The Nitrogen Fertilizer Value of Preplant-Incorporated Poultry Litter for Flood-Irrigated Rice


ABSTRACT

Poultry litter contains an abundance of nitrogen (N) and has been used to fertilize pastures and forage crops in western Arkansas for a number of years. The objective of this study was to determine the N-fertilizer value of preplant-incorporated fresh and pelletized litter in comparison to urea fertilizer applied before flooding rice at the five-leaf stage. Studies were conducted on two silt loams and one clay soil in 2003. Litter was preplant-incorporated at rates of 0, 30, 60, 120, 180, and 240 lb total-N/acre and compared with urea applied preflood at 0 to 150 lb N/acre for silt loam soils and 0 to 250 lb N/acre for the clay soil. Rice N content and grain yield were used to estimate the value of litter as a N fertilizer source. Fresh and pelletized litter behaved similarly with both litter sources being less efficient N fertilizers when compared with urea. Maximum N uptake and rice yield were produced only when urea-N was applied at rates from 90 to 150 lb N/acre for silt loam soils and 200 to 250 lb N/acre for the clay soil. Averaged across litter-N application rates, rice recovered between 0 and 10% of litter-N by 0.5-in. internode elongation (IE) and 5 to 25% of litter-N by early heading compared to >40% of urea-N.

INTRODUCTION

Poultry litter contains an abundance of N and has been used to fertilize pastures and forage crops in northwest Arkansas for a number of years. In Pennsylvania, poultry manure use recommendations indicate that 15 to 75% of the total-N content of...
poultry manure is plant available for summer crops during the first year, depending on
the time of application and incorporation following application (Beegle, 1997). The
total-N content of poultry litter ranges from 34 to 136 lb N/ton (dry weight basis) with
an average of about 82 lb N/dry ton (Edwards and Daniel, 1992).

Poultry litter has been used as a soil amendment to help restore the productivity
of precision-leveled soils in eastern Arkansas, but its contribution towards the sea-
sonal nutrient requirements for rice has never been documented. Therefore, the objec-
tive of this study was to determine the N-fertilizer value of preplant-incorporated fresh
broiler and pelletized litter in comparison to urea fertilizer applied before flooding rice at
the five-leaf stage. Our hypothesis was that the N-poultry litter would be a much less
efficient N source for flood-irrigated rice when compared to urea.

PROCEDURES

Three study sites were established in 2003. Sites included a Calhoun silt loam at
the Pine Tree Branch Station (PTBS) near Colt, Ark.; a Dewitt silt loam at the Rice
Research Extension Center (RREC) near Stuttgart, Ark.; and a Sharkey clay at the
Northeast Research and Extension Center (NEREC) in Kieser, Ark. Eight composite soil
samples (0- to 4-in. depth), two from each replicate, were taken to characterize soil
chemical properties before treatments were applied (Table 1). Soybean \textit{Glycine max}
(Merr.) L.] was the previous crop at all locations.

Fresh broiler and pelletized poultry litters (Plant Right, Inc., Purdy, Mo.) were
broadcast by hand to plots that were 16 ft long and 6 ft wide. Fresh poultry litter was
obtained from the University of Arkansas Savoy poultry production facility. Approxi-
mately 18 months had passed since the previous clean-out and the initial bedding
application of a combination of rice hulls and sawdust. Both litter sources were ana-
lyzed for nutrient content (Table 2) using procedures outlined by Peters (2003).

Litter was applied at rates of 0, 30, 60, 120, 180, and 240 lb total-N/acre with rates
calculated using the moist litter-N concentrations of each source. Moist-weight litter
application rates ranged from 721 (30 lb N) to 5926 (240 lb N) lb/acre. Poultry litter was
shallowly incorporated with a small tiller (RREC and NEREC) or a field cultivator (PTBS)
within five hours after application to reduce ammonia volatilization. To ensure that P
and K were not yield-limiting factors, triple superphosphate (100 lb/acre) and muriate
of potash (100 lb/acre) were also broadcast-applied to plots that would receive preflood
urea-N before seeding. ‘Wells’ rice was drill-seeded (100 to 120 lb seed/acre) at each
location with each plot containing nine 16-ft long rows of rice with 7-in. drill spacing
and an 18- to 24-in. alley separating adjacent plots.

