NITROGEN CONTRIBUTION FROM DIFFERENT MANURE SOURCES

Edwin Ritchey and Jesse Gray
University of Kentucky, Department of Plant and Soil Sciences, Princeton, KY
Edwin.ritchey@uky.edu

ABSTRACT

Nitrogen fertilizer equivalencies (NFE) from manure are influenced by manure type, application method, crop selection, and environmental conditions. Much of the research to determine NFE of manure was conducted in tilled systems but many producers use no-tillage (NT) to reduce soil erosion and labor requirements. The objective of this study was to determine NFE for different manure types used in corn (*Zea mays* L.) cropping systems. Manures consisted of composted swine manure (CSM), poultry litter (PL), and biosolids (LG). These studies were conducted in western Kentucky at multiple sites from 2013 to 2015 on silt loam soils. Manure applications occurred at planting or shortly after crop emergence. Nitrogen fertilizer as urea or ammonium nitrate (AN) was applied at increasing rates to calculate NFE. Substantial NFE variation was observed between and within cropping season and ranged from 0 to 94%. Composted swine manure resulted in the lowest product NFE and LG the highest, regardless of year. Predicting NFE of these manure sources is difficult due to annual environmental variation. Different environmental conditions influence NFE and N fertility should be adjusted in-season if possible. Nitrogen fertilizer equivalencies developed for tilled fields appear to be higher than those for NT fields. All these factors should be considered when determining N application rates.

INTRODUCTION

Animal manures are used in crop production to provide essential plant nutrients to crops. This practice was referenced by the Greek poet Homer in The Odyssey three thousand years ago and in the Bible (Luke 13:8) two thousand years ago. Land application of animal manures, such as poultry litter, has been proven to increase soil organic matter, provide plant nutrients, and boost crop yields (Adeli et al., 2005; Watts and Torbert, 2011; Slaton et al., 2013).The use of human waste has also been practiced in Asia for centuries (King, 1911). Utilization of processed sewage sludge (biosolids) for crop production has become more acceptable in the United States (USEPA, 1994), has many of the same benefits as animal manures, and reduces landfilling a beneficial material.

With increasing livestock densities, manure production has the potential to outpace available land for application with the potential for negative environmental impacts. Liquid or high moisture manures are particularly problematic since the nutrient content of the manure is not sufficient to allow economically viable transportation to distant off-site locations. In lieu of this approach, some producers are composting manure to reduce the total volume and weight of the manure, concentrate the nutrient content, and produce a stabilized product that can be economically transported off-site (Cook et al., 2015).

Poultry production has also increased in certain areas, including Kentucky. As a consequence, poultry litter (PL) use has also increased dramatically in the past decade.

Historically, PL was spread in close proximity to the area it was generated causing an increase in soil nutrient loading, especially P, which may result in negative environmental impacts. The use of PL on areas distant from its place of origin has increased recently due to the increased cost of fertilizer, promoted “soil health” agendas, increased organic crop production, and greater availability. The increased PL use should be coupled with greater crop utilization efficiency so that the full nutrient benefit of the manure is realized. This includes timely application to the specific crop, proper use of soil testing to balance nutrient levels, and fully accounting for the N contribution of the applied manure.

Nitrogen availability depends on the crop, type of manure, proportion of inorganic and organic N, application method, and environmental conditions (Rasnake, 2002). The N availabilities from manure in Kentucky reportedly range from <20% to >80% as influenced by the factors previously listed. The preference of some producers is to apply PL post harvest in the fall. This practice is attributed to more available time for the operation, drier soils, and manure availability. This practice does not fully realize the N contribution from added manures, even with the use of a cover crop, due to slow plant growth and low nutrient uptake, wetter soils with greater potential for denitrification and leaching, and potential manure loss via surface movement of water. Spring manure application has the potential to increase manure N utilization in Kentucky agriculture. This paper summarizes several studies conducted in Kentucky that investigated nitrogen fertilizer equivalencies (NFE) of different manure sources used in corn production systems.

MATERIALS AND METHODS

Several studies were conducted in Western Kentucky on silt loam soils using corn. Generally, manure was applied at planting or immediately prior to or following crop emergence. All manures were tested at the University of Kentucky Regulatory Services Soil Test Laboratories to determine manure nutrient content. Corn was produced following University of Kentucky Extension recommendations for all management operations, with the exception of fertility. The equivalent amounts of P and K contained in the manure were applied to plots that did not receive manure applications. Manure sources were CSM, PL, and LG. Corn was harvested for yield determination and adjusted to appropriate moisture levels. Both small plot and large plot studies were conducted. Some studies utilized a strict manure source at increasing rates without additional N fertilizer. Nitrogen in these studies was applied based on total N (TN) as determined by manure analyses. Other studies used a combination of manure N (assumed 50% NFE) and additional fertilizer N to achieve the desired N rate of 200 lb N/A. Studies were conducted in fields that had no history of manure application as well as in fields that had repeated manure applications at known rates. This allowed the determination of first year N contributions and residual contributions over time. Commercial fertilizer N was applied to all fields at increasing rates. This provided information to develop a fertilizer response curve specific to that environment. A comparison could then be made between manure or manure/fertilizer additions and NFE could be calculated. Crop yields typically fit a quadratic or linear response curve. The response function was solved to determine the equivalent amount of fertilizer N that would result from the manure application, based on adjusted crop yields.

