Report to the Iowa Egg Council

Study of Nitrogen and Phosphorus Transformations from Poultry Manure and Fertilizer Using Soil Incubation and Soil Testing: A Complement to Ongoing Field Demonstrations

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Introduction and Review of Research Objectives

The general goal of this study was to improve our knowledge of the reactions and chemical transformations of poultry manure nitrogen (N) and phosphorus (P) in soils in order to better utilize the nutrient value of this important resource for crop production. All the laboratory work has been completed, but data management continues at this time to complete statistical analysis and summarize and publish the results. Therefore, this report summarizes work done and the results available at this time. Strongly supported conclusions are not possible at this time because several statistical and data analyses have not been completed.

The work was conducted to achieve the specific objectives established in the proposal. We conducted two separate incubation experiments, each using appropriate methods to assess the availability of N and P in poultry manure. Incubation studies are valuable for measuring the transformations of N and P in poultry manure because they can be conducted under well-controlled conditions, allow for measurements that would be impractical in the field, and minimize variability due to application and sampling error. The N study focused on measuring the production of inorganic N (crop available N) from application of manure to soil and on determine mineralization of organic N forms contained in manure. The P study focused on measuring the effect of manure P application on plant-available P as measured by various soil test methods. The results of these incubation experiments provide information regarding the potential release of N and P from poultry manure, using and generating information that can supplement field trial research.

Summary of Procedures

Two typical Iowa soils testing low in P were used for the experiments. One was Clarion and the other Canisteo. Summarized soil-test information is shown in Tables 1 through 3. The soils were air-dried and sieved through a 2 mm sieve prior to the addition of the treatment materials. Two manure sources were used. Turkey litter was collected from commercial turkey buildings and egg layers manure was collected from a caged egg-cracking facility. The turkey litter was a mix of feces and small grain hulls used for bedding while egg-layers manure consisted mainly of feces with some egg shells. The manure chemical analyses are summarized in Table 4.

Eleven treatments used across both experiments (11) are listed in Table 5. A low and high rate of each manure type was used based on total manure N to represent the rates recommended for one-half and full N needs for corn grown after soybean, and were 75 and 150 lb total-N/acre in a field application. In addition to the manure, the treatments included urea (a common N fertilizer), uric acid (the main organic N form in excreted poultry manure), and calcium phosphate (of the type in triple superphosphate). The application rates of urea and uric acid were similar to the total N applied with the manure. Because N-based application of manure resulted in different amounts of P applied for the turkey and egg-layers manures, two separate sets of egg-layers manure rates were used: one to match the turkey litter-N rates applied and the other to match the turkey litter-P rates applied. The inorganic P rates were based upon P applied by the turkey litter-N rates.

The materials were thoroughly mixed with 1 kg (on a dry weight basis) of each soil using appropriate weights according to the treatments. One hundred grams of the mixtures (or soil alone for the control treatment) were packed into 5-oz plastic cups with lids. The lids had three holes to allow for air circulation. Enough cups were used to be able to include three replications and six sampling dates at 0, 7, 14, 28, 56, 84 and 112 days of incubation (the sampled cups were discarded). The cups were placed in an incubation chamber at 86°F constant temperature and 100% relative humidity. Distilled water was added to achieve 80% of soil water holding capacity and the soil moisture was monitored every 5 days based upon average weight loss, and water was added as needed to maintain the 80% water holding capacity. At each sampling date, the corresponding cups were removed, the material was thoroughly mixed, and one-half of the material was stored frozen and the rest was oven-dried. The sample treatment and analyses were different for N and P measurements and are not summarized.

The samples suitable for the N study were analyzed for inorganic ammonium (NH_4) N (ammonium) and nitrate (NO_3) N. Ammonium-N and nitrate-N derived from the sources applied were determined by subtracting ammonium- N and nitrate-N concentration measured in the control treatment. The amount of net N mineralized from the organic-N in manure was determined by subtracting the initial mineral-N from that derived at each sampling date. The P of samples suitable for the P study were analyzed by three agronomic soil tests (Bray-P1, Mehlich-3, and Olsen), one environmental test (a test that estimates water-extractable P), total P, and by a standard P fractionation procedure. The fractionation procedure (based on the Headley method) classifies soil P into specific pools by using various sequential extracting solutions. These pools were water-extractable P, weak alkaline-soluble inorganic P (Bicarb-Pi) and organic P (Bicarb-Po), alkaline-soluble inorganic P (NaOH-Pi) and organic P (NaOH-Po), weak acid-soluble P (DilutedHCl-P), strong acid-soluble inorganic P (Conc.HCl-Pi) and organic P (Conc.HCl-Po), and recalcitrant residual P (Res-P). Water-extractable P represents the pool of P most easily dissolved and removed. Alkaline-soluble P forms include P held in organic and inorganic pools, with the sodium-bicarbonate fraction being more easily removed than the sodium-hydroxide fraction. The P extracted by weak hydrochloric acid is in calcium-bound forms and is almost entirely an inorganic form. The P extracted with concentrated sulfuric acid includes P more strongly bound P in acid-soluble organic materials, highly resistant calcium phosphates, and others mineral P. Residual P includes forms mainly in primary minerals extremely resistant to weathering.