At the five-leaf stage, urea was broadcast-applied to plots that received no litter.
For the silt loam soils at the PTBS and RREC, urea was applied to a dry soil surface at
rates from 0 to 150 lb N/acre in 30 lb N/acre increments. Plots were flooded two days after
urea was applied. For the clay soil at the NEREC, urea was applied to a dry soil surface at
rates from 0 to 250 lb N/acre in 50 lb N/acre increments and followed by flooding five days
later. No midseason-N was applied. The dates of litter application, flooding, and several other agronomically important plot management events are listed in Table 3.

Whole, aboveground plant samples were taken at the 0.5-in. IE (panicle differentiation) and early-heading growth stages of rice (Table 3). Plant samples were taken from a 3-ft section from the first inside row of each plot. Samples were dried to a constant weight in forced-draft oven, weighed, ground to pass a 1-mm sieve, and analyzed for N concentration by combustion. Aboveground rice-N content was calculated using rice-N concentration and dry-matter accumulation data and expressed as lb N/acre. At maturity, grain yields were determined from the middle four or five rows of rice using a small-plot combine and adjusted to a uniform moisture content of 12% for statistical analysis.

Each experiment was a randomized complete block design with a 3 (nutrient source) x 5 (application rate) factorial treatment structure compared to an unfertilized control. Since total N rates were occasionally different among sources, each N rate was assigned a value from 0 (lowest N rate) to 5 (highest N rate) for statistical comparison. Each treatment was replicated four times. Differences among treatments were identified using the Fisher’s protected Least Significant Difference (LSD) test at the 0.05 significance level.

RESULTS

Nitrogen Content at 0.5-in. IE and Heading

Plant-N content was not measured before the 0.5-in. IE growth stage, but litter application visually increased rice seedling and weed growth before flooding on both silt loam soils. Plants receiving poultry litter were taller and appeared more vigorous before flooding than plants that had not yet received urea N. Seedling growth was also stimulated on the clay soil at the NEREC, but not to the same magnitude as observed for the silt loam soils. By seven to ten days after flooding at all locations, rice receiving preflood urea was green and growing vigorously whereas plants receiving litter had started to turn yellow and were growing slowly indicating N deficiency.

The N source x application rate interaction was significant for plant-N content at 0.5-in. IE for the PTBS (P<0.0001), RREC (P<0.0001), and NEREC (P<0.0001, Fig. 1). In general, plant-N content at all three locations showed similar trends. Fresh and pelletized litter behaved similarly with both litter sources being less efficient N fertilizers when compared with urea. The N contents of rice receiving poultry litter were statistically similar to the unfertilized control (0 lb N/acre) with the numerical N contents increasing gradually as litter-N rate increased. The N contents of rice fertilized with urea preflood increased incrementally as urea-N rate increased up to the highest (PTBS) or second highest N rate (RREC and NEREC). The lowest preflood urea-N rate generally produced similar plant-N contents as litter-N rates from 120 to 240 lb N/acre. Although N loss via denitrification was not measured, we assume that an appreciable amount of organic N mineralized, underwent nitrification between application and flooding, and was subsequently lost via denitrification upon flooding.
The N source x application rate interaction was also significant for plant-N content at beginning heading for the PTBS (P<0.0001), RREC (P<0.0001), and NEREC (P<0.0038, Fig. 2). The general trends for plant-N content among N sources and rates were similar to those described for the 0.5-in. IE sample time. However, the highest litter-N application rates (180 to 240 lb N/acre) tended to produce significantly greater N contents than the unfertilized control, which suggests that N continued to be mineralized from the preplant-incorporated litter and may possibly reduce the need for supplemental midseason-N.