RESULTS AND DISCUSSION

On-farm Studies: Small Plot

The NFE for the PL can be calculated with the PL+0 plots only. It is not possible to separate the magnitude of the yield response from the manure and additional N fertilizer, so they are reported as a cumulative effect. Small plot NFE data varied considerably across location and years for the off-station locations (Table 1). The NFE for the PL with no additional N ranged from 0 to 76%. The PL was surface applied and not incorporated at all locations except Hopkins 2015, where it was lightly incorporated the day it was applied. Incorporation likely eliminated any substantial volatilization losses of N at this location. Hopkins County 2015 appeared to receive the greatest benefit from the PL additions alone and above the contribution of the AN fertilizer.

Henderson County 2014 resulted in very good yields, where the 0 N check yielded 169 bu/A and the 200 lb N/A rate yielded 262 bu/A. However, there was no response to the added PL alone which was unexpected since the PL+70 treatment was equivalent to the 160 lb N/A treatment (Table 1). No rainfall occurred within one week of PL application and would have allowed volatilization losses of ammonium, but losses were greater than expected or can be explained. Yields at Henderson 2014 did not increase for the PL+140 treatment and was the only site year that did not maximize yield at the PL+140 rate. The low calculated NFE's at Henderson are difficult to explain by other losses alone since there was a definite manure contribution from the PL+70 treatment. The Hopkins 2013 PL+N treatments were in general agreement with the PL+0 treatment in that little to no yield increase above the added fertilizer N was observed. The same was generally true for the McLean 2014 PL + N treatments. It has been suggested that the addition of fertilizer N will stimulate the mineralization of manure. This mechanism may explain some of these results, but not all.

On-farm Studies: Large Plot Studies

The PL was applied at a rate of 140 lb TN/A and assumed 50% NFE to result in ~70 lb plant available N from the PL. The target N-rate was 200 lb/A and was achieved by adding 130 lb N/A as ammonium nitrate. Results from the large plot studies were typically in agreement with the small plot studies conducted in the same field when fertilizer was applied with the PL (Table 1 and 2). It was evident in the small plot studies, where no additional N was used with the PL, that NFE of the PL was far below 50% for all but Hopkins 2015 (Table 1). The large plot yield data was similar between treatments and indicated that assumed 50% NFE was reasonably accurate (Table 2). Results from the Hopkins 2015 location were significantly greater (Pr>F = 0.0445) for the PL treatment than the ammonium nitrate treatment (Table 2). There are multiple possible reasons for this result. This was the only field where PL was incorporated by tillage and occurred within one day of PL application. Tillage incorporation would conserve N by reducing volatilization losses. These plots received 70 lb of plant available N/A (assuming a 50% NFE) three years in a row and residual N would be higher than the plots that only received ammonium nitrate. The multiple additions of PL coupled with tillage would encourage higher mineralization rates of N with the PL plots. There was no clear advantage of one nitrogen source over the other in the large plot studies, except in Hopkins 2015.

On-station Studies

A different approach was used for the on-station trials. Instead of including commercial fertilizer with the manure treatments, only varying rates of manure were applied. The three products CSM, PL, and LG differed considerably between years and products (Table 3). Crop yields were more favorable in 2013 then 2014. The NFE was greatest for LG>PL>CSM. The NFE was greater in 2014 than 2013 for PL and LG, but not for CSM. In 2013, PL and LG had comparable NFE's across rates with the exception of LG 300 which decreased at this rate. Although NFE's were greater in 2014, there was also more variation within products.

The CSM had the lowest NFE of the products and ranged from 0 to 15% over the two years of this study (Table 3). The low NFE for CSM is attributed to a much more stable form of N. The C/N ratio of ~11 seemed favorable for N mineralization (Cook et al., 2015). However, the carbon source for the CSM was screened wood chips. It is suspected that even with the favorable C/N ratio the larger wood chips were immobilizing the N contained in the compost. This was particularly evident at the CSM 100 rate in 2014 which exhibited severe N deficiencies.

