Influence of Poultry Litter on N-ST*R Soil-test Values During a Laboratory Incubation

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BACKGROUND INFORMATION AND RESEARCH PROBLEM

Rice (*Oryza sativa* L.), is grown on approximately 1.2 million acres in Arkansas annually, making Arkansas the leading rice-producing state in the U.S. Concurrently, poultry litter (PL) is one of the most nutrient-rich soil amendments and is applied to a large number of row-crop acres each year in Arkansas. Poultry litter is typically applied to satisfy phosphorus (P) and potassium (K) recommendations; however, a study conducted by Golden et al. (2006) indicated that about 25% of the total nitrogen (TN) applied as PL was recovered by the rice crop. Most of the nitrogen (N) in PL is found in the organic form, ~90%, with the remaining 10% of the TN found in PL as inorganic-N, mainly in the form of NH$_4$-N. With mineralization catalyzed by microbial activity, the rate in which the organic-N fraction of PL is mineralized can be rapid and is influenced by litter characteristics and soil temperature, moisture, and texture. Laboratory incubation research conducted by Diaz et al. (2008) and Gordon (2011) indicated soil NH$_4$-N concentrations following a PL application peak within 1 week.

The most recent advancement in predicting N fertilizer needs for rice production in Arkansas was the correlation and calibration of the Nitrogen-Soil Test for Rice (N-ST*R) developed by Roberts et al. (2011). This is a site-specific soil-based N test that predicts potentially mineralizable soil-N (e.g., amino sugars, amino acids, and NH$_4$) as alkaline hydrolyzable-N (AH-N). Alkaline hydrolyzable-N is used to determine N fertilizer needs for rice on silt loam soils and uses the direct steam distillation (DSD) method of determination (Bushong et al., 2008). The N-ST*R has been released for use in Arkansas to predict field-specific N requirements; however, there has been little research concerning the effect of PL applications on N-ST*R soil-test values. Rice producers are applying PL and using N-ST*R, so it is important to understand how PL rate and application time influence N-ST*R soil-test values. Therefore, the objective of this research was to quantify PL influences on N-ST*R soil-test values and determine the minimum time following a PL application to collect soil samples for N fertilizer recommendations.

PROCEDURES

To evaluate the effects of PL source on N-ST*R soil-test values using the DSD, a 60 day aerobic laboratory incubation was conducted. Treatments for this experiment included an untreated control (no-PL) and five sources of PL (Table 1), arranged in a randomized complete block design with three replications. Four of the PL sources used in this incubation were collected from fresh litter samples from northwest Arkansas sent to the University of Arkansas System Division of Agriculture Diagnostic Laboratory for nutrient analysis. The fifth PL sample was pelleted poultry litter (PPL). Each of the four fresh PL sources was blended and stored in sealable bags. Soil used in the incubation was collected from the University of Arkansas Pine Tree Research Station (Calhoun silt loam, pH 7.9) from the top 6-in. of the soil surface, dried in a greenhouse, and crushed to pass a 2-mm sieve.

Incubations were performed in 100-mL specimen cups filled with 100 g of soil. Soil was moistened and placed in the incubation chamber at 23 °C (73 °F) for a 10 day preincubation period. A -85 kPa matric potential (20% gravimetric moisture) was maintained throughout the duration of the incubation using deionized water. Immediately after the preincubation, PL was weighed (0.1612 to 0.3701 g PL/100 g soil; to the nearest 0.0001 g) to supply 148 lb N/acre (equivalent to 2 ton/acre of the PPL) and added to the appropriate cup and mixed. Specimen cups with the amended PL were loosely covered with plastic wrap and returned to the incubation chamber at a constant temperature of 23 °C. Extractions to quantify AH-N were performed at 0, 3, 7, 11, 15, 24, 33, 42, 51, and 60 days after initiation of the incubation. At each extraction time, specific specimen cups were removed from the incubator and soil was transferred into soil boxes, dried at 55 °C, crushed to pass a 2-mm sieve, and sent to the University of Arkansas N-ST*R Soil Testing Lab to analyze AH-N using the DSD method outlined by Bushong et al. (2008).

Statistical analyses were carried out using JMP PRO 9.0 (SAS Institute, Inc., Cary, N.C.). Data was analyzed as a split-plot design with PL source as the whole-plot factor and extraction time as the split-plot factor. Means were calculated by averaging the replicates at each extraction time. Means were separated using the least significant difference (LSD) test, assessing significance at $P < 0.05$. 
RESULTS AND DISCUSSION

There was a significant influence on AH-N values as a result of PL application, which was further influenced by the two-way interaction of PL source and extraction time ($P < 0.0001$). This interaction is a result of significant differences in the AH-N values among litter sources for the 0- and 3-day extraction times. Substantial fluctuations in AH-N were observed within the first 7 days and the AH-N values peaked within the first 3 days. Similar results were observed for an incubation experiment using PL and a Calhoun silt loam soil in Arkansas conducted by Gordon (2011), who reported a peak in NH$_4$-N concentrations within the first 7 days after PL was applied. Significant differences among PL sources were observed only within the first 3 days of our incubation (Fig. 1).

