

Project Title: Field Assessment of the Plant N Availability Coefficient for Land Application of Anaerobic Swine Lagoon Sludge in North Carolina.

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Objectives:

- 1) to conduct a field assessment of the plant N availability (PAN) coefficient (0.60) currently used in developing recommendations for application of lagoon sludge N to cropland.
- 2) To determine the rate of N release from the slowly mineralizable organic N fraction in sludge amended soil after harvest of crops supplied swine lagoon sludge

Methods:

In this report we share information generated from two sludge tests with winter wheat (Fall 07 – Spring 08), two sludge test with corn (Spring – Summer 08) and a N residual test with wheat (Fall 08-Spring 09) -. In the tests with wheat, lagoon sludge treatments were 0, 165, 330, 495 and 660 lbs total N ac⁻¹ and a 100 lb N ac⁻¹ as urea ammonium nitrate (UAN) treatment was used to assess plant availability of N in the sludge treatments. Since limited land was available, only one UAN level was used for the tests. In the corn tests, lagoon sludge treatments were 0, 147, 291, 441 and 590 lbs total N ac⁻¹ and urea ammonium nitrate treatments were 0, 50, 100, 150, 200, 250 lbs N ac⁻¹. Comparison of yield and N accumulation response curves for the two N sources is used to assess the plant availability of N in the lagoon sludge. Grain and stover yields and N accumulation in grain and stover at harvest were measured. Soil NO₃-N concentrations were measured to a depth of 36 inches to evaluate movement of NO₃-N below the root zone. After harvest of corn the plots were planted in wheat (November, 2008). In June 2009 grain and straw were harvested for measurement of biomass and N content. This allowed an assessment of recovery of residual N from plots that received different amount of lagoon sludge and fertilizer N (urea-ammonium-nitrate).

Results:

Plant available N in swine lagoon sludge: Wheat test

A significant response of wheat grain yield to applied swine lagoon sludge was observed at two sites. The Pork Plus site had a higher yield potential (75 bu ac⁻¹) than the Shavings Mill site (45 bu ac⁻¹)(Figure 1A). The relatively high yield was associated with cool and moist conditions in May and June. Lower yield at the Shavings mill site was associated with the deep sandy soil and the associated low water holding capacity which probably resulted in some degree of water stress during grain fill even though rainfall was plentiful. The optimum N rate for grain yield occurred between 165 and 330 lbs total sludge N ac⁻¹.

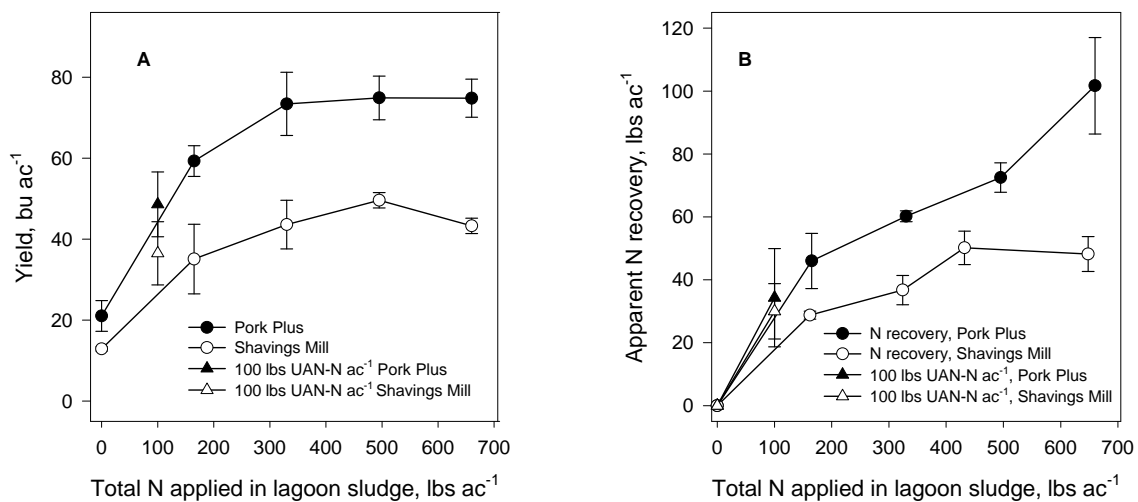
At the Shavings Mill site, yield for the 165 lb total N treatment was almost equal to the 100 lb N ac⁻¹ as UAN treatment (36.7 vs 37.5 bu ac⁻¹)(Figure 1A). The ratio of the

