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Tanner Douma
Dordt College

Emily Hummel
Dordt College

Wendi Jo Vande Voort
Dordt College

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TANNER DOUMA, EMILY HUMMEL, WENDI JO VANDE VOORT OF DORDT COLLEGE

IN COLLABORATION WITH
CLA-DON FARMS, SIOUX COUNTY FARM BUREAU, AND DORDT COLLEGE

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Abstract

Utilizing agriculture animal and biodegradable waste can reduce the input costs of fertilizers while enhancing the soil. This comparative study focuses on the nutrient values soil receives from agricultural waste. The central objective was, “Due to the historical over-application of manure leading to environmental concerns, a comparative study of soil fertility and economic viability of manures and compost are analyzed in a one-year study”. On an 18.7 acre corn plot, 11 strips were applied with four different manure types, which were randomized, during the 2017 growing season. Chicken litter, compost, hog manure, wet cattle manure, and control strips were replicated twice. Six 6 inch soil cores were sampled during pre-, mid-, and post-season in two locations of each strip to determine soil fertility. Mid-season plant tissue tests were taken to determine nutrient uptake in plants. Because this was a one-year study, there was no significance for any nutrients between the difference manure strips. Statistical significance was partially low because 32% variable rate liquid nitrogen was unintentionally applied to the field. Yield was measured at harvest for seven of the eleven strips due to the four eastern strips being accidentally chopped instead of combine harvested. An economic analysis occurred to discover how the values of manure differed from each other according to the nutrients in each type.

Introduction and Rationale

In the past, agriculture had a pragmatic view of farming. One of the prevailing mentalities resulting in the overapplication of manures due to simply getting rid of it rather than using it as effectively as possible to give the ground the correct nutrients for the crops' needs. Spreading manure is a go-to way of fertilizing fields in the fall, winter, and spring for most livestock producers, so providing information that demonstrates the nutrient value, economic feasibility, and yield is essential. It is important to remember that fertilizers are more than a yield increaser; manures also have environmental and social benefits to the community. Environmentally manures aid soil chemical and physical properties. Socially, communities thrive when local money stays in the local economy; one way to benefit local communities is by utilizing animal waste as a soil-crop fertilizer instead of using synthetic fertilizers.

As the cost of agriculture inputs increase and commodity prices remain unchanged, meeting a break even becomes more difficult. Utilizing agriculture animal and biodegradable waste can reduce the input costs of fertilizers while enhancing the soil. While also being an opportunity to provide a value-added product with the sale of excess waste. Agriculture relies on manures and artificial fertilizers to increase crop yields. This comparative study focuses on the nutrient values soil receives from agricultural waste.

There are a number of environmental concerns that manure affect in positive and negative ways. When manure is over-applied, the soil contains more nutrients than it is able to hold. This then causes nutrients to leach out of the soil with the assistance of water into groundwater sources, then causing other environmental concerns. An overabundance of nitrogen in groundwater, for example, can cause the growth of algae and bacteria which harm humans, animals, and plant life. Another environmental concern that farmers should be concerned about is soil erosion. The addition of manure to the soil builds up the organic matter in topsoil. Increased organic matter can in turn decrease the amount of soil lost from a particular field.

Research Objectives

The question considered for the project was: how does chicken litter, compost, hog manure, and wet cattle manure affect soil fertility? The research objective states: due to the historical over-application of manure leading to environmental concerns, a comparative study of soil fertility and economic viability of manures and compost were analyzed during one growing season.

1) The point was to compare the impact of each manure type on soil fertility.
2) Run an economic nutrient breakdown analysis of each manure type.
3) Collect sufficient data regarding different types of manure in order to give farmers a side-by-side look at the nutrients and organic matter of each manure type.

