THE USE OF ORGANIC SOIL AMENDMENTS FOR WINTER WHEAT PRODUCTION IN KENTUCKY

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Abstract

Most animal manures are land-applied in the fall and spring after crops have been harvested or prior to planting. Surface application of manures in the fall have more potential for nitrogen (N) loss when applied to fallow land compared to land cropped to winter wheat. This study was conducted to determine the N availability of fall applied organic fertilizers and resulting wheat grain yields compared to urea-N fertilizer. The effects of three organic fertilizer sources and rate on wheat yield and nitrogen availability coefficients (AC) were compared to urea-N on a Zanesville silt loam soil following corn. Composted swine manure (CSM), poultry litter (PL), and a processed biosolid - Louisville Green (LG) were applied at rates of 100, 150, and 200 lbs total N/A. Commercial fertilizer (CF) was split applied in the spring at rates of 0, 30, 60, 90, and 1200 lb N/A. Grain yield was collected and analyzed. Overall yields were higher in 2012 than 2011. In 2011, LG appeared to be the superior organic product based on yield response data, but N availability was ≤ 20.7% of urea-N for all LG treatments. Both PL and LG had higher yields and AC in 2012, but considerable variation within sources (35 – 40% differences in AC) was present. Yields and AC for CSM were the lowest of the three sources and often not different than the untreated check. Considerable variation within organic sources, coupled with low AC and wheat grain yields, suggest that adequate N is not being supplied to the plant at these rates and that supplemental inorganic N should be considered to maximize wheat yield.

Introduction

Animal manures have been used for millennia to supply essential nutrients to crops. The use of human waste to supply essential crop nutrients has also been practiced in Asia for centuries (King, 1911) and recently has become a more acceptable method of "disposing" processed sewage sludge (biosolids) in the United States (USEPA, 1994). The proportion of organic and inorganic nitrogen (N) varies among manure type, length of storage, and other environmental factors, but solid manure is typically dominated by organic forms of N (Rasnake, 2002). The vast majority of the organic fractions of nitrogen contained in manure must be mineralized to inorganic forms prior to being utilized by the plant, regardless of the manure source. Mineralization rates are governed by temperature, moisture, C:N ratio, homogeneity , soil biota, etc. and can vary considerably among manure sources and environmental conditions N (Flavel and Murphy, 2006; Bitzer and Sims, 1988).

The two dominant loss mechanisms for N common to Kentucky agriculture are volatilization and denitrification. Manures and biosolids are subject to both loss mechanisms, depending on weather, soil conditions, and soil type. Surface application of any source of N that contains urea or NH_3-N (such as manure) has potential for N volatilization. Incorporation of manures or urea fertilizers can reduce the volatilization potential. Further, urea and surface applied manure can be “incorporated” with sufficient rainfall (Rasnake et al., 2000). Denitrification occurs when soils become saturated for extended periods and available oxygen becomes limiting. Denitrification loss potential increases as soil drainage decreases and is typically highest during the spring and winter, coinciding with wheat production.

Animal manures are typically applied at two main times for row crop production in Kentucky: in the fall after crop harvest and in the spring prior to planting. From a nutrient management standpoint, a spring application should conserve more of the N present in the manure. Conversely, from a time management standpoint, fall applications are typically better suited to many farming operations. Manure applied to a field that has or will have ground cover during the fall and winter will help conserve the N contained in the manure for subsequent crops. Fields cropped to winter wheat can provide a good opportunity to better utilize the manure N and should reduce the likelihood of off-site movement of nutrients.

Winter wheat requires a minimal amount of N (≤ 40 lbs N/A) in the fall for establishment and early tillering. Considerably greater amounts of N are needed after wheat breaks dormancy (≤ 120 lbs N/A). Mineralization rates in the fall are typically low, but coupled with the residual N from the proceeding corn crop, and inorganic N contained in the manure, should be sufficient for fall growth. As temperatures increase in the late winter and early spring, N demand will increase as will N mineralization rates. However, consideration should be given to the sufficiency of mineralization and N availability in the limitation of wheat yield prior to utilizing a strict organic N source. The objective of this study was to determine the N availability of different organic fertilizer sources and wheat grain yields compared to urea N for winter wheat production in Kentucky.

