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Composting of Feedlot and Dairy Manure: Compost Characteristics and Impact on Crop Yields

Galen E. Erickson
University of Nebraska-Lincoln, gerickson4@unl.edu

Terry J. Klopfenstein
University of Nebraska-Lincoln, tklopfenstein1@unl.edu

Walker Luedtke
University of Nebraska-Lincoln

Mark Schroeder
Agricultural Research and Development Center, Mead

Chuck Francis
University of Nebraska-Lincoln, cfrancis2@unl.edu

See next page for additional authors

Authors
Galen E. Erickson, Terry J. Klopfenstein, Walker Luedtke, Mark Schroeder, Chuck Francis, and Gary Lesoing

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Galen Erickson
Terry Klopfenstein
Walker Luedtke
Mark Schroeder
Chuck Francis
Gary Lesoing[1,2]

Compost fertilization increased yields of irrigated corn and soybeans, dryland corn, wheat, and grain sorghum. The increased yield offset application costs for all crop rotations except soybeans.

Summary

Since 1993, approximately 17,600 tons of beef feedlot and dairy compost have been spread on 1,100 acres. Crop yields were measured to determine the impact of a one-time compost application by using no-compost check strips in large-scale production fields. Adding compost to irrigated corn, irrigated soybeans, and dryland corn acres significantly increased yields, with four-year average increases of 2.3, 1.5, and 2.7%, respectively. For all crops measured, the response to compost was greatest the first year following application and declined linearly in subsequent years. The increased yield from compost application offsets spreading costs using average prices for crops.

Introduction

Managing manure and nutrients is becoming increasingly important for agricultural producers. For these reasons, numerous projects were initiated at the University of Nebraska to help producers become more aware of the challenges with managing manure, and also the costs associated with nutrient management. The primary focus of this article is to summarize compost characteristics and average yield responses from a one-time compost application to irrigated corn and soybeans, or dryland corn, soybeans, wheat and grain sorghum.

Procedure

Composting was initiated in 1993 to handle manure from the 1500-head research beef feedlot and the 150-cow dairy at the University of Nebraska Agricultural Research and Development Center near Mead, Neb. Since then, compost as a waste management system has been evaluated by determining costs of composting, costs of spreading, nutrient recoveries during composting and yield impacts from compost amendment to soil. Research progress reports have been provided in previous beef reports (1996 Nebraska Beef Report, pp. 77-79; 1997 Nebraska Beef Report, pp. 88-91). However, until this past year, sufficient replication for detailed summaries of crop yield impacts from compost amendment were unavailable.

Yield differences from treatments were evaluated using both increased revenue and cost of treatments. Corn price was based on Nebraska Agricultural Statistics Service for marketing years from 1992 to 1998 or \$2.50 per bushel. The soybean price was also based on Nebraska Agricultural Statistics Service for marketing years from 1992 to 1998 which is \$6.05 per bushel.

Composting was done in windrows during the summer months (May to October) and was dependent on manure supply and timing. Once windrows were formed, samples were collected from random locations. Compost was considered finished when windrows no longer produced heat two to seven days after turning. Dairy manure was amended at the time of windrow formation with organic residue that varied from year to year. In 1998 and 1999, feedlot compost was amended with organic residue to increase carbon content and the C:N (carbon:nitrogen) ratios. After complete composting, windrows were again sampled. Samples were composited by time and by windrow and analyzed for DM, OM , N (nitrogen), P (phosphorus), K (potassium), and most mineral elements. Nitrogen recoveries were calculated using total ash as an internal marker and the following equation:

Nitrogen recovery = 100 x [(% ash before ÷ % ash after) x (% N after ÷ % N before)]. Ash and N concentrations are on a DM-basis.

Since 1993, approximately 1100 acres have received compost through this research project. Check strips, where no compost was applied, have been maintained in large-scale production fields by GPS/GIS technology to ensure strip identity and integrity. Yield data have been collected and summarized for compost produced from 1993 to 1998. Until 1997, compost application was targeted at 10 tons (as-is) per acre. In 1998 and 1999, compost application was increased to 20 tons (as-is) per acre. Fields were chosen based on Bray-P1 soil phosphorus test less than 15 ppm as the critical soil test value, and the availability of compost.