Historical Information

Composted manure is more easily stored than fresh, the transportation costs are lower, there is little or no odor present with compost, and pathogens and weeds are usually destroyed during the composting process (Olson, McKenzie, Larney, & Bremer, 2010). Composted manure is composed of fecal matter and different bedding types which have decomposed into fine soil particles. Compared to fresh manure, compost contains less water soluble carbon, meaning less of it leaches into groundwater. Composted manures reduces denitrification rates more than fresh manure. Denitrification is the process of bacteria releasing usable nitrogen into the air (Miller, Beasley, Drury, & Zebarth, 2012). This does not mean that composted manure holds all the nutrients found in it. Research shows that composted manure does not necessarily have high amounts of nutrients due to the long composting time and process (Olson, McKenzie, Larney, & Bremer, 2010). Unfortunately for farmers who use compost, the chances of soil erosion are high due to wind or water runoff because of the finer particles that compost incorporates into the soil (Miller, et al., 2012). Composted dairy cattle manure produces lower yield rates when compared to fresh dairy manure and inorganic N fertilizers (Paul & Beauchamp, 1993). Similarly, it has been found that composted manure produced lower yield rates than stockpiled manure (Paul & Beauchamp, 1993). When testing residual nutrients a few years after the last application, there was a slight difference between nutrients from composted versus solid manures, and these nutrient rates were greater than those in plots spread with liquid manure or urea fertilizers (Paul & Beauchamp, 1993).

Nitrogen is an essential nutrient for plant growth, development, and maturation. Plants can only uptake nitrogen in an inorganic form. Nitrogen recovery by plants is studied to ensure that sources of nitrogen contain the usable form for plants. Nitrogen recovery by plants was lower when composted manure was used as compared to fresh or partially decomposed manure. This was because composted manure, when it is spread onto a field, contains more organic nitrogen and less inorganic nitrogen (Paul &

Beauchamp, 1994). The main ways inorganic nitrogen can be lost is through leaching of the nutrient through the soil into groundwater as well as denitrification, where nitrogen is released back into the atmosphere. Other factors, such as soil temperature, can also affect nitrogen recovery in addition to what type of manure is spread.

About the Plot

For the past eight years the test plot has been in a corn on corn rotation and chopped into silage for beef cattle. There was an application of anhydrous ammonia for a short period of time as a synthetic fertilizer, but historically the plot has been applied with animal waste manures such as hog manure, cattle bedding pack, and compost.

According to NRCS (Natural Resources Conservation Services) Websoil Survey, the test plot is predominantly made up of silty clay loam and silt loam from loess and alluvium parent materials. The soil is slightly erodible, prone to severe soil rutting, and has a low to medium susceptibility to compaction. The soil's ability to drain water depends on the soil type: 8 percent of the soil has poor drainage, 44.9 percent of the soil is somewhat poorly drained, and 47 percent of the soil is well drained. Flooding is not likely.

According to the Midwest Laboratories soil sample results, the left over nutrients in the soil from last year's growing season are 33.6 ppm of nitrate, 191.3 ppm of phosphorus, and 383.7 ppm of potassium.

Materials and Methods

The comparative trial took place during the 2017 growing year on an 18.7 acre plot that is 1234.2 feet long by 720-feet wide with eleven strips of 60 feet each. The eleven manure and control strips were randomized and replicated twice, and then charted before spreading the manure. The strips were not replicated three times because the project had to be limited to 20 acres. The strips in order from West to East were: control, wet cattle, compost, hog, chicken, compost, hog, wet cattle, chicken, 10-ton compost, and control. (The 10-ton compost was a private study for Cla-Don Farms. Cla-Don Farms was testing whether one or a split application was possible.) In each strip, two sample locations had six 6 inch cores extracted for pre-season soil tests, which took place on March 22, 2017.

The manures were goodwill donations from different operations in Sioux County: the hog manure from Van Berkel Farms, the compost and wet cattle manure from Doug Winterfeld and Cla-Don Farms, and the chicken manure from Center Fresh Eggs. Each manure type was sampled and sent to Midwest Laboratories. In the spring of 2017 the compost, wet cattle, and chicken manures were tested. The hog manure was tested in September 2015 by Van Berkel Farms. Manures were spread on March 25 after the end of a relatively early winter.