Materials and Methods

The experiment was conducted on a Zanesville silt loam soil (Fine-silty, mixed, active, mesic Oxyaquic Fragiudalf) at the University of Kentucky Research and Education Center (UK-REC) located in Princeton, Kentucky from 2011 to 2013. Hereafter, the crop year 2011-2012 will be referred to as 2011 and the 2012-2013 crop year will be referred to as 2012. Two separate areas within a field were utilized for subsequent wheat crops that had been in a corn-soybean rotation prior to initiating the experiment. Phosphorus (P) and potassium (K) were added to all plots prior to planting in 2011 based on soil sample results and accounting for the nutrients applied with the manure. A uniform application of phosphorus (P) and potassium (K) were added to all plots prior to planting in 2012 so that neither nutrient were at levels that should limit wheat yields. Existing vegetation was chemically killed with Roundup PowerMax at a rate of 32 oz/A prior to planting. Wheat (Pioneer 25R32) was planted into corn residue and existing vegetation at a rate of 159 lbs/A (42.5 seed/ft^2) on 10-28-11 and 10-30-12 with a NT drill. All other management operations followed current University of Kentucky Cooperative Extension recommendations.

Forty lbs N/A was added to CF plots after wheat emergence in the fall of 2011. No additional N was added to the plots that received the organic fertilizer treatment in 2011 or any of the plots in 2012. The 2012 corn crop left ample residual N present for fall wheat growth due to poor corn yields resulting from severe drought. Organic fertilizer treatments were applied by hand shortly after wheat emergence (approximately 3 weeks after planting) to individual plots. All treatments were applied based on total N (TN) as determined by nutrient label or lab analyses (manure testing). Manure testing was conducted by the University of Kentucky, Regulatory Services Soil Testing Lab in Lexington, KY. Treatments consisted of: Commercial fertilizer (CF) that utilized untreated urea (46-0-0); Composted Swine Manure (CSM) with an average nutrient analysis of 1.5-2.2-1.9; Poultry Litter (PL) with an average nutrient analysis of 2.8-2.6-2.6, and Processed biosolids - Louisville Green (LG) with a nutrient analysis of 5-3-0. All nutrient analyses were reported in % of N – P_2O_5- K_2O after adjusting for moisture content. The spring application rates used for the CF were 0, 30, 60, 90, and 120 lbs N/A and did not include the N added at the fall application. All N for the CF treatments received a split application, applying 50% in February (at greenup) and 50% in March (at jointing). All other products were applied at target rates of 100, 150, and 200 lbs TN/A in the fall post emergence.

Wheat was harvested with a plot combine that recorded grain weight, grain moisture, and grain test weight. Grain yield data was reported after adjusting to 13.5% moisture. Statistical significance between treatments for individual years was determined using PROC GLM and reported for the 90% confidence interval (CI). Treatment means were separated using the pdiff procedure in SAS 9.3 (SAS Institute, 2012). Grain moisture and test weights were found to not differ significantly between treatments and are not reported. A quadratic production function for the CF treatments was fitted and equivalent N rates were determined for individual organic fertilizer treatments based on the CF response curve. Nitrogen availability coefficients (AC) for the organic fertilizers were calculated based on the CF response data.

Results and Discussion

The growing season varied considerably between the two years of this study (Table 1). The 2011 growing season experienced considerably warmer weather than the 30 year mean, particularly in March and May. This elevated temperature, when coupled with substantial negative deviations for rainfall during April and May, was detrimental to wheat growth and subsequent grain yield. The 2012 growing season was much more favorable for wheat growth. Rainfall was adequate and temperatures were modest, particularly during head emergence and grain fill, and yield potential was excellent for the 2012 growing season. Many producers in Kentucky experienced lodging issues associated with high levels of residual N, particularly with dry land corn production, but lodging was not an issue for this study and did not influence grain yields.

Yield data is plotted for the 2011 (Table 2) and 2012 (Table 3) crop years and varied considerably between the two years. The CF treatments resulted in a well fitted quadratic response curve in both years. The CF treatments responded as expected to increasing N rates for both years of the study. However, neither year resulted in a plateau at the highest rate of N. This indicated that a higher N-rate should have been included as a treatment, but the highest N Cooperative Extension Service recommendation was utilized (Murdock and Ritchey, 2012).