Alkaline hydrolyzable-N stabilized with 85 to 90 mg N/kg soil after 11 days into the incubation for all PL sources, with no significant changes in AH-N for all fresh PL sources following the 11-day extraction (Fig. 2a, b, c, and d). There was a significant increase in AH-N for the PPL at the 33-day extraction (Fig. 2e); however, this increase was not a significant amount when determining N fertilizer recommendations using N-ST*R. Previous research has shown PL mineralization can be separated into two distinct phases including a rapid initial flux of N mineralization followed by a slower phase (Hadas et al., 1983). Correspondingly, this experiment displays two phases of N mineralization with the initial rapid phase occurring in the first week trailed by a slower rate of mineralization which is relatively constant (Fig. 1). The AH-N concentrations followed similar trends as soil NH$_4$-N concentrations following a PL application as shown by Hadas et al. (1983) who reported that soil NH$_4$-N reached a maximal concentration within the first week followed by a substantial decrease.

The fresh-2, -3, and -4 litters contained greater initial inorganic N concentrations than the fresh-1 and PPL (data not shown), resulting in an immediate decrease in AH-N values from the establishment of the incubation until reaching a plateau at the 11-day extraction. However, the fresh-1 and PPL sources had greater proportions of N in the organic form, resulting in an initial increase in AH-N from the 0- to 3-day extractions followed by a significant decrease. The AH-N in all litter amended soils reached a plateau at the 11-day extraction time, with a steady mineralization rate (Fig. 1). Also, PL sources that displayed delays in their peak AH-N concentrations (PPL and fresh-1) had low (<20%) initial moisture contents compared to the other litter sources (Table 1). The higher moisture content of the fresh-2, -3, and -4 litter sources potentially could have been the reason why we observed no delay in mineralization at the start of the incubation. The dry state of the litter-1 and PPL may have delayed microbial activity.

If N recommendations were based on AH-N values within the first week following the PL application, the resulting N recommendation from N-ST*R would have been underestimated and could have been as low as 84 lb N/acre (156 mg N/kg soil; Roberts et al., 2011). However, the lowest N rate recommenda-

PRACTICAL APPLICATIONS

Information relating the influence of PL on N-ST*R soil-test values across time allow us to ensure that the proper N recommendation is determined using N-ST*R following a PL application. The results of this study demonstrate the ability to design soil sampling protocols, recommending that producers applying PL need to wait at least 11 days following a PL application before collecting soil samples for N recommendations using N-ST*R.

ACKNOWLEDGMENTS

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LITERATURE CITED


Table 1. Characteristics of the poultry litter utilized in the 60-day incubation study.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Litter type</th>
<th>Bedding material</th>
<th>Animal type</th>
<th>Total N (% of dry weight)</th>
<th>Total C (% of dry weight)</th>
<th>Moisture (% of dry weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPL*</td>
<td>pelleted</td>
<td>none given</td>
<td>none given</td>
<td>3.70</td>
<td>30.24</td>
<td>11.40</td>
</tr>
<tr>
<td>fresh-1</td>
<td>fresh</td>
<td>rice hull</td>
<td>cornish hen</td>
<td>4.56</td>
<td>32.27</td>
<td>16.70</td>
</tr>
<tr>
<td>fresh-2</td>
<td>fresh</td>
<td>shavings/sawdust</td>
<td>pullet</td>
<td>2.54</td>
<td>20.62</td>
<td>29.09</td>
</tr>
<tr>
<td>fresh-3</td>
<td>fresh</td>
<td>none given</td>
<td>broiler</td>
<td>3.33</td>
<td>22.03</td>
<td>43.08</td>
</tr>
<tr>
<td>fresh-4</td>
<td>fresh</td>
<td>rice hull/shavings</td>
<td>broiler</td>
<td>1.99</td>
<td>29.21</td>
<td>27.40</td>
</tr>
</tbody>
</table>

* PPL, pelleted poultry litter obtained from Perdue AgriRecycle (Seaford, Del.).

Fig. 1. Influence of poultry litter source and sample time on alkaline hydrolyzable-N (AH-N) to compare litter sources within the same extraction time. The * indicates a significant difference among litter sources within an extraction time at the $P < 0.05$ level.
Fig. 2. Influence of poultry litter (PL) source and sample time on alkaline hydrolyzable-N (AH-N) for a) fresh litter-1 b) fresh litter-2 c) fresh litter-3 d) fresh litter-4 and e) pelletized PL. Means with the same letter are not significantly different at the $P < 0.05$ level.