In general, plant uptake of N from both poultry sources followed a linear trend at both sampled growth stages with plant-N contents increasing very slowly as litter-N rate increased at all three locations (Figs. 1 and 2). For the silt loam soils, plant-N contents also increased linearly as urea-N rate increased although the rate of increase was more rapid compared to poultry litter. In contrast, by heading, plant-N contents for the clay soil at the NEREC showed a non-linear (quadratic) increase due possibly to greater total urea-N rates that were applied, greater N fixation, greater N loss, or combinations of all these factors. By heading, the total-N content of plants receiving 120 to 150 lb N/acre for silt loam soils contained about 150 to 160 lb N/acre. Despite the higher urea-N rates applied to the clay soil at the NEREC, maximum N uptake at heading ranged from 115 to 125 lb N/acre when 150 to 250 lb N/acre were applied, which was numerically less than N uptake by rice on the silt loams soils at the PTBS and RREC.

**Grain Yield**

At the PTBS, the main effects of N source (P<0.0001) and application rate (P<0.0001) significantly affected rice grain yield. The site at the PTBS had been cropped to soybean for the previous two years and apparently had greater available soil N (Fig. 1 and 2), which reduced the N rate needed to produce maximum grain yields. When averaged across all N application rates, urea (7766 lb/acre) produced greater yields than both fresh (6365 lb/acre) and pelletized litter (6164 lb/acre), which had similar yields that were greater than the unfertilized control (4785 lb/acre, LSD(0.05) = 617 lb/acre). All N rates, averaged across N sources, produced greater yields than the unfertilized control, with 90 to 150 lb N/acre producing equal and significantly greater yields than 30 to 60 lb N/acre (data not shown).

The N source x application rate interaction was significant for grain yield at the RREC (P=0.0024) and NEREC (P<0.0001, Fig. 3). Rice yields showed similar trends among sources and application rates as shown for plant-N content at heading (Fig. 2). Litter application rates of 30 lb N/acre (< 1000 lb litter/acre) typically produced similar rice yields as the unfertilized control, but litter-N rates >30 lb N/acre significantly increased grain yield, indicating that litter has some N fertilizer value when applied at rates >1000 lb litter/acre.

Maximal rice yields were produced only when urea-N was applied at rate ranges of 90 to 120 lb N/acre at the PTBS, 90 to 150 lb N/acre at the RREC, and 200 to 250 lb N/acre at the NEREC. Averaged across litter-N application rates, rice recovered between
0 and 10% of litter N by 0.5-in. IE and 5 to 25% of litter N by early heading compared to >40% of urea-N (data not shown). Based on grain-yield response, application of 2000 lb/acre of poultry litter that is immediately preplant-incorporated on silt loam soils is equal to no more than 25 lb N/acre (54 lb urea/acre). The same 2000 lb/acre application rate provided negligible grain yield increases on the clay soil that could be attributed to its N content.

SIGNIFICANCE OF FINDINGS

Three site-years of data indicate that rice recovers a low percentage (10 to 25%) of the total N in preplant-incorporated poultry litter by heading. Fresh and pelletized litter provided similar amounts of plant-available N to flood-irrigated rice when applied at equal total-N rates. Poultry litter improved rice and weed seedling growth before flooding at the five-leaf stage, especially on the silt loam soils, but failed to provide adequate N to sustain maximum rice growth after flooding at all application rates and locations. Based on the results of another study conducted in 2003, poultry litter may be an adequate alternative to inorganic P and K fertilizers with the mineralized N serving as starter fertilizer. Manipulation of the time rice is flooded (i.e., flood sooner or later than five-leaf stage) may enhance the N contribution from litter by preventing denitrification losses of mineralized N and should be investigated in further studies.

LITERATURE CITED


Table 1. Selected soil chemical properties of research sites at the Northeast Research Extension Center (NEREC, Sharkey clay), Pine Tree Branch Station (PTBS, Calhoun silt loam), and Rice Research Extension Center (RREC, Dewitt silt loam) in 2003.