fertilizer N rate to the sludge N that results in equal yields is the plant N availability coefficient. Therefore, a plant N availability coefficient of 0.61 (100 lbs UAN-N ac⁻¹/165 lbs total sludge N ac⁻¹) was obtained for the Shavings Mill test. Extrapolation of yield with the 100 lbs UAN-N ac⁻¹ treatment to the yield response curve for the swine lagoon treatments indicates that 127 lbs of total sludge N produced the same yield as 100 lbs UAN-N ac⁻¹ at the Pork Plus site (Figure 1A). In this case, the plant N availability coefficient is 0.79 (100/127).

Apparent N accumulation is obtained by correcting total crop N accumulation in a given treatment for crop N accumulated in the zero applied N check treatment (Figure 1B). Plant N availability coefficients can be obtained from these data by comparing apparent N recovery values for sludge treatments to apparent N recovery values for the 100 lb UAN-N ac⁻¹ treatment (Figure 1B). This procedure produced plant N availability coefficients similar to those derived on basis of grain yield (0.59 for Shavings mill site and 0.80 for the Pork Plus site).

Note that apparent crop N recovery at the Pork Plus site increased up to 660 lbs sludge N ac⁻¹ (Figure 1B) even though yield reached a maximum at less than 330 lbs sludge N ac⁻¹ (Figure 1A). This indicates excessive uptake of N which was associated with increased N concentrations in the grain and an increase in the ratio of stover biomass to grain biomass (data not shown).

Figure 1. Yield and apparent N recovery responses of wheat to N applied in swine lagoon sludge



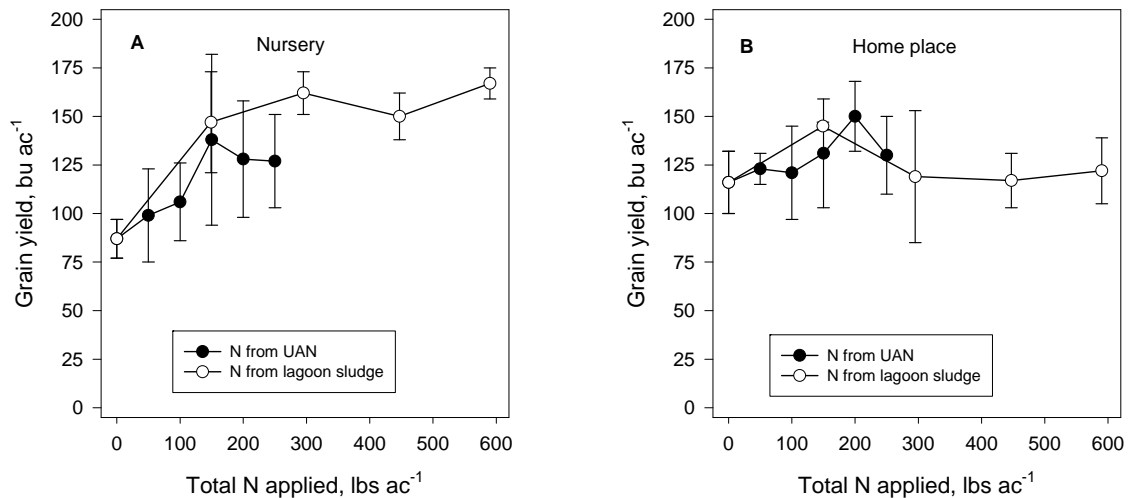
Plant available N in swine lagoon sludge: Corn test

A significant yield response of corn to application of swine lagoon sludge occurred at one of two test sites (Figure 2). At the nursery site (Figure 2A), yield approached maximum levels (150- 160 bu ac⁻¹) at 147 lbs total sludge N ac⁻¹. Maximum yield with the series of UAN-N treatments were only 125 bu ac⁻¹ and highly variable. The yield response to UAN-N was influenced by P deficiency. Although soil P levels based on a composite soil

sample for the field taken in the previous fall indicated sufficient soil P, sampling of individual plots after planting indicated significant variation in soil P that ranged from deficient to sufficient levels and that P levels decreased across the field in a systematic manner. The variation in soil P levels had little to no impact on crop yield response to sludge N because sludge contains high levels of P which was sufficient to alleviate P deficiency at the lowest rate of sludge application. This explains why sludge N appears to be used more efficiently than UAN-N. The P deficiency means that the yield response curve for UAN treatments can not be used in assessment of the plant N availability coefficient for lagoon sludge.