In 2011, the CF 120 was the highest yielding treatment and no organic treatment was similar. This differed from 2012 where CF rates ≥ 60 lbs N/A were similar to all organic treatments with the exception of CSM at all rates (Table 3). There was variation within the PL treatment in 2012 but not statistically significant. The yield variation with PL in 2012 is not understood other than variation of material, spreading consistency, or other “noise” associated with the treatment. The PL 100 and PL 200 treatments resulted in similar yields as CF 120, but the PL 150 treatment did result in a lower yield than the CF ≥ 90 lbs N/A. Mineralization potential in 2011 may have been greater than in 2012, but the growing conditions in 2012 were more favorable for mineralized N utilization.

The 150 and 200 LG treatment resulted in the highest yield for any of the organic products in 2011 (Table 2) and was similar to the CF 30 treatment. In 2011, the PL treatments yielded less than the LG treatments at similar N-rates, but higher than CSM. Generally, the LG was similar to the PL treatments in 2012 with some minor variation. Numerically the LG 200 treatment was the highest yielding treatment in 2012 but not statistically greater than the CF ≥ 60 lbs N/A treatments. The CSM treatments were consistently the lowest yielding organic amendment utilized and were often not different than the 0 N rate for CF. The CSM had a larger portion of N immobilized by microbial biomass and was less available in the time frame of this study than other sources.

The mineralization rates of the organic products were potentially influenced in a similar fashion as wheat yield. Based on calculated response curve data, it appears that mineralization rates in 2012 were higher than 2011, although 2012 was generally cooler and wetter. The negative deviations in rainfall are not sufficient to suspect that moisture was limiting mineralization rates in 2011, but some factor favored this in 2012. Furthermore, the 2012 crop had better growing conditions at the critical time for yield potential to utilize any mineralized N. The % N availability appeared higher in 2012 than 2011 and was likely a combination of more favorable growing conditions and greater utilization of mineralized N at critical growth stages (Bitzer and Sims, 1988).

The amount of urea equivalent N was calculated to be 14.0, 31.1 and 36.3 lbs/A for the LG 100, 150, and LG 200 treatments respectively in 2011 (Table 2). Comparing yield to the CF fertilizer response curve at three rates of LG, the corresponding AC resulted in 14.0, 20.7, and 18.1% of N from urea fertilizer for these treatments in 2011. The amount of urea equivalent N increased with increasing N-rates and AC increased accordingly in 2012 for the same LG treatments (Table 2). Poultry litter treatments also had greater AC in 2012, with the PL 100 rate being unusually high for unknown reasons. The variation in yield data in 2012 within the PL and LG treatments was reflected by considerable variation in AC the respective treatments.

Wheat yields for the CSM did not differ between rates and all AC were lower than 10%. The nutrient analysis for CSM would indicate that N would become plant available because the C:N ratio is approximately 12:1. The N would be expected to be mineralized for plant use, but some mechanism is not allowing the material to be utilized by the plant. Because the CSM was composted, the material is in a relatively stable form. Additionally, a large portion of N was tied up in microbial biomass. The potential long-term recycling of nutrients by microbial biomass might be one reason that more N is not available to the crop. Another potential mechanism that might be causing lower mineralization rates than expected is reflective of the carbon source; wood chips screened to pass a 2-inch opening. Nutrient analyses were conducted on the entire sample, including the larger sized wood chips. The highly lignified wood chips, coupled with the large particle size would reduce potential mineralization rates of the CSM. The PL contained rice hulls (as a bedding material) with smaller particle sizes for the carbon source and were more readily mineralized. The differences between carbon sources contained in the products influenced the mineralization potential. Regardless of the mechanism responsible, it is suspected that this N will become available for subsequent crops relative to the PL and LG.

Conclusions

If a fall application of animal manure is made, then the use of a winter crop such as wheat should help to conserve N contained in that manure and utilized for crop growth. Winter cover crops and winter wheat have been estimated to utilize 50% of the TN applied in the fall without tillage incorporation in Kentucky. Based on limited data from this study, it appears that value may be high when not considering tillage incorporation.

