# Nutrient Plant Availability Coefficients for Manures in North Carolina

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Commercial fertilizers contain known quantities of specific nutrient compounds. Upon their addition to soils, this known composition of commercial fertilizers facilitates the prediction of plant-available nutrients. Contrastingly, large portions of nutrients in manures consist of various organic compounds, each with different rates of mineralization (i.e., conversion) to plant-available forms. A long-lasting and continuing challenge for determining the nutrients available from manures is to know the percentage of nutrients released from these materials over the growing season of the receiver crop. The release of these nutrients from manure or any organic source is referred to as plant availability.

## Plant Availability of Manure Nitrogen

Ammonium ($NH_4^+$) and nitrate ($NO_3^-$) are the two forms of N taken up by plants from the soil solution. Pierzynski and co-authors (2005) defined plant-available N (PAN) as the fraction of manure N potentially available upon decomposition after added to soils; mathematically, this was expressed as

$$PAN = [k_m(N_o)+e_f(NH_4\text{-}N+NO_3\text{-}N)]$$

where,

$N_o$ = quantity of organic N in the manure;
$k_m$ = the % of organic N mineralized in the soil; and
$e_f$ = the efficiency of plant recovery of inorganic N ($NH_4$ and $NO_3$) in the manure.

For poultry manures in Delaware, Sims (1987) estimated PAN by the following expression:

$$PAN = 80\%N_i + 60\%N_o$$

where,

$N_i$ = $NH_4$-N+$NO_3$-N in the manure, and
$N_o$ = organic N in the manure = total manure N – $N_i$.

The expressions described above are data intensive, requiring at least three measurements of N in the manure (total N, $NH_4$-N and $NO_3$-N) plus two separate estimates of plant availability among these N fractions. Due to difficulties in tracking whether N taken up by a plant originated from an inorganic or organic fraction, many labs use a more cost-effective expression based on total manure N (TN) of

$$PAN = PA_{coeff}(TN)$$

where,

$PA_{coeff}$ = plant availability coefficient.

The quantity of manure N that is plant-available often is estimated via a laboratory mineralization, wherein the manure is added to the soil and incubated at a favorable moisture content. The soil is sampled, periodically during incubation, and analyzed for the plant-available forms of N (($NH_4$ and $NO_3$). A separate soil sample without added manure is also incubated and analyzed to determine the amount of plant-available N mineralized from the native soil organic matter. The amount of plant-available N mineralized from the manure is estimated as the difference in $NH_4$ plus $NO_3$ measured in soils with and without added manure. Figure 1 illustrates this laboratory procedure for a soil from the Belhaven series treated with 133 ug of total N $cm^{-3}$ as layer poultry manure. In addition to the soil sample without added N, an additional sample with the same amount of N added as urea fertilizer was included for purposes of comparison between N sources.