Yields were determined by collection of total weight from check strips (Figure 1) by using a 550 bu Brent (model 672) grain cart equipped with J-star load cells, or by truck scale. When weighing capability was unavailable, yields were determined by calibrated yield monitors (Agleader PF3000) from grain combines. Most of the corn yields and 50% of soybean yields were determined with weights from the grain cart, with the remaining soybean yields determined using yield monitors. Fields were

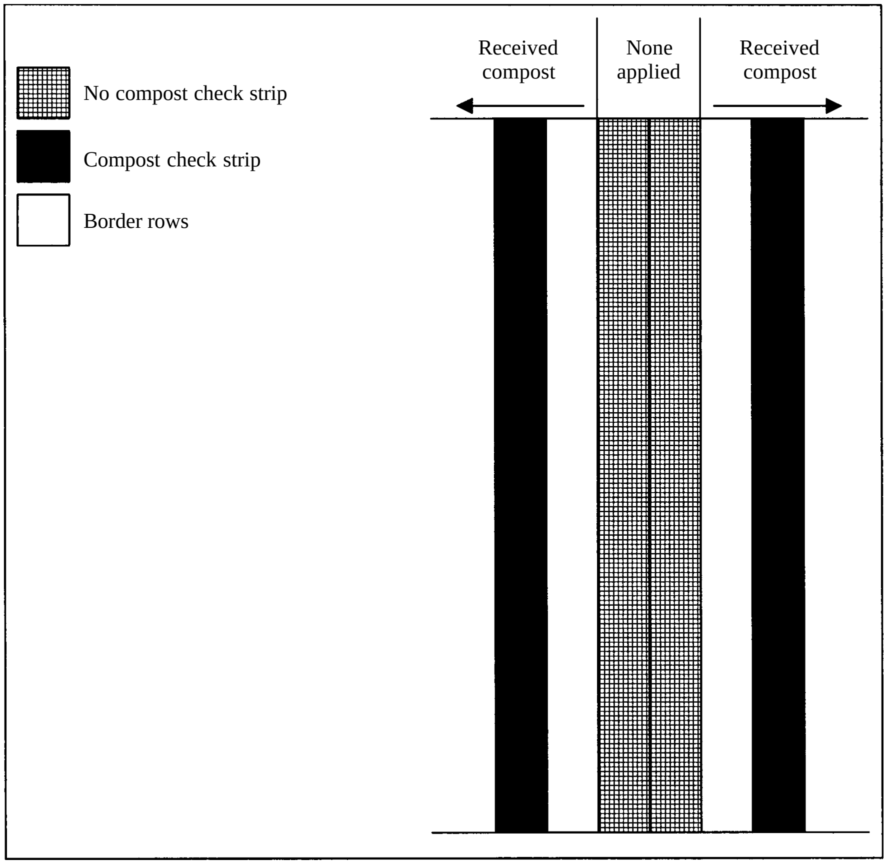

Figure 1. Diagrammatic representation of check strips for yield comparisons between compost treatment versus no compost treatment. Each strip represents an 8-row (20 foot) width which matches planting and harvest equipment.

Table 1. Compost nutrient composition and tonnage for 1993 to 1999. The year represents the summer that composting occurred.

Feedlot compost			Lb per ton of DM		
	Tons(as-is)	DM, %	N	P	N recovery
1993	2700	83.2	.2	6.7	
1994	600	77.3	16.0	10.0	64-77
1995	450	82.9	13.4	6.8	
1996	1450	77.4	16.1	14.5	84
1997	560	76.1	18.8	10.3	61
1998	1425	82.8	7.1	9.2	89
1999	900	71.8	13.6	8.0	84
average	1155	78.8	12.9	9.4	

Dairy compost			Lb per ton of DM	
	Tons(as-is)	DM, %	N	P
1993	1955		9.0	9.0
1994	1500	65.5	17.6	13.0
1995	1360	77.9	15.3	11.9
1996	965	70.5	20.1	14.2
1997	1180	66.5	22.1	13.3
1998	1865	73.9	19.0	14.2
1999	690	77.0	20.0	8.9
average	1360	71.9	17.6	12.0

managed similarly in terms of crop, variety or hybrid, irrigation, N fertilization and planting/harvesting dates. No commercial P was applied.