Results for the Nitrogen Study

Highlights of Results.

Results available at this time are for the Clarion soil. The initial measured ammonium-N (as percent of applied total N) at application (day zero) was significantly lower than the total N applied for all treatments (Fig. 1). This would be due to N forms present that are not measured as ammonium-N or nitrate-N; for example urea, uric acid, proteins, and amino acids. Urea showed the highest initial ammonium-N, suggesting a relatively rapid hydrolysis and conversion to ammonium-N. Layer manure had slightly higher initial ammonium-N than turkey litter, and uric acid had the lowest initial level. At 7 days after application, the ammonium-N with uric acid increased while the other sources had a rapid decrease. This indicates that the uric acid had a slower initial conversion to ammonium-N. At 14 days the ammonium-N was low for all treatments, and by 28 days was at background levels.

Nitrate-N accumulation was rapid and had an inverse relationship to the ammonium-N disappearance. This would be expected as nitrification of the ammonium-N was taking place. The soils were incubated at a warm temperature; so rapid nitrification would be expected. Nitrate-N accumulation was significantly greater for urea and uric acid (Fig. 1) than either manure source. Except for uric acid, the accumulated concentration of nitrate-N was less than the intended N application rate. Soil treated with layer and turkey litter accumulated nitrate-N at approximately 70% of the total-N applied.

Net inorganic-N mineralized from the poultry manure sources was rapid, with most inorganic N released within 28 days (Fig. 2, high application rate). The presence of a slow release pool of N in layer manure was not evident as the disappearance of ammonium-N and accumulation of nitrate-N was initially similar to urea and uric acid and there was no continued accumulation of nitrate-N after 28 days (Figs. 1 and 2). Any difference in N mineralization between the manure sources would be due to different levels of readily mineralizable organic N in the egg-layers manure (most likely uric acid).

Results for the Phosphorus Study

Manure P Fractions.

Soil P fractionation work for manure and soil P has been completed, but data analysis continue for most dates. We can summarize here only results for the manures because that helps interpret the results of extractable P from the soils after manure application. The data in Fig. 3 indicate that most of the manure P was inorganic (95% in the turkey litter and 88% in the egg-layers manure). This result confirms results form other research, and confirm how mislead are many farmers who believe that a major portion of the P in poultry manure is organic. However, the inorganic P is not necessarily readily available for crops. In fact, there was very little water-soluble P in both in both manures (36% for turkey litter and 20% for egg-layers manure). The manure P extracted with weak hydrochloric acid, which most likely was derived form di-calcium phosphate, was about one-half of the total manure P (49% for turkey litter and 57% for egg-layers manure). In general, researchers believe that the manure P less likely to be available for a first crop is represented by the sodium hydroxide, concentrated hydrochloric acid, and residual P pools, which in this study totaled 9% for turkey litter and 13% for egg-layers manure.

<u>Assessment of manure-P availability based on agronomic and environmental P tests</u>.

Laboratory work was completed for all P testes (Bray-P1, Mehlich-3, Olsen, water-extractable, and total P) but only results for the Olsen and water-extractable tests can be shown at this time. Study of results of the Olsen test were completed first for comparisons with the environmental P test (water-extractable P) because research in Iowa and the Midwest has shown that it provides reliable estimates of plant-available P across acid and neutral soils (such as the Clarion soil used) and calcareous soils (such as the Canisteo soil used). The results for the Bray-1 and Mehlich-3 tests require additional study that is being conducted at this time.