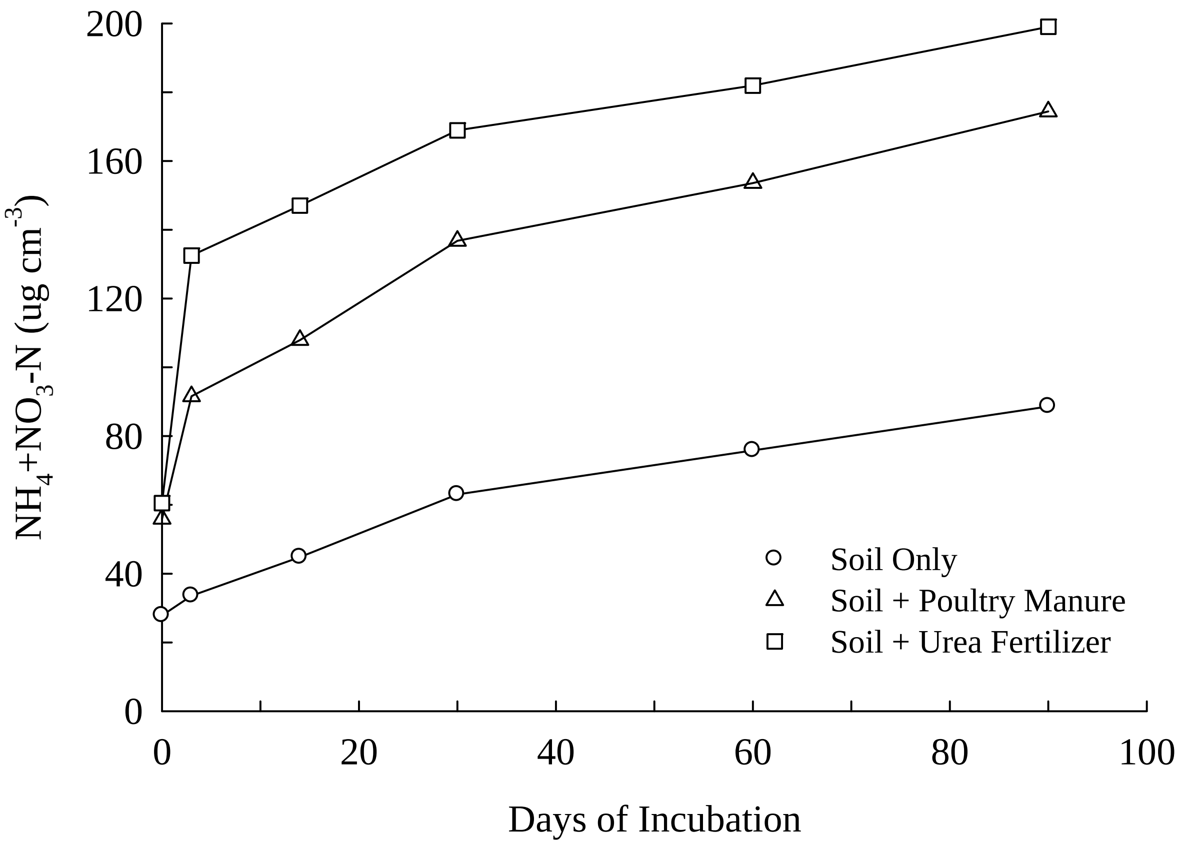


Figure 1. Inorganic N ($NH_4$-N+$NO_3$-N) released from a Belhaven soil during 90 days of incubation at constant soil moisture with no external source of N or with 133 ug $cm^{-3}$ of total N added as either layer poultry manure or commercial urea fertilizer (Montalvo et al., 2010).

The maximum quantity of net N mineralized from the two N sources (Fig. 1) are estimated as the difference in inorganic N at 90 days between soil treated with each N source and soil without added N. These estimated values are 86 ug N $cm^{-3}$ for the poultry manure and 110 ug N $cm^{-3}$ for the urea fertilizer. A plant available N coefficient ($PAN_{coeff}$) can be calculated as the fraction of total N (133 ug N $cm^{-3}$) that is in the inorganic N form at the completion of the incubation. Thus, the $PAN_{coeff}$ is 0.64 for the layer poultry manure and 0.83 for the urea fertilizer.

The value of 0.83 for $PAN_{coeff}$ for the urea means that 17% of this fertilizer N was not recovered as inorganic N in the incubation experiment. The $PAN_{coeff}$ for urea in similar mineralization studies with a Cecil and Lynchburg soil were 0.76 and 0.84, respectively (Montalvo et al., 2010).

Failure to recover all of the N from a highly soluble commercial fertilizer source is indicative of the degree of uncertainty associated with these numbers, due to experimental error and other effects like microbial immobilization of N.

Soil type is included among the factors influencing the $PAN_{coeff}$ value for a given manure. Mineralization experiments with the same composted layer manure in samples from three soils yielded $PAN_{coeff}$ values of 0.53 for a Belhaven, 0.33 for a Cecil and 0.73 for a Lynchburg soil (Montalvo et al., 2010). Mineralization of organic N from the same broiler litter manure sample in nine Ultisols from Georgia were suitably predicted with knowledge of the soil pH, sand content and moisture content at field capacity (Figure 2). It is unknown, however, whether the same soil variables would provide an adequate prediction of N mineralized for a variety of different animal manures.

