An Integrated Approach to Understanding Poultry Litter Use in Corn-Soybean Production Systems

Edwin Ritchey, Erin Haramoto, and Carl Bradley

University of Kentucky, Princeton, KY

edwin.ritchey@uky.edu

ABSTRACT

The majority of poultry litter (PL) in Kentucky is generated in the western third of the state, the same area that produces approximately 80% of corn, soybean, and wheat. This PL is applied to row crop fields as a nutrient source. Producers and commodity board representatives were concerned with reported nutrient availability coefficients, nutrient value, and long-term use of PL. Four field sites in a NT corn-soybean rotation were identified in the fall of 2012 with low to medium soil test values and no history of PL use. In 2013 two locations were planted to soybean and two planted to corn for studies that consisted of a large plot trial, an N response trial, and a soybean late-season N study. The large plot study had equivalent nutrients applied as either commercial fertilizer or PL plus ammonium nitrate (AN) fertilizer. The nitrogen (N) response trial was a combination of increasing N alone or in addition to PL. Soybean in the late season N study received 100 lb N/A as AN at R1, R3, or R5 and compared against the non-treated check. Both corn and soybean yields in the large plot study were similar between treatments in 13 out of 16 site-years. Two soybean yields and one corn yield was significantly greater with PL use than with comparable rates of commercial fertilizer. The greater corn yield was attributed to reduced N volatile losses with PL and greater denitrification losses with AN fertilizer. No mechanism was identified for the increased soybean yield, but we suspected late season N mineralization from PL. This was not confirmed with the soybean late season N study. The N response corn trial typically showed that yields increased as N rates increased, to a point. In some site-years, 120 lb N/A maximized corn yield but greater rates were needed in other site-year. Soil test phosphorus (P) was greater in PL treated plots than plots that received commercial fertilizer due to the 0.80 P availability coefficient and greater total amounts of P added. Soil test zinc (Zn) was found at 2–3 times higher soil concentrations with PL than commercial fertilizer. Comparable yields between the PL and commercial fertilizer additions indicated that either nutrient source is acceptable when applied at similar rates if N is not limiting. Soil test values and the price of PL and comparable fertilizer sources should be considered prior to making any nutrient application.

INTRODUCTION

Many benefits of manure additions to improve soil quality have been promoted over the years including supply of micronutrients, improved soil structure, drainage, workability, and resistance to compaction (Sistani et al., 2004; Eghball et a., 2004). There are approximately 3,000 commercial broiler poultry houses in Kentucky that generate an estimated 600,000 to 750,000 tons of PL annually. The majority of this manure is applied to fields used for row crop production for a nutrient source in either the fall or spring when manure is cleaned out of the production facilities. Poultry production is mainly concentrated in the western third of the state, the same area that produces 80% of the corn, soybean, and wheat grown in Kentucky. Many producers and commodity board representatives were concerned with the reported nutrient availability coefficients for N, P, and potassium (K), the nutrient value relative to the price paid for the manure, long-term, and the potential to introduce herbicide resistant weed seed suspected of being in the rice hull bedding materials (i.e. glyphosate resistance pigweed species). The same individuals were also interested in potentially positive attributes such as increased soil organic matter, water infiltration rates, plant available water, crop yields and reduced soil penetrometer resistance. The Kentucky Soybean Promotion Board and the Kentucky Corn Promotion Council jointly funded this research project to address the above questions with poultry litter use in Kentucky.

MATERIALS AND METHODS

Four field sites in a corn-soybean rotation were identified in the fall of 2012 that had appreciable levels of soybean cyst nematodes, low to medium soil test values, and no history of PL use. In 2016, one location scheduled to be planted to corn was planted to soybean due to excessive soil moisture and delayed planting date. Three years into this study, each location consisted of three studies: a large plot study, a small plot N-rate study, and a soybean late season N study. Plot width for the large plot studies at all locations was 60 ft and plot length varied with location from 200 ft to 400 ft. Plot dimensions for the small plot and soybean late season N studies were 10 ft by 40 ft. All soils are poorly to somewhat poorly drained.

Nutrients for the large plot study were applied as PL or commercial dry fertilizer at similar rates. Nutrient availability coefficients for PL of 0.5, 0.8, and 1.0 were used to calculate plant available N, P_2O_5, and K_2O, respectively. Comparable commercial dry fertilizer rates were applied based on the availability adjustments above. A target of 70 lb N/A from PL, assuming 50% N availability, and total N content of manure determined final PL application rate for individual years. All locations received the same manure rate in a given year. An additional 130 lb N/A, as AN, was applied to the PL treatment when plots were cropped to corn to bring the total plant available N to 200 lb/A. No additional fertilizer N was applied when large plot fields were cropped to soybean. The N response trial was a combination of increasing N alone or in addition to PL. Soybean in the late season N study received 100 lb N/A as AN at R1, R3, or R5 and compared against the non-treated check. All manured fields received a comparable amount of fertilizer P and K as received in the PL application. All nutrients were surface applied without incorporation, with the exception of Hopkins County in 2015.