The manure application rate varied by type; hog at 7,000-gallons per acre, compost at 5-ton per acre, wet cattle at 10-ton per acre, and chicken at 3-ton per acre. Compost and wet cattle manure were applied at the average rate that Cla-Don Farms applies. Hog manure was applied at the recommended rate from Van Berkel Farms. Chicken litter was applied at the recommended rate of Hull Co-op. After the manure application, the plot was cultivated in early April. A week later, on April 28, Dekalb 6067 corn was planted at a population of 33,929 seeds per acre. The seed had a 110-day maturity.

During the V10 stage of growth, on June 28, 2017, the mid-season soil and plant tissue samples were collected. The locations used in the pre-plant sampling were used for the mid-season sampling. A three-row radius was used to sample plant tissue. Unfortunately early in July , shortly after tassel, a y-drop 32% liquid nitrogen fertilizer was spread on the test plot at a variable rate for all strips when the field received fertilizer. The 18.7-acre plot was not supposed to receive any form of fertilizer. In early September, the four east strips (control, 10-ton compost, chicken, and wet cattle manure) were chopped accidently.

On September 23, 2017, the remaining strips were combine harvested as high moisture corn. Yields were collected, weighed, and the moisture adjusted yield was calculated. The following year, on April 12, the collection of post-season soil samples occurred. The samples may have been taken earlier in the spring, but heavy snow prevented that. The post-season soil samples were taken in the same locations as the pre- and mid-season samples.

Results

Statistical Significance

When the data was received from Midwest Laboratories, a multiple means applet was used to assist with the analysis. The p-value and f-statistic assess all nutrients, as well as the organic matter and soil pH, for each strip of manure to determine if a significant difference existed between strips. The p-value tells the level of significance between different samples.

Nutrients	P-Value	F-Statistic	Significant?
Organic Matter	0.9556	0.149	No
Soil pH	0.1967	2.267	No
Nitrate	0.068	4.393	Mildly
Phosphorus (Weak)	0.4875	1	No
Phosphorus (Strong)	0.5359	0.881	No
Potassium	0.7692	0.452	No
Boron	0.7585	0.469	No
Zinc	0.7767	0.44	No
Calcium	0.5077	0.946	No
Magnesium	0.7239	0.525	No

FIGURE 1

A p-value of 0.05 or lower indicates a significant statistical difference, which was not the case for any of the nutrients in the study. The closest nutrient to having a significant difference was nitrate with a p-value of 0.068. This means that there was no actual significant difference, but the number was closer to being significant than any others.

The f-statistic takes the means of the samples and tests them for significance, with a significant value being any number above 3.97. When looking at the chart above, it's clear that between the different strips, there was significance for nitrates, with an f-statistic of 4.393, but not for any other nutrient.

The micronutrients analyzed all relate back to nitrate uptake by the plants. Higher boron counts increases the nitrates that are available for plant use. The boron levels for the test plot were moderately high for each strip, so there was no significant difference between any of the strips. The zinc levels were very high for each manure strip, causing no significant difference to be present. Zinc is important because it assists the plants in their use of nitrates. Calcium actually works against zinc, iron, and manganese when present in the soil, making these other nutrients less available to assist plants. When

tested, results showed that all the strips had a moderate to high amount of calcium. Magnesium is important for plants because it increases chlorophyll storage and activates different enzyme systems in the plant. When looking at the results, there was no significant difference between the different strips because all strips had a moderate to low level of magnesium.

NPK Levels in the Soil

The nitrate, phosphorus, and potassium rates were looked at for each type of manure as well.

An average was taken between the two strips for each sample period, and then plotted on a graph. Figure 2 shows the nitrate levels for each manure in the three different sample periods (pre-, mid-, and post-season soil samples). According to Illinois State University, the optimal level of nitrates in the soil for corn to grow is 16-36 parts per million (ppm). As can be deduced from the chart, the level of nitrate was well above the required level needed for corn to grow well.