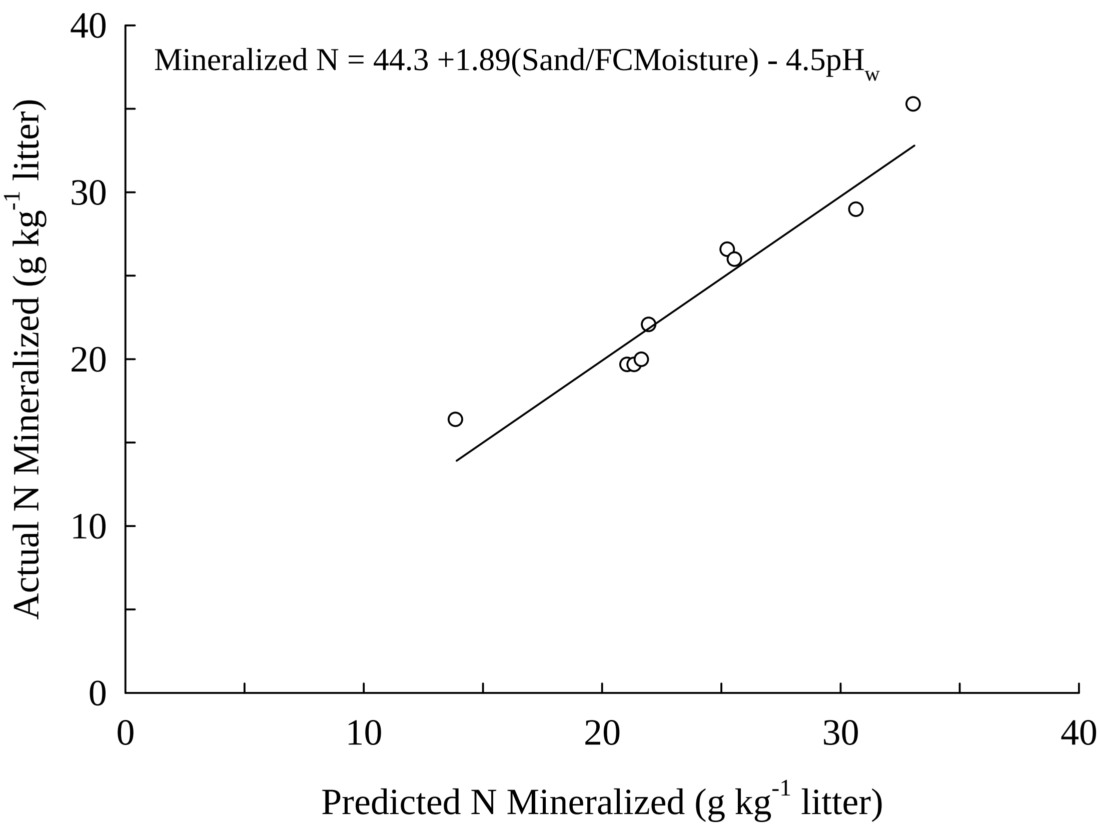


Figure 2. Relation between mineralized N from broiler litter in nine Ultisols and predicted mineralized N predicted based on soil sand content (sand), water content at field capacity (FC Moisture) and pH in water (Adapted from Gordillo and Cabrera, 1997b).

The fraction of manure N that mineralizes to inorganic forms can also be influenced by the chemical composition of the manures. Montalvo and co-workers (2010) compared $PAN_{coeff}$ for the application of 133 ug total N $cm^{-3}$ of three separate poultry manures (fresh, composted and pelleted) to each of three soils (Belhaven, Cecil and Lynchburg). Mean $PAN_{coeff}$ values for the manures, averaged across the three soils, were in decreasing order of fresh > composted > pelleted (Table 1). The ranking in N mineralization matched the manure ranking in total N content.

Table 1. Nitrogen composition and average plant available N coefficients for three poultry manures each incubated with three soils (Belhaven, Cecil and Lynchburg).

| **Manure** | **Total N** | **$NH_4$-N** | **$NO_3$-N** | **Urea-N** | **$PAN_{coeff}$** |
|---|---|---|---|---|---|
| | -------------------- g $kg^{-1}$ dry matter -------------------- | | | | |
| Fresh | 65.3 | 5.6 | 0.04 | 0.04 | 0.60 |
| Composted | 52.9 | 5.6 | 0.01 | 0.01 | 0.53 |
| Pelleted | 37.4 | 2.8 | 0.03 | 0.07 | 0.44 |

(Montalvo et al., 2010)

Gordillo and Cabrera (1997a) evaluated the N mineralization of broiler litter from 15 different houses in northern Georgia on a Cowarts sandy loam soil. Total N in the litter ranged from 29-60 g $kg^{-1}$ dry litter, and, likewise, the $PAN_{coeff}$ ranged from 0.54 to 0.83 (Table 2). Variation in mineralized N among the broiler litter samples was suitably predicted by the following expression:

$$\text{Mineralized N} = -1.02+0.44\text{Total N} + 0.77 \text{ Uric Acid N}$$

Nevertheless, we do not know if this expression would predict N mineralized from a variety of different animal manures or when applied to different soils.

