[a]
N^2	-0.0021	0.0002	-8.4960[a]
C	7.3367	1.4292	5.1336[a]
C^2	-0.3094	0.1480	-2.0910[a]
N*C	-0.0219	0.0051	-4.2984[a]
Year 1987	-11.7000	2.3463	-4.9866[a]
Year 1988	12.2500	1.7893	6.8463[a]
Year 1989	-6.4500	1.6854	-3.8270[a]
Year 1990 (Base Year)			

F-Statistic = 48.801

Adjusted R^2 = .7516

[a] Indicates coefficients that are statistically significant using a 95% confidence level.

Table 4. Profit-Maximizing Levels of Commercial Nitrogen and Composted Manure at Different Compost and Nitrogen Prices Using Production Function Analysis.

P_n	P_c	Commercial N (lbs/ac)	Composted Manure (tons/ac)
$0.284	$ 8.57	93.99	2.90
$0.284	$ 9.31	97.11	2.30
$0.284	$12.25	109.52	0
$0.309	$12.25	106.54	.04
$0.178[a]	$ 9.31	109.75	1.85
$0.178[a]	$12.25	122.15	0

[a] An estimate of the profit-maximizing level using commercial N from an anhydrous ammonia source at $0.178 per pound including application charges is included for comparison, although anhydrous ammonia was not used in the field study.

Endnotes

1. The cost of $0.50/lb of N is based on the experimental design premise that compost is a substitute for N; all other nutrients are not valued. Therefore, the cost of compost was equal to the value of N in the compost. Schlegel reports that N made up 1.4% of the compost and assumes a 43% nutrient availability; this results in 12.04 pounds of available N per ton of compost; and a cost of $0.50/lb.