Yield data for large plot studies were collected with producers' combines. Yields for small plot and late season N studies were collected by hand harvesting corn or with a plot combine for soybean. Soil samples were collected at 0 to 3 and 3 to 6 inch depth increments in the fall of each year after crop harvest and analyzed for pH, P, K, magnesium (Mg), calcium (Ca), Zn, and soil organic matter (SOM) by UK Regulatory Services. Statistical analysis was conducted using Proc GLM in SAS version 9.4 and a 90% confidence interval.

RESULTS AND DISCUSSION

Yield Data

There were few statistical differences between commercial fertilizer and poultry litter nutrient sources for soybean or corn (Table 1). Corn yield at Hopkins County in 2015 was statistically greater with PL over commercial fertilizer. Nutrients at Hopkins County in 2015 were immediately incorporated after application and prior to planting. Nutrient incorporation would reduce volatile N losses at this location and help explain the 10 bu/A yield advantage with

PL over commercial fertilizer. Further, excessive rainfall in 2015 at this location would promote denitrification of nitrate-N. The AN used would have a greater potential for denitrification losses compared to PL.

All other corn yields were statistically similar. This can be an indication that a 50% N availability coefficient is appropriate for NT corn production under “normal” Kentucky growing conditions. This can also indicate that the 200 lb N/A rate was more than sufficient to maximize yield and that less than 200 lb N/A was truly needed. Finally, similar yields between nutrient sources could indicate that denitrification losses with AN fertilizer were similar to ammonia volatilization losses associated with surface application of PL. Additional information must be collected to confirm the specific mechanism(s) responsible, but based on small data the 200 lb N/A was more than typically needed to maximize corn yield.

The small plot yield data both supports and contradicts the large plot data (Tables 2, 3, and 4). Corn yield increases with increasing amounts of total plant available N. At McLean 2016 and Daviess 2015 there was no yield benefit to rates greater than120 lb N/A. However at Henderson in 2014, yields benefits at N rates greater than 120 lb N/A. The 50% N availability coefficient appears reasonable when any fertilizer N is applied with the PL, but is deficient without additional fertilizer N as with the PL 70 + CF 0 treatment (Tables 2 and 3). At this level, the availability coefficient is closer to 25%. This small plot data supports the hypothesis that N rates of 200 lb/A are excessive for many of the site-years of data collected during this study.

Soybean yields were also generally similar between nutrient sources (Table 1). Two site-years that yields were favored by PL additions were Henderson County in 2015 and Daviess County in 2014. All other site-years resulted in similar yields to indicate that P and K content are similar regardless of nutrient source. The mechanism for the statistical increase in soybean yield with the use of PL is elusive. It was thought that late season mineralization of N contained in the PL was responsible. This was the basis for including the addition of the late season N study to this project which will be discussed in more detail below.

Nutrient Status

After four years of PL applications to the same plots and equivalent rates of P and K applied using commercial fertilizer (i.e. 0-45-0 and 0-0-60), all soil test P values increased more with the use of PL than with commercial fertilizer (Table 5). This was most evident at the Daviess County and Henderson County locations where the values were about twice as high in the PL plots. Two factors could lead to these results. The University of Kentucky reports a P availability coefficient of 0.8 (Rasnake, 2000). Thus in reality, 20% more P is being applied with PL than with the commercial fertilizer. Another possibility is that P availability is generally higher with PL after nutrients in PL mineralize. For example, if equal amounts of P are applied with 0-45-0 and PL, initially more P will be in solution with the 0-45-0, but will then decline with time. However, the mineralization of PL will “release” P throughout the season and likely have greater available P later in the season. Long-term use of PL can also lead to excessive levels of soil test P and application is not warranted when P is not limiting (He, 2008; Kingery et al., 1994).

Increases in soil test K values were not as pronounced or consistent with the use of PL compared to commercial fertilizer (Table 5). This is likely due to the 1.0 availability coefficient for K and the same amount of total nutrients are being added with both nutrient sources. Another notable result is with soil test Zn. The amount of Zn is typically 2-3 times greater when PL is used as the nutrient source compared to commercial fertilizer. We did not “balance” the Zn present in the manure with commercial fertilizer. The results clearly indicate the Zn contribution from PL (Table 5).

Poultry litter has a slight liming effect due to poultry feed rations and is estimated at a relative neutralizing capacity of approximately 10. With continued use of PL in these plots over time, we expected to see pH slightly higher in the PL amended plots. This was true at two of the locations, but not at the other two. A reason for this discrepancy is not known since all PL used in a particular year was sourced from the same poultry house.