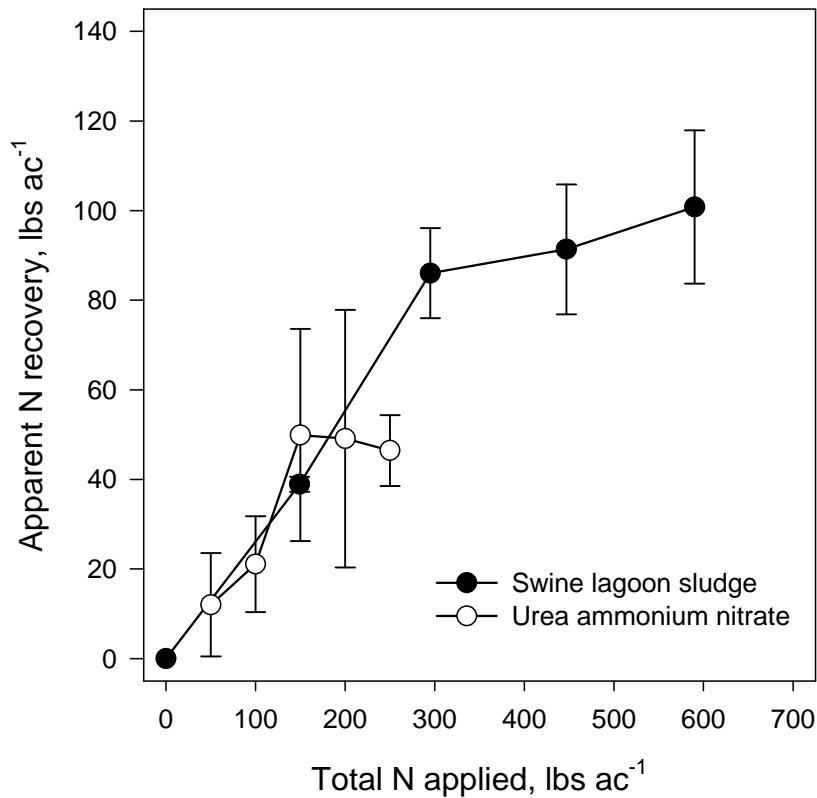
The second corn test at the Home place site did not show a yield response to applied N from either source of N (Figure 2B). Although located only 3 miles from the Nursery site, this site had much lower rainfall during the critical period of tasseling, silking and pollination. Crop N accumulation in zero check plots also indicated a high level of residual N (85 lbs ac⁻¹). Hence data is not useful for assessing plant N availability coefficients

Figure 2. Yield response of corn to N from swine lagoon sludge and UAN.



Apparent N recovery by corn in UAN treatments was also impacted by the P deficiency (Figure 3) at the Nursery site. However numerous fertility trials have shown efficiency of fertilizer N use (ie. N recovered in crop divided by N applied in fertilizer) in corn to be in the range of 0.4 to 0.6 (Moll et al., 1982, Kamprath, 1986). An estimate of the plant N availability coefficient for the sludge can be made using 0.5 as the N use efficiency for corn in the linear phase of the apparent N recovery curve. Apparent N accumulation (values corrected for N accumulated in zero checks) for the sludge treatments was linear up to 295 lbs total sludge N ac⁻¹. The slope of the relationship was 0.288 with an r² of 0.997. The ratio of the slopes for the sludge response and the 0.5 N use efficiency for fertilizer N gives a plant N availability coefficient of 0.58 (0.288/0.50).

Figure 3. Apparent N recovery from UAN and swine lagoon sludge by corn grown at the Nursery site.



Influence of N application on soil N

A concern about application of any source of N to crops is movement of $\text{NO}_3\text{-N}$ below the root zone and potentially to the shallow water table. Therefore, the distribution of $\text{NO}_3\text{-N}$ in the top 36 inches of the soil profile was evaluated in the two corn tests at black layer (physiological maturity, 8-21) (Figure 4) and after harvest of grain, 9-18 (Figure 5). Data for the Nursery test site are presented here. The highest rates and agronomic N rates for each N source are compared to the zero check treatment in each figure. Also note that scales for X-axes in the two figures are quite different (0 to 40 for Figure 4 and 0 to 14 for Figure 2) Nitrate-N concentrations (X axis) are plotted at the midpoint of each depth increment (Y axis).