To account for variation from field to field, field and compost treatment were included in the yield model. Most fields (majority of the data) were maintained on either an irrigated, no-till corn-soybean rotation or a non-irrigated, no-till corn-soybean rotation. Some data were collected on non-irrigated, no-till wheat and grain sorghum crops. Data were analyzed within each crop by year from application time, i.e. whether one, two, three and four or more years from compost amendment, using proc GLM in SAS.

Results

Compost production

Nitrogen concentration is usually an indicator of compost quality and soil contamination. In 1993 and 1998, feedlot compost was lower in quality (Table 1). Those years were associated with unusually wet springs and therefore pens were cleaned and more soil unavoidably removed. Total tonnage was also relatively high those years which is further evidence that more soil was removed. Animal capacity was unchanged and therefore more manure would not be associated with animal production. Averaging across the seven years, the 1500-head feedlot produced an average of 1,155 tons (as-is) annually of finished compost that contained 12.9 lb of N and 9.4 lb of P per ton of DM. Dry matter concentration averaged 78.8%. Therefore, 10.2 lb of N and 7.4 lb of P were produced per ton of as-is compost. Converting P to a P_2O_5 basis leads to 16.9 lb of P_2O_5 per ton of as-is compost from the feedlot. Using the average N concentration of 10.2 lb, the value of N is $1.14 per ton (as-is) assuming N is priced at $0.112 per lb ($NH_3$ = $185 per ton equivalent, based on 2000 prices). Similar calculations for P suggests that the value of P is $4.97 per ton (as-is) assuming $0.294 per lb of P_2O_5 (11-52-0 = $330 per ton equivalent).

Dairy compost was relatively consistent across years and was generally higher quality based on N concentration due to manure production and handling differences relative to feedlot manure. Dairy manure was hauled "fresh" to the compost yard daily, and stored. Differences exist between fresh dairy manure and feedlot manure; however, manure

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collected fresh from feedlot animals would produce compost similar to dairy compost rather than typical feedlot compost from manure collected on open-dirt pens. In the summer, manure was placed in windrows and mixed with organic residue. As a result, soil contamination was much lower and compost tonnage was more constant. Beginning in 1999, less manure was hauled to the compost yard due to direct applications of fresh dairy manure on other ARDC acres. Averaged across the seven years, the 150-cow dairy produced 1,360 tons (as-is) annually of finished compost that contained 17.6 lb of N and 12.0 lb of P per ton of DM. Dry matter concentration averaged 71.9%. Therefore, 12.6 lb of N and 8.6 lb of P were produced per ton of as-is compost. Converting P to a P_2O_5 basis leads to 19.8 lb of P_2O_5 per ton of as-is compost from the dairy. Using the average N concentration of 12.6 lb, the value of N is $1.41 per ton (as-is) assuming N is priced at $0.112 per lb. Similar calculations for P suggests that the value of P is $5.82 per ton (as-is) assuming $0.294 per lb of P_2O_5.

During composting, energy is required in the form of carbon (organic matter) to maximize N recovery. Therefore, a critical measure in manure is the carbon to nitrogen (C:N) ratio. That ratio in feedlot manure is usually 12:1 whereas optimal C:N ratios are 25:1 or greater. The consequences of low C:N ratios are greater N losses. Table 1 contains N recovery ranges for feedlot compost in these studies. N recovery is variable but ranges from 60 to 90%, which suggests that the majority of N is transformed from inorganic N to organic N. Once applied, organic N should be more stable than that in manure and eventually be used by the growing crops.

Table 2. Yield responses (bu/acre) from compost treatment on irrigated and dryland corn.