As N content in the organic materials increased, the respective yields also tended to increase between products. Although equivalent rates of TN were applied for the organic amendments, yields tended to rank according to TN content of the amendment. The greater the TN content of the material, the more mineralizable the material appeared to be based on yield response data. Mineralization rates would be expected to be low during winter but coupled with residual N from the previous corn crop, sufficient to satisfy the N demands of the wheat prior to breaking dormancy. When wheat breaks dormancy, mineralization rates would be expected to increase due to the increase in soil temperature and supply the required N. Although LG appeared to provide more N than PL and CSM, none of the organic N fertilizers were sufficient to optimize yield at the rates used for the two years of this study. These products either did not mineralize sufficiently to supply adequate N to wheat, or considerably more N from the organic sources was lost to some mechanism (i.e. volatilization or denitrification) than urea N. Given the TN rates utilized and calculated AC for this study, it suggests that some CF would benefit wheat yields when utilizing fall applied organic amendments.

Table 1. Mean annual temperature (F) and precipitation (in) at UK-REC for the 2011-2012 and 2012 -2013 growing seasons.

Year	Month	Avg. Temp (F)	Avg. Temp Departure†	Precipitation (in)	Precipitation Departure
2011	Oct	57	-2	1.35	-1.70
2011	Nov	51	+4	9.12	+4.49
2011	Dec	42	+3	6.13	+1.09
2012	Jan	40	+6	3.01	-0.79
2012	Feb	44	+6	1.73	-2.70
2012	Mar	60	+13	3.27	-1.67
2012	Apr	60	+1	0.62	-4.18
2012	May	71	+4	1.36	-3.60
2012	Jun	74	-1	2.38	-1.47
2012	Oct	57	-2	2.94	-0.11
2012	Nov	45	-2	2.11	-2.52
2012	Dec	45	+6	4.77	-0.27
2013	Jan	38	+4	6.31	+2.51
2013	Feb	39	+1	3.09	-1.34
2013	Mar	42	-5	4.34	-0.60
2013	Apr	57	-2	5.72	+0.92
2013	May	66	-1	4.26	-0.70
2013	Jun	74	-1	7.55	+3.70

† Departure from the 30 year mean for both temperature and precipitation.

Table 2. Wheat grain yields and N availabilities for the 2011 crop. LSD = 6.7

Production Function: $Y = -0.0031X^2 + 0.7662X + 23.091$ ($R^2=0.9899$)				
N Source	N-Rate	Yield (bu/A)	Eq. Urea-N	% N Avail†
CF	0	21.9e	0	-
	30	45.6c	30	-
	60	58.3b	60	-
	90	64.5b	90	-
	120	72.1a	120	-
CSM	100	20.3e	-3.6	≤ 0
	150	19.5e	-4.6	≤ 0
	200	22.4e	-0.9	≤ 0
PL	100	29.9d	9.2	9.2
	150	31.6d	11.7	7.8
	200	33.9d	15.0	7.5
LG	100	33.2d	14.0	14.0
	150	43.9c	31.1	20.7
	200	46.8c	36.3	18.1

† Availabilities are compared to commercial fertilizer N response data. Slight differences in equivalent urea-N and subsequent availabilities are attributed to the variation in the fitted line verses the actual response. Values followed by the same letter are not different at the 90% CI.

Table 3. Wheat grain yields and N availabilities for the 2012 crop. LSD = 15.56

Production Function: $Y = -0.0016X^2 + 0.4879X + 71.087$ ($R^2=0.9987$)				
N Source	N-Rate	Yield (bu/A)	Eq. Urea-N	% N Avail†
CF	0	70.8fg	0	-
	30	85.1cdef	30	-
	60	94.0abcd	60	-
	90	101.8ab	90	-
	120	106.4ab	120	-
CSM	100	67.9g	-6.4	≤ 0
	150	75.4fg	9.2	7.4
	200	76.5efg	11.6	7.1
PL	100	96.5abcd	66.7	66.7
	150	81.6defg	23.3	15.6
	200	91.7bcde	50.7	25.3
LG	100	91.8bcde	50.9	25.4
	150	92.7abcd	53.7	26.9
	200	108.0a	140.3	70.2

† Availabilities are compared to commercial fertilizer N response data. Slight differences in equivalent urea-N and subsequent availabilities are attributed to the variation in the fitted line verses the actual response. Values followed by the same letter are not different at the 90% CI.

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