The use of PL is promoted to build SOM. There was a slight numerical increase in SOM with the PL treatments, but not statistically significant. The PL used in this study had a carbon content of approximately 35 – 40% on a dry matter basis (data not shown). Poultry litter application rates varied from 2 – 2.7 tons/A due to nutrient content and targeting 70 lb plant available N/A. Based on these values, about 6,500 lb C was added per acre during the timeframe of this study that was not added with the commercial fertilizer treatments. The small potential change and sampling variability would make it hard to detect the minor increase in SOM content for this study.

Soybean Late Season N Study

Due to slight but consistent yield increases in soybean yield with the use of PL (Table 1), we wanted to investigate the mechanism responsible for this result. Shibles (1998) reported that free nitrate interferes with the infection *Bradyrhizobia* and reduces the capacity to fix atmospheric N_2. Further, N_2-fixation naturally declines rapidly after growth stage R5. Based on these observations, we suspected that application of early fertilizer N was reducing nodule formation and function. We suspected that the mineralization of N from PL likely occurs throughout the season and may be responsible for the slight yield increase observed. However, six site-years of data do not strongly support this hypothesis (Table 6). The only statistical yield increase to date was observed at Daviess County in 2016 where a 7 bu/A yield increase was observed (Table 6). No consistent results have been observed for this study for dryland soybean production.

SUMMARY

Comparable yields were generally realized when either PL or commercial fertilizer are used at the same nutrient application rate for corn and soybean production. There were three out of 16 site years that crop yields were statistically higher with PL than with commercial fertilizer. Commercial fertilizer never resulted in greater crop yields than PL. The higher corn yield with PL was attributed to conservation of N with PL incorporation and higher denitrification rates of the AN fertilizer. Increased soybean yields in two site-years was attributed to season long mineralization of N contained in the PL, but six site-years of the application of N did not confirm this hypothesis. Corn yields were maximized in two years with 120 lb N/A, but in one year, greater N rates were needed to maximize corn yields. The N availability coefficient of 0.50 appears to be high in most years based on the N response trials and probably due to volatilization of surface applied PL. In the years reported, 200 lb N/A was more than adequate to maximize corn yields. Soil test values, particularly P, increased at greater rates when PL was used as the nutrient source. This was attributed to more total P added due to the P availability coefficient of 0.80 used in Kentucky for PL. Soil test Zn was found at 2–3 times higher soil concentrations with PL than commercial fertilizer. Comparable yields between the PL and commercial fertilizer additions indicated that either nutrient source is acceptable when applied at similar rates. Soil test values and the price of PL and comparable fertilizer sources should be considered prior to making any nutrient application.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support provided by the Kentucky Soybean Promotion Board, the Kentucky Corn Promotion Council, and cooperating producers

REFERENCES

Eghball, B., D. Ginting, and J. E. Gilley. 2004. Residual Effects of Manure and Compost Applications on Corn Production and Soil Properties. Agron. J. 96:442-447.

He, Z., I. A. Tazisong, Z. N. Senwo, and D. Zhang. 2008. Soil Properties and Macro Cations Status Impacted by Long-Term Applied Poultry Litter. Commun. Soil Sci. Plant Anal. 39: 858-872.

Kingery, W. L., C. W. Wood, D. P. Delaney, J. C. Williams, G. L. Mullins, and E. van Santen. 1994. Impact of long0term application of broiler litter on environmentally related soil properties. J. Environ. Qual. 23:139-147.

Rasnake, M., B. Thom, and F. Sikora. 2000. AGR-146 Using animal manures as nutrient sources. University of Kentucky Cooperative Extension Publication.

Shibles, R.M. 1988. Soybean nitrogen acquisition and utilization. Proceedings of the 28th North Central Extension-Industry Soil Fertility Conference, Des Moines, IA. Vol. 14. p. 5-11.

Sistani, K. R., G. E. Brink, A. Adeli, H. Tewolde, and D. E. Rowe. 2004. Year-round Soil Nutrient Dynamics from Broiler Letter Application to Three Bermudagrass Cultivars. Agron. J. 96:525-530.

Table 1. Corn and Soybean yields for large plot studies at all locations for 2013 to 2016.