The NFE's for the PL treatments were very consistent in 2013 (Table 3). Manure was applied one week prior to receiving 0.33 inches of rainfall and another week passed before receiving 0.45 inches of rainfall in 2013. Although this rainfall reduced the potential for ammonia volatilization by potentially "incorporating" some of the manure, the warm temperature (highs ~ 80F) were sufficient to allow some ammonia volatilization. The NFE's were higher in 2014 but varied more between rates. The plots received ~0.5 inches of rain within one day of manure application in 2014 and appeared to be sufficient to "incorporate" the manure and reduce volatilization losses (Rasnake, 2002). Generally, these results supported University of Kentucky Extension recommendations where availability decreases by ~5% for every two days manure is not incorporated (Rasnake et al., 2002). The values reported by Rasnake et al., 2002 are slightly higher than our results but were developed in tilled systems which would contribute additional N, above that contained in PL, by the mineralization of soil organic matter.

The biosolids (LG) resulted in the highest NFE overall across the three products although it varied considerably between years (Table 3). Growing conditions and subsequent corn yields were more favorable in 2013 than 2014 for all treatments, including the LG. This product also benefited from rainfall "incorporation" as the PL, but also has lower inherent potential for volatilization losses than PL. The LG appeared to be the best "organic" product for corn production regarding NFE. However, LG lacks significant K and would need to be supplemented if soil test values indicated a need.

SUMMARY

There are definite benefits to using organic sources of N in a soil fertility program, some better than others. The CSM is questionable regarding first year N availability, but may benefit over time with residual contributions. Both LG and PL can substantially contribute to the N fertility program, but NFE varies considerably between years and environments. In most cases, the highest rates of a strict organic source of N have lower NFE's compared to lower rates (i.e. lower rates are more efficient than higher rates). Incorporation of PL does reduce volatilization potential and stimulates N mineralization. The benefits of incorporation should be weighed against the benefits of NT production and may not be warranted in many situations common to Kentucky. Considerations should include erosion potential, soil moisture dynamics, weed control, etc. Producers should always compare the price of organic fertilizer sources to available commercial fertilizer sources prior to use and be willing/able to adjust N rates later in the season based on environmental conditions.

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Table 1. Small plot data from off-station locations in 2013 to 2015.

N-Rate (lb/A)[1]	--------------------Yield (Bu/A)--------------------			
	Hopkins 2013	Henderson 2014	McLean 2014	Hopkins 2015
0	161	169	134	101
40	197	183	159	111
80	215	224	162	139
120	224	219	186	172
160	223	241	171	190
200	235	262	180	205
PL+0	172 (7%)[2]	167 (≤0%)	142 (9%)	157 (76%)
PL+70	208 (34%)	241 (74%)	170 (41%)	189 (78%)
PL+140	234 (51%)	233 (49%)	182 (50%)	203 (67%)
Response Function	$Y=-0.0022x^2+0.7644x+164.98$	$Y=0.4508x+171.32$	$Y=-0.0016x^2+0.5373x+135.65$	$Y=0.5641x+ 96.758$

[1] PL + indicates that 140 lbs/A of total N was applied to the plot along with additional N.

[2] Calculated nitrogen fertilizer equivalency in (parenthesis); PL+0 for PL only, PL+70 and PL+140 included additional fertilizer N contribution.

Table 2. Large plot data (on-farm) where 140 lb total N/A of poultry litter was applied in addition to 130 lb N/A ammonium nitrate or 200 lb N/A of ammonium nitrate.[1]

Location/year	Treatment	Yield (bu/A)
Hopkins 2013	PL + AN	181 a[2]
	AN only	185 a
Henderson 2014	PL + AN	250 a
	AN only	245 a
McLean 2014	PL + AN	211 a
	AN only	211 a
Hopkins 2015	PL + AN	189 a
	AN only	179 b

[1] Poultry litter was applied every year at planting starting in 2013at 140 lb/A total N and assuming 50% available N.

[2] Values followed by the same letter within a location/year are not different at the 90% CI.

Table 3. Small plot data from UK-REC in 2013 and 2014.

N-Source[1]	N-Rate (lb/A)	----------UK-REC 2013---------		--------- UK-REC 2014---------	
		Yield (Bu/A)	NFE (%)	Yield (Bu/A)	NFE (%)
Urea-N	0	102	-	58	-
	50	191	-	96	-
	100	206	-	113	-
	150	216	-	148	-
	200	226	-	ND[2]	-
CSM	100	128	14	54	≤0
	200	146	15	72	10
	300	121	3	75	8
PL	100	157	35	94	58
	200	189	34	121	53
	300	213	34	130	40
LG	100	172	49	109	84
	200	211	49	168	94
	300	211	33	176	67
Response Function		$Y=0.0046x^2+1.4736x+110.24$		$Y=0.5682x + 61.126$	

[1] CSM= Composted swine manure, PL= Poultry Litter, LG=Louisville Green Biosolids

[2] ND= No data was collected, treatment was compromised

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NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 31

November 4-5, 2015
Holiday Inn Airport
Des Moines, IA

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John E. Sawyer
Iowa State Univ
Ames, IA 50011
(515) 294-7078
jsawyer@iastate.edu

PUBLISHED BY:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page**: www.IPNI.net**

ON-LINE PROCEEDINGS:

http://extension.agron.iastate.edu/NCE/