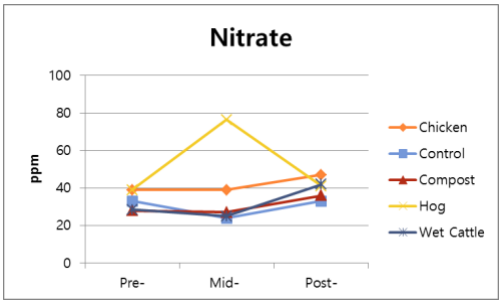

FIGURE 2

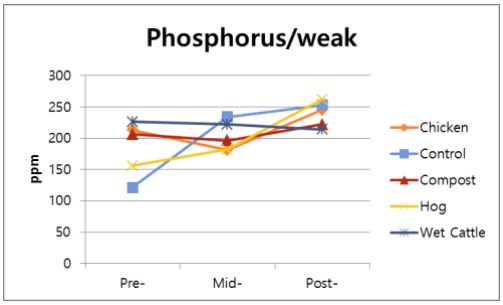

FIGURE 3

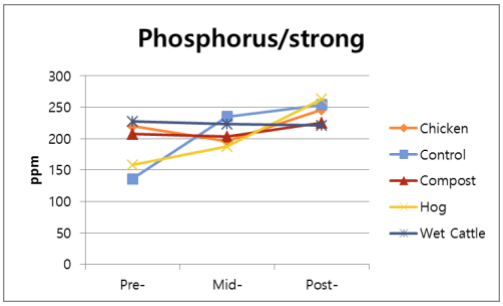

FIGURE 4

According to Iowa State University, the optimal level of phosphorus for plant growth is 17-23 ppm. Again, looking at the figures 3 and 4, it is clear that the phosphorus levels for the test plot were much higher than the required amounts. The phosphorus from the test plot ranged between 121 ppm and 263 ppm, meaning there was an excessive amount of phosphorus in the soil of the test plot.

Figure 5 showing potassium levels from the test plot. These levels ranged from 222 ppm to 598 ppm, which are much higher than the required amount for corn crops. ISU records the optimal potassium levels to be 124-160 ppm. What is interesting to note about the potassium is that while most of the manure types drop in potassium level between the pre- and mid-season soil samples, the compost strips actually increased a small amount between the two sample periods.

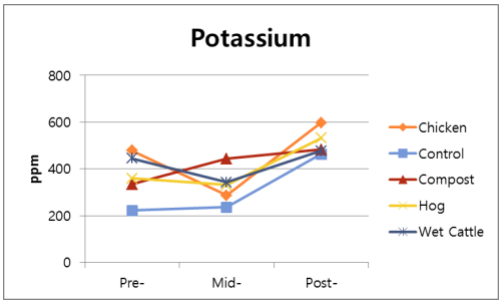

FIGURE 5

Figures 2 through 5 show, overall, is that the corn planted in the test plot was not lacking in the three major nutrients of nitrate, phosphorus, and potassium. The excessive amounts of each nutrient is slightly concerning when considering the impact of excess nutrients on the rest of the environment.

Plant Tissue Significance

Figure 6 shows the results of the plant tissue tests taken in June. The results show that there was no significant difference between manure types with regards to nutrient uptake in the plants. For all the strips, the plants utilized approximately an equal amount of nutrients for each manure type.

Nutrient	P-Value	F-Statistic	Significant?
Nitrogen	0.4693	1.042	No
Phosphorus	0.8844	0.272	No
Potassium	0.3562	1.394	No

FIGURE 6

Yields

Figure 7 shows the average yields for each manure strip for the test plot, except for three strips. Data from the three strips that were chopped was not available because the crop was chopped instead of combine harvested. (The strips missing are chicken manure, wet cattle manure, and a control strip.) The yield results vary between each of the strips, however there are a few things that can be noted.