At black layer stage, $\text{NO}_3\text{-N}$ concentrations in the top 6 inches of the profile were 25 to 35 mg kg^{-1} for the highest N rates for each N source (Figure 4). At the third depth (12-18 inches), concentrations had declined below 6 $\text{mg NO}_3\text{-N kg}^{-1}$ at the highest N rates for each source. Below the 6 inch layer, $\text{NO}_3\text{-N}$ concentrations for the agronomic N rate treatments were the same as for the zero check treatment for both UAN and lagoon sludge. One month later after harvest the distribution in the profile was different as concentrations in the top 6 inches of the profile had decreased below 10 $\text{mg NO}_3\text{-N kg}^{-1}$.

These decreases were not the result of crop N uptake because crop growth had ceased by the initial sampling date.

Calculation of total mass of $\text{NO}_3\text{-N}$ in each layer showed that in high N treatments for both N sources the decrease in $\text{NO}_3\text{-N}$ in top 6 inches of soil was greater than the increase in total accumulation of $\text{NO}_3\text{-N}$ between 6 and 36 inches. This indicates leaching of $\text{NO}_3\text{-N}$ below the 36 inch depth of sampling. This site received over 5 inches of rain during the one month interval between black layer stage and harvest. At agronomic N rates for both N sources (150 lbs UAN-N ac^{-1} and 295 lbs total sludge N ac^{-1}), similar calculations indicate that $\text{NO}_3\text{-N}$ in the soil at black layer stage remained in the top 36 inches of soil after harvest.

Figure 4. Distribution of $\text{NO}_3\text{-N}$ in soil profile at black layer stage as influenced by N source and N rate.

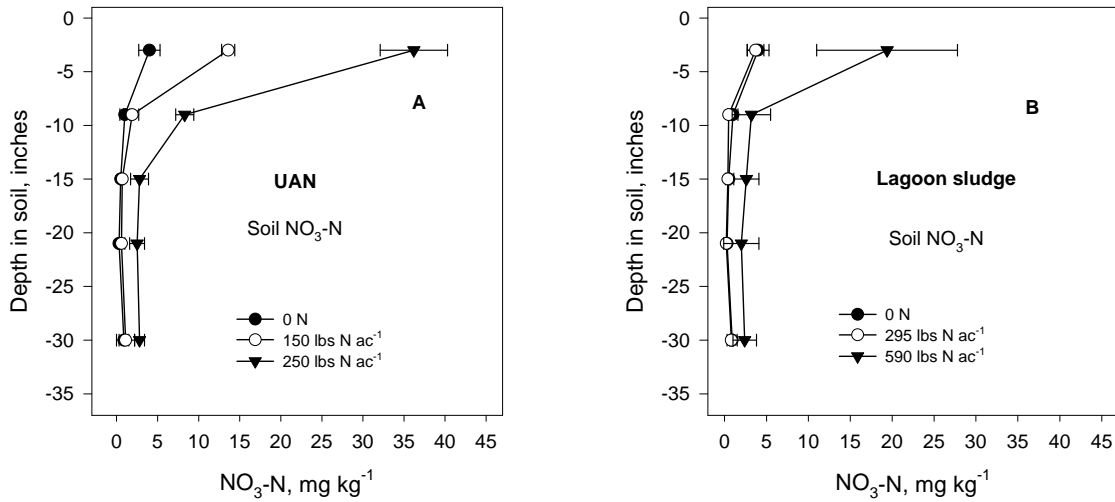
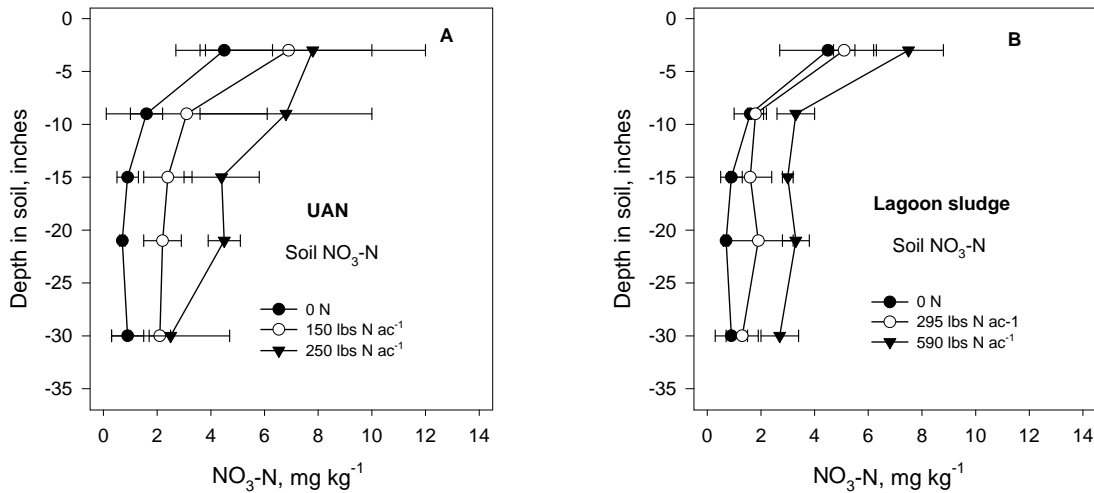