Table 2. Nitrogen composition and N mineralization coefficients for 15 broiler litter samples in a Cowarts sandy loam.

| | **Total N** | **Inorganic N** | **$PAN_{coeff}$** |
|---|---|---|---|
| | ---------- g $kg^{-1}$ dry litter ---------- | | |
| Average | 41.4 | 4.4 | 0.66 |
| Range | 29-60 | 2.6-5.7 | 0.54-0.83 |

(Gordillo and Cabrera, 1997a)

Moore and co-workers (2005) evaluated N mineralization in a Wagram soil from the addition of sludges from nine separate swine lagoons at the rate of 200 mg total N $kg^{-1}$ soil. Despite the range of values for selected sludge properties, as shown in Table 3, there was no significant difference in N mineralized among the sludges over 12 months of incubation. But soil temperature regime influenced the rate of N mineralized. More inorganic N was released during the initial months of sludge incubation with summer rather than winter the soil temperatures (Figure 3). At 12 months of incubation, however, 73% of the applied N had mineralized in either temperature regime.

Table 3. Mean values and range for selected properties of nine swine lagoon sludges investigated by Moore et al. (2005).

| | **Total Kjeldahl N** | **Total Solids** | **C:N Ratio** | **pH** |
|---|---|---|---|---|
| | g/l | % | | |
| Average | 5.0 | 11.0 | 7.7 | 7.5 |
| Range | 4.0-6.3 | 8.1-16.2 | 7.1-8.3 | 7.4-7.6 |

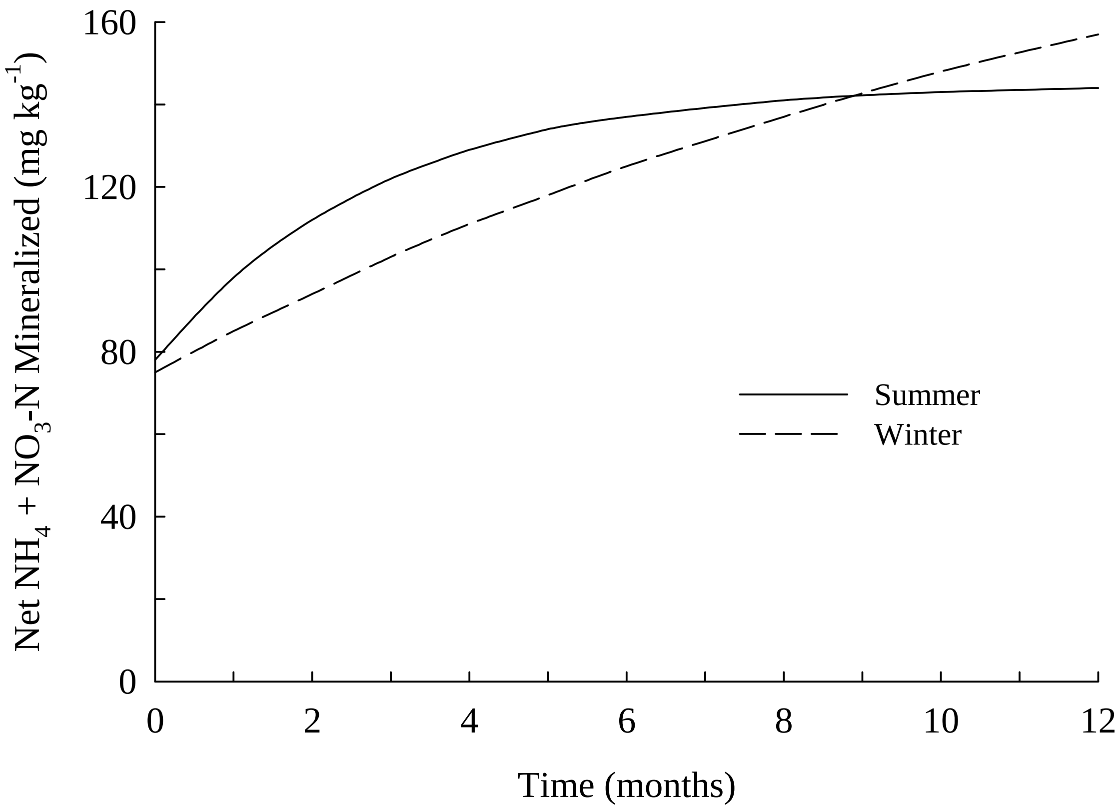


Figure 3. Inorganic N mineralized from swine lagoon sludge incubated in a Wagram soil at summer and winter soil temperature regimes for Kinston, NC. Adapted from Moore et al., 2004.