Years[a]	-comp	+comp	diff (bu)	diff (%)	fields	SE	P=
Irrigated							
1	148.1	157.0	8.9	6.0	6	1.65	.01
2	154.5	158.3	3.8	2.5	4	.88	.06
3	169.6	169.3	-0.3	-0.1	4	.31	.54
4+	198.0	199.6	1.6	0.8	5	.80	.25
overall avg	167.6	171.1	3.6	2.3			
Dryland							
1	124.7	134.7	10.0	8.0	5	2.20	.04
2	104.9	106.9	2.0	1.9	12	.94	.16
3	179.5	180.9	1.4	0.8	3	.65	.27
4	133.4	135.5	2.1	1.6	9	.76	.08
4+	142.8	144.5	1.7	1.2	13	7.01	.87
overall avg	136.7	140.1	3.4	2.7			

[a]Years is the number of years following a one-time compost application, -comp is treatment not receiving compost, +comp is treatment receiving compost, differences in bushels and percentage calculated as +comp minus -comp divided by -comp treatment, fields is a measure of replication, SE is the standard error of the mean, and P= is the probability that the +comp and -comp treatments are equal when variation due to fields is accounted for.

Table 3. Yield responses (bu/acre) from compost treatment on irrigated and dryland soybeans.

Years[a]	-comp	+comp	diff (bu)	diff (%)	fields	SE	P=
Irrigated							
1	60.0	61.3	1.3	2.2	3	.24	.06
2	61.5	62.7	1.2	2.0	4	.31	.54
3	58.9	59.7	0.8	1.4	4	.49	.32
4+	61.2	61.3	0.1	0.2	5	.59	.96
overall avg	60.4	61.3	0.9	1.5			
Dryland							
1	52.0	52.3	0.3	0.6	3	1.70	.90
2	50.5	51.9	1.4	2.8	3	1.09	.45
3	43.2	43.6	0.4	0.9	6	.87	.79
4+	58.3	58.6	0.3	0.5	14	1.25	.86
overall avg	51.0	51.6	0.6	1.2			

[a]Years is the number of years following a one-time compost application, -comp is treatment not receiving compost, +comp is treatment receiving compost, differences in bushels and percentage calculated as +comp minus -comp divided by -comp treatment, fields is a measure of replication, SE is the standard error of the mean, and P= is the probability that the +comp and -comp treatments are equal when variation due to fields is accounted for.

Crop yields

Adding compost to irrigated acres improved ($P < .10$) corn yields in the first and second years following application (Table 2). Yields were increased by 8.9 bushels, which was 6% the first year and by 3.8 bushels or 2.5% the second year. Ten fields were planted with corn those two years. After the second year, compost treatment had no impact ($P > .25$) on corn yield. Assuming a 3.6 bushel increase in corn yield each year for four years (based on overall average response), then compost treatment increases gross returns by $36 per acre if average price for corn is $2.50 per bushel for those four years (3.6 bushels x 4 years x $2.50 per bushel). If application costs average $2.50 per ton (based on previous calculations; 1997 Nebraska Beef Report, pp. 88-91), then total spreading costs are $25 per acre for 10 tons per acre application rates or $50 if 20 tons per acre are applied. Application costs are variable and dependent on size of operation and distance traveled. We used an average, but individual producers would need to assess their application costs. Most of the yield data presented here follows an application rate of 10 tons per acre (five of the six years). In these calculations, only four years were used in the economic calculations to obtain conservative estimates, whereas some of these fields received compost six years earlier. Therefore, total income would be increased by approximately $11 per acre if compost is used on irrigated corn ground.

Adding compost to non-irrigated corn acres increased ($P < .04$) yields by 10 bushels or 8% the first year after application. In subsequent years, the impact of adding compost was not statistically significant except for the fourth year after compost application. Based on the results in Table 2, compost

Table 4. Crop yield responses (bu/acre) from compost treatment on dryland wheat and grain sorghum yields.