			Yields (bu/A) for Nutrient Sources	
County	Crop	Year	Poultry Litter[1]	Commercial Fert.[2]
Daviess	Soybean	2016	82 a	80 a
Henderson	Soybean	2016	56 a	58 a
Hopkins	Soybean	2016	78 a	76 a
McLean	Corn	2016	176 a	173 a
Daviess	Corn	2015	198 a	199 a
Henderson	Soybean	2015	64 a	60 b
Hopkins	Corn	2015	204 a	194 b
McLean	Soybean	2015	79 a	74 a
Daviess	Soybean	2014	86 a	83 b
Henderson	Corn	2014	250 a	245 a
Hopkins	Soybean	2014	64 a	61 a
McLean	Corn	2014	211 a	211 a
Daviess*	Corn	2013	146 a	169 a
Henderson	Soybean	2013	55 a	52 a
Hopkins	Corn	2013	181 a	185 a
McLean	Soybean	2013	67 a	64 b
Average	Corn	All Years	195 a	197 a
Average	Soybean	All Years	70 a	68 a

* Straight line winds damaged the crop introducing yield data variability

[1] Poultry litter was applied at 2.3 tons/A (70 lbs N/A from PL), an additional 130 lbs of N was applied as ammonium nitrate fertilizer. No additional N was applied for soybeans

[2] Commercial P and K Fertilizer was applied at "equivalent" rates to the PL, total N = 200 lbs/A

[3] Yields followed by different letter within a site-year are statistically different at the 90% CI

Table 2. Corn yield data for McLean County in 2016.

Location	Crop	Treatment [1]	Yield (bu/A) [2]
McLean	Corn	PL 70 + CF 140	179 a
McLean	Corn	CF 160	173 ab
McLean	Corn	CF 200	172 ab
McLean	Corn	CF 120	171 ab
McLean	Corn	PL 70 + CF 70	163 bc
McLean	Corn	CF 80	156 c
McLean	Corn	CF 40	120 d
McLean	Corn	PL 70 + CF 0	118 d
McLean	Corn	CF 0	86 e

[1] CF = commercial fertilizer N rate (lb/A), PL = poultry litter N rate (lb/A) assuming 50% availability coefficient for N

[2] Yields followed by different letters are significantly different at the 90% CI

Table 3. Corn yield data for Daviess County in 2015.

Location	Crop	Treatment [1]	Yield (bu/A) [2]
Daviess	Corn	CF 120	184 a
Daviess	Corn	CF 200	183 a
Daviess	Corn	CF 160	181 a
Daviess	Corn	PL 70 + CF 140	179 a
Daviess	Corn	CF 80	121 b
Daviess	Corn	PL 70 + CF 70	107 bc
Daviess	Corn	CF 40	103 bc
Daviess	Corn	PL 70 + CF 0	81 bc
Daviess	Corn	CF 0	68 c

[1] CF = commercial fertilizer N rate (lb/A), PL = poultry litter N rate (lb/A) assuming 50% availability coefficient for N

[2] Yields followed by different letters are significantly different at the 90% CI

Table 4. Corn yield data for Henderson County in 2014.

Location	Crop	Treatment [1]	Yield (bu/A) [2]
Henderson	Corn	CF 200	262 a
Henderson	Corn	CF 160	241 ab
Henderson	Corn	PL 70 + CF 140	233 ab
Henderson	Corn	CF 80	224 b
Henderson	Corn	CF 120	219 b
Henderson	Corn	PL 70 + CF 70	214 bc
Henderson	Corn	CF 40	183 cd
Henderson	Corn	CF 0	169 d
Henderson	Corn	PL 70 + CF 0	167 d

[1] CF = commercial fertilizer N rate (lb/A), PL = poultry litter N rate (lb/A) assuming 50% availability coefficient for N

[2] Yields followed by different letters are significantly different at the 90% CI

Table 5. Soil phosphorus, potassium, zinc, soil pH, and soil organic matter (SOM) content for top three inches of soil for spring 2016.

		----------Soil test values (lb/A)----------						---H Ion---		---Percent ---	
		PL[1]	Fert.[2]	PL	Fert.	PL	Fert.	PL	Fert.	PL	Fert.
County	Crop	P	P	K	K	Zn	Zn	pH	pH	SOM	SOM
Daviess	Soybeans	208	111	383	318	12	4	6.8	6.3	2.7	2.4
Henderson	Soybeans	228	96	135	149	10	3	6.0	6.9	2.5	2.3
Hopkins	Corn	187	139	276	283	14	7	7.3	7.2	2.8	2.9
McLean	Soybeans	128	88	242	205	8	3	6.5	6.1	2.1	1.9

[1] Poultry litter was applied to achieve 70 lbs N/A from PL using a 0.5 availability coefficient (for example, 2.3 tons PL/A was applied in 2016 to achieve this N rate)

[2] Commercial P and K Fertilizer was applied at "equivalent" rates to the PL, based on availability coefficients: P = 0.80 and K = 1

Table 6. Yield effect of late season nitrogen applied to soybean.

Treatment	McLean 2015	Henderson 2015	UKREC 2015	UKREC 2016	Henderson 2016	Davies 2016
None	66	55	46	65	48	69 b[1]
R1	62	60	48	60	51	76 a
R3	64	54	45	59	46	71 ab
R5	60	57	48	58	50	70 b
Pr>F	0.9451	0.3281	0.1168	0.2111	0.8606	0.0482

[1] Yields followed by different letters are significantly different at the 90% CI