Figure 5. Distribution of $\text{NO}_3\text{-N}$ in soil profile after grain harvest as influenced N source and N rate.



An assessment of how much sludge N was recovered by the corn crop in relation to the amount that remained in the soil after harvest is given in Table 1. Analysis of lagoon sludge used to establish N rates indicated that $\text{NH}_4\text{-N}$ comprised 29 +/- 2 % of the total N. This value was used to calculate $\text{NH}_4\text{-N}$ and organic N supplied by each treatment. The amount of applied N remaining in soil N was calculated by subtracting N recovered in corn from total N applied. Applied N not recovered by the corn crop increased from 111 to 489 lbs N/ac as sludge rates increased from 150 to 590 lbs N /ac .Since the crop would have absorbed much of the readily available $\text{NH}_4\text{-N}$ applied in sludge, most of the N remaining in soil would be in organic forms. This indicates that availability of this organic N remaining in soil after harvest of corn needs to be evaluated.

Residual N from lagoon sludge recovered by wheat

After harvest of corn, the plots were planted in wheat (November 2008) and did not receive any additional N. Plots were harvested for measurement of grain and straw yields in June 2009. The residual effect of N treatments was assessed by subtracting yield of zero check plots from yield of plots that received N for the corn crop. Data in Figure 5 is expressed as yield in excess of the check plots in relation to the total N applied to the previous corn crop. For sludge N treatments, linear increases in grain yield as a function of N applied to corn were obtained at both test sites. Correlation coefficients of 0.93 were obtained at both sites.

While consistent residual effects on grain yield were observed, the amount of N accumulated in the crop must be assessed. The tissue N levels have not been measured at this point, but reasonable estimates can be made using the average tissue concentrations from the zero N and 150 lbs total N/ac treatments in the 2008 wheat tests. Average N concentrations in the grain and straw were 1.74% and 0.58% (respectively). These concentrations along with excess grain and straw biomass above the zero check were used to estimate recovery of residual N in the 295 lbs N/ac treatment since this rate was sufficient to produce maximum corn yield (ie. agronomic optimum)(Figure 2, panel A) Such estimates indicate that the N recovery in excess of the zero check averaged 10 lbs N/ac for the two test sites.

Assuming that the recovery efficiency of $\text{NH}_4\text{-N}$ applied in the 295 lb N/ac treatment was 0.5, then 42 lbs N/ac of the 84 lbs $\text{NH}_4\text{-N}$ N/ac (Table 1) available in soil was accumulated in the corn. The other 44 lbs N/ac accumulated by the corn would be derived from mineralization of organic N applied in the sludge Assuming that the uptake efficiency of inorganic N derived from mineralization of organic N was 0.5, then 88 lbs N/ac (44 lbs N/ac/0.5) would be released from the organic N pool. Thus applied organic N remaining in the soil after the corn harvest would be 123 lbs N/ac. **Therefore, only 8% of the organic N available in the 295 lbs N/ac treatment after corn harvest was recovered by the following wheat crop.**

Figure 5. The residual effect of N applied to the previous corn crop on yield of the subsequent wheat crop.