<table>
<thead>
<tr>
<th>Site</th>
<th>pH</th>
<th>N</th>
<th>C</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>S</th>
<th>Cu</th>
<th>Zn</th>
<th>Moisture</th>
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</thead>
<tbody>
<tr>
<td>PTBS</td>
<td>6.6</td>
<td>0.10</td>
<td>1.2</td>
<td>23</td>
<td>103</td>
<td>1230</td>
<td>40</td>
<td>8</td>
<td>1.9</td>
<td>2.1</td>
<td></td>
<td>8.5</td>
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<tr>
<td>RREC</td>
<td>6.9</td>
<td>0.11</td>
<td>1.1</td>
<td>21</td>
<td>114</td>
<td>1204</td>
<td>52</td>
<td>6</td>
<td>1.4</td>
<td>2.4</td>
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<td>NEREC</td>
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<td>1.6</td>
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<td>4451</td>
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<td>15</td>
<td>3.0</td>
<td>3.0</td>
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<td></td>
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</tbody>
</table>

* Extracted with the standard Mehlich-3 method (1:10 v:v extraction). All values are the mean of eight composite soil samples (0- to 4-in.) taken from the plot area.

* Multiply mg/kg by 2 to get lb/acre.

Table 2. Selected chemical and physical properties of two poultry litter sources used at the Northeast Research Extension Center (NEREC), Pine Tree Branch Station (PTBS), and Rice Research Extension Center (RREC) in 2003.

<table>
<thead>
<tr>
<th>Litter source</th>
<th>pH</th>
<th>C</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>S</th>
<th>Cu</th>
<th>Zn</th>
<th>NH₄-N</th>
<th>NO₃-N</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>8.5</td>
<td>39.5</td>
<td>4.16</td>
<td>1.23</td>
<td>2.26</td>
<td>0.5</td>
<td>313</td>
<td>2270</td>
<td>30</td>
<td>20.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pelletized</td>
<td>6.4</td>
<td>37.3</td>
<td>4.05</td>
<td>1.38</td>
<td>2.55</td>
<td>0.6</td>
<td>406</td>
<td>6508</td>
<td>239</td>
<td>11.0</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

* All values are the mean of two subsamples from each litter source.

Table 3. Selected dates of agronomically important management events for studies conducted at the Pine Tree Branch Station (PTBS), Rice Research Extension Center (RREC) and the Northeast Research and Extension Center in 2003.

<table>
<thead>
<tr>
<th>Event</th>
<th>PTBS</th>
<th>RREC</th>
<th>NEREC</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter application and seeding</td>
<td>4/17</td>
<td>4/15</td>
<td>4/30</td>
<td>(Month/day)</td>
</tr>
<tr>
<td>Preflood-N applied</td>
<td>5/27</td>
<td>5/27</td>
<td>5/27</td>
<td></td>
</tr>
<tr>
<td>Flood established</td>
<td>5/29</td>
<td>5/29</td>
<td>6/2</td>
<td></td>
</tr>
<tr>
<td>Samples at panicle differentiation</td>
<td>6/24</td>
<td>6/24</td>
<td>7/2</td>
<td></td>
</tr>
<tr>
<td>Samples at heading</td>
<td>7/22</td>
<td>7/22</td>
<td>7/29</td>
<td></td>
</tr>
</tbody>
</table>
Fig. 1. Rice-N content at 0.5-in. internode elongation (IE) as affected by N source and application rate at the Northeast Research Extension Center (NEREC), Pine Tree Branch Station (PTBS), and Rice Research Extension Center (RREC) in 2003.
Fig. 2. Rice-N content at early heading as affected by N source and application rate at the Northeast Research Extension Center (NEREC), Pine Tree Branch Station (PTBS), and Rice Research Extension Center (RREC) in 2003.
Fig. 3. Rice grain yield at maturity as affected by N source and application rate at the Northeast Research Extension Center (NEREC), Pine Tree Branch Station (PTBS), and Rice Research Extension Center (RREC) in 2003.