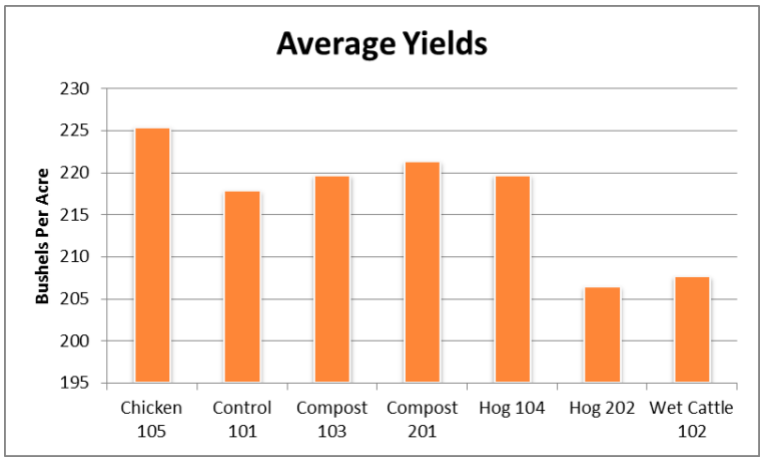

FIGURE 7

Economic Analysis

When looking at the economics of different manure types, the nutrients found in the manure need to be considered to assist with price figuring. The prices shown are the value of the manure types according to the value of the nutrients found in them. The hog manure price is so much lower than the others because normally it is sold by the gallon. For the purposes of the chart, gallons were converted to tons so a price comparison could be made. According to the prices in Figure 8, it seems like chicken manure would be the most economical to sell, at $37.30, to neighboring farms according to nutrient content.

	Chicken	Hog	Compost	Wet Cattle
Nitrogen ($0.40/unit)	$14.56/ ton	$1.59/ ton	$10.28/ ton	$4.48/ ton
Phosphorus ($0.42/unit)	$14.62/ ton	$2.95/ ton	$9.16/ ton	$5.54/ ton
Potassium ($0.28/unit)	$6.22/ ton	$2.81/ ton	$9.52/ ton	$4.54/ ton
Sulfur ($0.33/unit)	$1.90/ ton	$0.70/ ton	$4.40/ ton	$1.50/ ton
Total Value / ton	$37.30/ ton	$8.05/ ton	$33.36/ ton	$16.06/ ton

FIGURE 8

Nutrient Analysis				
	Chicken	Swine	Compost	Wet Cattle
Nitrogen	36.4 lbs.	3.98 lbs.	25.7 lbs.	11.2 lbs.
Phosphorus	34.8 lbs.	7.02 lbs.	21.8 lbs.	13.2 lbs.
Potassium	22.2 lbs.	10 lbs.	34 lbs.	16.2 lbs.
Sulfur	5.8 lbs.	2.12 lbs.	13.3 lbs.	4.5 lbs.

Figure 9

Nutrient Value Applied				
	Chickens	Swine	Compost	Wet Cattle
Nitrogen	109 lbs.	111 lbs.	128.5 lbs.	112 lbs.
Phosphorus	104 lbs.	196.5 lbs.	109 lbs.	132 lbs.
Potassium	67 lbs.	280 lbs.	170 lbs.	162 lbs.
Sulfur	17 lbs.	59 lbs.	66.5 lbs.	45 lbs.
Total Application Value	$111.90	$225.40	$166.80	$160.60

Figure 10

Discussion and Conclusion

Based on the tests of statistical significance, there was no significance between the manure type used and the nutrient availability to the crop. The only nutrient that was close to being significant was nitrates because of a few outliers in the individual strip data. The results of the project may be skewed based on a few conditions. First, the project took place in one growing season, making it more difficult to provide truly significant data for other interested parties to use in the future. Data may also be skewed due to residual nutrients found in the soil before the manure types were applied to the field and the mid-season nitrogen application that occurred accidentally.

A couple of changes can be made to the current project for groups who wish to continue this research in the future. It is recommended that a plot be used which has not been applied with manure in the previous two or three years, just to ensure that residual nutrients do not skew data as much. It is also recommended that more years of testing be done so that data can be compared from year to year on the same plot. More replications, better soil sample collecting techniques, and a better knowledge of technology used are also recommended to make projects run more smoothly in the future.

Acknowledgements

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Description	Supported by
Soil samples	Sioux County Farm Bureau/Cla-Don Farms
Plant tissue samples	Sioux County Farm Bureau/Cla-Don Farms
Chicken Litter	In kind support Center Fresh
Compost	In kind support Cla-Don Farms
Hog Manure	In kind support Van Berkel Farms
Wet Cattle Manure	In kind support Cla-Don Farms
Labor	In kind support Cla-Don Farms/Van Berkel Farms

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