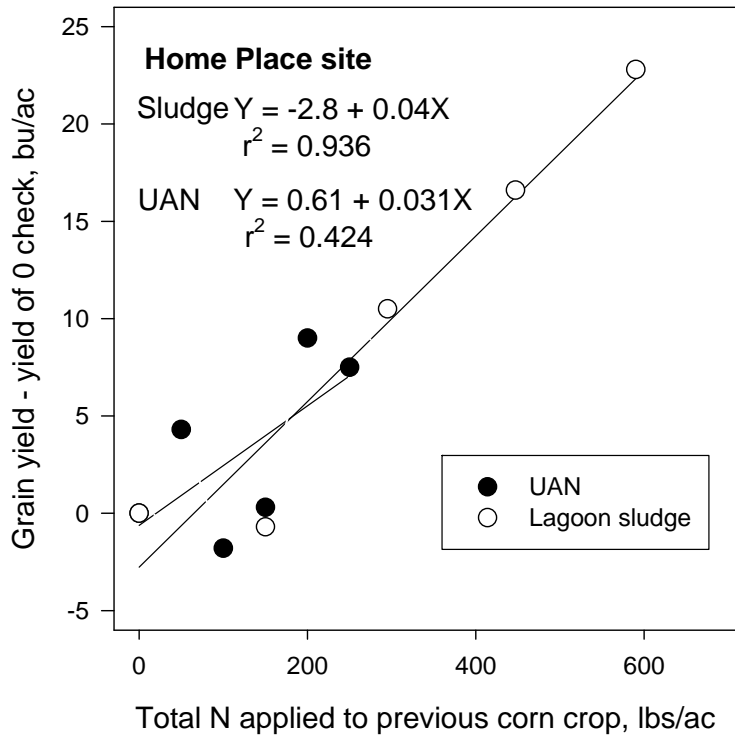
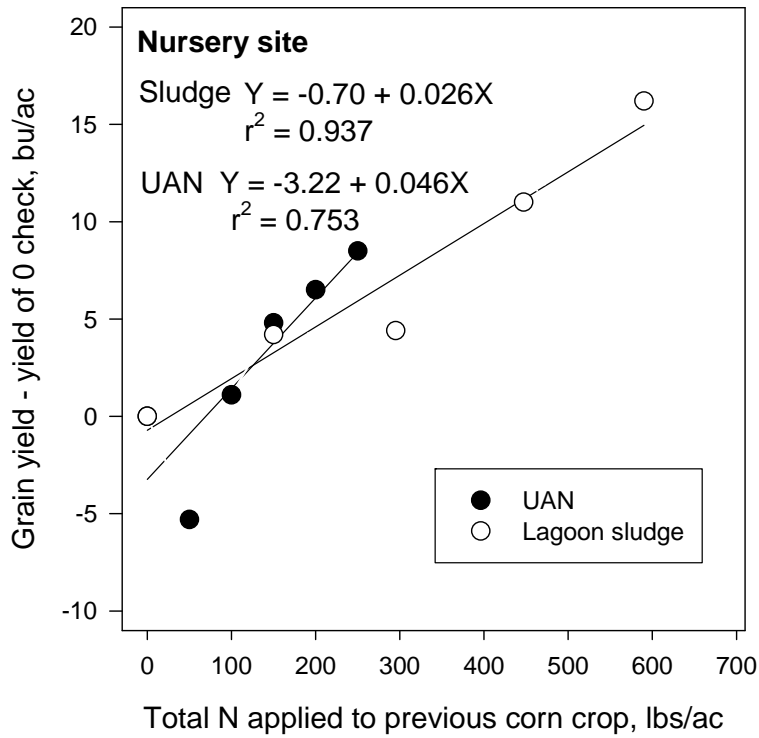


Table 1. An assessment of N recovered by corn that received different rates of swine lagoon effluent.

Total N applied	NH ₄ -N applied	Organic N applied	Total N accumulated in corn crop	Total N not recovered by corn
lbs/ac	lbs/ac	lbs/ac	lbs/ac	lbs/ac
150	43	107	39	111
295	84	211	86	209
447	128	319	91	356
590	169	421	101	489

Conclusions:

- We have provided field data that is consistent with the use of a plant N availability coefficient of 0.6 to calculate plant available N in lagoon sludge samples analyzed by NCDA’s waste analysis lab.
- At agronomic N rates, downward movement of NO₃-N through the soil profile was similar for UAN and swine lagoon sludge N. This means that potential N pollution of ground water by N derived from lagoon sludge would not exceed that caused by commercial N fertilizer (UAN).
- At the agronomic N rate for corn production, 10 lbs of N/ac was recovered in the following wheat crop. Thus when determining the N requirement for second crop after sludge N application a relatively small N credit for the sludge application would be needed (10 lbs N/ac).
- These results provide definitive experimental support for nitrogen availability coefficients used to calculate plant available N in swine lagoon sludge samples submitted to the NCDA Waste Analysis Laboratory.

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References:

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