The composition of manures varies significantly among animal types and management of both the animals and manures. Therefore, nutrient analysis of a "representative" sample of the manure is an important component of a recommendation for land application. Predicting the fraction of manure N that is potentially available to the receiver crop can be influenced by manure composition, soil type and even environmental factors such as soil temperature. Coefficients estimating plant-available N in manures, therefore, need to be developed under conditions similar to those where the manure N recommendations are used.

Plant Availability of Manure Phosphorus

Montalvo and co-workers (2010) evaluated whether the impact of P additions from three poultry manures on soil P availability, as measured with the Mehlich-3 extractant, were different from P added as a calcium phosphate fertilizer. The P treatments included four rates of calcium phosphate and two rates each of fresh, composted and pelleted layer manure, applied to an organic soil (Belhaven) from the Tidewater region and a Cecil from the Piedmont region. The relations between P added as calcium phosphate or manures and the resulting Mehlich-3 P values in each soil are shown in Figure 4. The Cecil soil, with a higher clay content and more Al and Fe oxides, required higher P additions than in the Belhaven to achieve the same Mehlich-3 soil P levels. However, the slope of the relation between added P and Mehlich-3 P in each soil was not influenced by P source. This means that Mehlich-3 soil P availability was directly related to the quantity of P applied, regardless of whether it was an organic source or a calcium phosphate fertilizer.

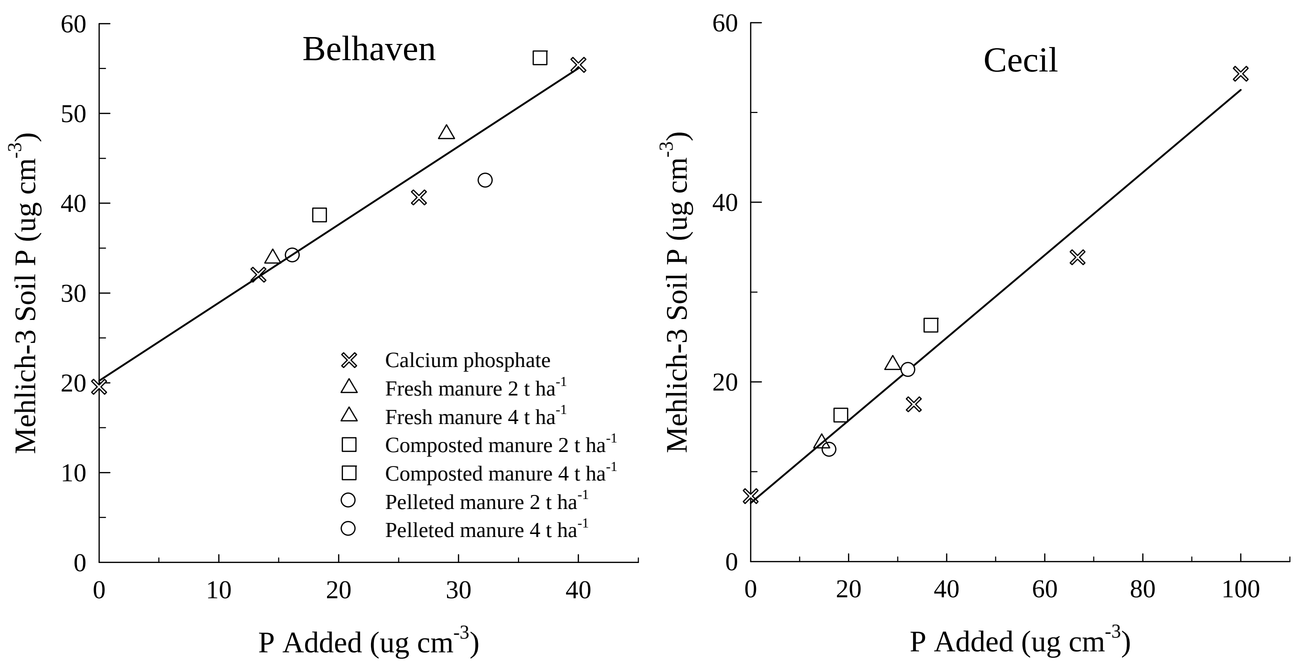


Figure 4. Mehlich-3 extractable P as a function of P added as manures and calcium phosphate to a Belhaven and Cecil soil.

The lack of a difference between manure and fertilizer P in these NC soils is consistent with other investigations. Sharpley and Moyer (2000) found that 84% of the P in poultry manure was in the inorganic form. Different manure P sources and inorganic fertilizer P had similar effects in Wisconsin on both soil test P and subsequent corn yield (Sneller and Laboski, 2009). Therefore, the important consideration for P applications from manures is to know the P content of a “representative” sample.

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