Years[a]	-comp	+comp	diff (bu)	diff (%)	fields	SE	P=
Wheat							
1	36.6	41.0	4.4	12.0	5	1.01	.04
Grain sorghum							
1,3,5	115.9	118.5	2.6	2.2	5	.66	.04

[a]Years is the number of years following a one-time compost application, -comp is treatment not receiving compost, +comp is treatment receiving compost, differences in bushels and percentage calculated as +comp minus -comp divided by -comp treatment, fields is a measure of replication, SE is the standard error of the mean, and P= is the probability that the +comp and -comp treatments are equal when variation due to fields is accounted for.

treatment numerically increased dryland corn yields in every year measured (up to six years); however, variation from year to year was probably due to precipitation differences. With variable yields due to weather effects during different years, effects due to compost application were not distinguishable. Biologically, a 1 to 2 percent improvement in yields observed during the second to fourth year is significant. If yield is increased 3.4 bushels due to compost treatment, then gross income is increased by $34 (3.4 bushels x 4 years x $2.50 per bushel). With similar calculations as in the irrigated corn example, net income would be increased by approximately $9 per acre if compost is applied at a rate of 10 tons per acre to dryland corn.

When soybeans were planted on irrigated acres, compost treatment increased ($P < .06$) yields by 1.3 bushels or 2.2% the first year (Table 3). In subsequent years, compost treatment did not statistically increase yields ($P > .32$). Yield improvements decreased linearly with year from application based on percent improvements from 2.2% (year 1) to 0.2% (years 4 and 5). Performing similar economic calculations with the soybeans as with the corn and an average yield improvement of 0.9 bushels, applying compost added about $21.50 return per acre (0.9 bushels x 4 years x $6.05). The differences in yield alone from compost application to irrigated soybeans does not offset the average application costs ($25) in this study. Because soybean yields are lower than those of corn in bushels per acre (60 versus 168), yield differences are more difficult to assess.

With non-irrigated soybeans, compost treatment did not result in statistical differences in yield (Table 3) when compared with the no-compost treatment. During each year from application, yields were increased by compost application. The overall average increase above the no-compost treatment was 1.2% or 0.6 bushels. Only three fields were used to measure dryland soybean yields in the first and second years following application. These fields were planted to other crops, either corn, wheat, or grain sorghum. If more observations were available, then the numerical differences may be significant. Based on the standard errors, variation in yields on dryland soybeans is greater than variation in yields from irrigated acres. The increased variation in dryland situations is presumably related to precipitation differences and the subsequent impact that weather has on yields. This trend is similar when corn is grown on dryland acres (Table 2).

On some of the non-irrigated acres previously discussed, wheat was grown the first year after spring application of compost. Wheat yield was influenced more than any other crop by compost treatment. Spreading compost on wheat acres increased ($P < .04$) yield by 12% or 4.4 bushels per acre the first year after application (Table 4). With the wheat crop, corn silage was harvested in September and compost applied just prior to wheat planting. When grain sorghum was grown on compost-treated acres, yield was increased ($P < .04$) by 2.2 percent or 2.6 bushels compared to the no-compost treatment. The yield response for grain sorghum was averaged across one, three, and five years following the one-time application of compost.

In summary, yields were increased when compost was applied to irrigated corn and soybeans, dryland corn, dryland wheat, and dryland grain sorghum. The economic returns were greatest for corn and covered costs associated with spreading. The costs associated with composting ($1.50 per ton based on 1997 Nebraska Beef Report, pp. 88-91) are not included in the economic returns. However, the value of nutrients in compost in this study were also not included nor were the costs associated with disposal of manure. In this project, N fertilization was not reduced in the compost treated strips. Thus all the reported increases in yields and income were over and above the yields from crops receiving the recommended N fertilizer rates based on soil tests. There would be some cost savings if N fertilization were reduced on compost-treated fields, assuming compost will provide a portion of crop available N. Because N fertilization was held constant, we conclude that the yield response is probably due to P but other nutrients might have influenced yield. Whether yield improvements result from added P, OM, K, or other nutrients is not known, only that there is a benefit from one of these or a combination.

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[1]Galen Erickson, graduate student, Terry Klopfenstein, Professor, Animal Science, Lincoln; Walker Luedtke, research coordinator, Mark Schroeder, farm operations manager, Agricultural Research and Development Center, Mead; Chuck Francis, director, Center for Sustainable Agricultural Systems, Gary Lesoing, former research assistant professor, Center for Sustainable Agricultural Systems, Lincoln

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