Figure 4 shows summarized results of soil P measured by the Olsen test for both the low and high P rates for each soil. The trends for both tests were similar for the two P application rates, except that P levels were higher for the high rate, and were very different for the two soils. Results for the Olsen test indicated that the apparent manure-P availability about 4 weeks after application was 50 to 60% of the fertilizer-P availability in both soils. After that period, manure-P availability increased to levels almost similar to the fertilizer for the Clarion soils but remain less and about constant during the entire incubation period for the Canisteo soil. Moreover, the graphs show that the manure-P availability was similar for turkey and egg-layers manure, although the rate of soil P increase for the turkey litter seemed lower than for the egg-layer manure in the high rate of P applied to the Clarion soil. This result may indicate some differences in the manure-P efficiency between soils with different chemical properties. The soil P increases in the fertilized treatments were almost one-half for the Canisteo (calcareous) soil compared with the Clarion soil, but seems the manure-P efficiency was more affected than the fertilizer-P efficiency by the calcareous soil. The ratio of soil P change between fertilizer and manure treatments can be used to estimate the relative efficiency of fertilizer and manure P. Calculations based on average soil P change for fertilizer and manure across the sampling dates indicate that the apparent recovery of applied P in the Canisteo soil was 73% remaining approximately constant over time. For the Clarion soil, the initial recovery was 58% and climbed to 85% by the end of the incubation period, and there was no apparent plateau indicating that measured P would have increased further if the incubation time had been longer.

Figure 5 shows the trends for water-extractable P in the soil. Water-extractable P can be used to show the most readily plant available P and potential for soil P losses with runoff or subsurface drainage. In general the results and trends were similar then for the Olsen P test, with a few differences. One significant difference was that in the Clarion soil with the low P application rates the increase of water-extractable P for the manure treatments compared with fertilizer P was greater than for the Olsen P test, and the sources did not differ by the end of the incubation period. The reason why this happened for the low P rate but not for the high P rate is unclear. Another significant difference between P tests was that in the Canisteo soils, the difference in availability between manure and fertilizer P was much greater for the water-extractable P test than for the Olsen P test, especially for egg-layers manure. In fact, the water-extractable P was almost the same for the egg-layers manure and the control that received no P.

Differences in the efficiencies between fertilizer and manure or between soils are being studied and are unclear at this time. However, we believe it is related to slower mineralization or dissolution of manure-P forms compared with the fertilizer P forms in the soil with higher pH and higher calcareous content (Table 3). In this study water-soluble P in manures averaged 36% for turkey litter and 20% for egg-layers manure in comparison to the fertilizer source in which it was nearly 100%.

Preliminary Conclusions

Nitrogen: The rate of inorganic ammonium-N disappearance and nitrate-N accumulation from poultry manure was quite similar to that of urea fertilizer and uric acid, and significant inorganic N accumulation occurred within 14 to 28 days of application. This implies that poultry manure should provide readily available inorganic N for plant use. Also, the main source of this N in the poultry manure is ammonium and uric acid, with uric acid hydrolysis and nitrification similar to those for urea fertilizer. Both manure sources did not result in as much inorganic N accumulation as with urea or uric acid application. This could mean other organic N compounds in the manure had not yet mineralized, or that the rate of N application was actually lower with the two poultry manure sources. However, after 28 days of incubation there was no further net release or accumulation of inorganic N from either manure source. This indicates limited potential for slow or residual release of N from layer or turkey litter, which is being evaluated in field studies.

Phosphorus: Although a major proportion of the manure P was inorganic (95% in the turkey litter and 88% in the egg-layers manure), only a small proportion was in the readily available soluble form (36% for turkey litter and 20% for egg-layers manure). These manure characteristics explained a great deal of the results of extractable P after applying manure or fertilizer P to two soils in this short-term incubation study. The plant-availability of applied manure P as evaluated by soil P tests was almost one-half of that for fertilizer P during the first 4 weeks after P application. The relative availability of manure P increased significantly during the rest of the incubation period for the Clarion soil to become almost similar to that for fertilizer P, but remained low for the Canisteo soil. These preliminary results indicate that poultry manure P availability a few weeks after application is 50 to 60% compared with fertilizer P, that its availability increases significantly in some soils, but may increase much less or not increase significantly in high-pH and highly calcareous soils. However, supported conclusions in this progress report are not possible because study of results from other tests and data analysis continue at this time.

Table 1. Soil classification data.

Soil Series	Classification	Particle Size Distribution			Available Water Holding Capacity
		Sand	Silt	Clay	
		------------ % ------------			% of volume
Canisteo	Typic Endoaquoll	20.2	47.5	32.3	15.1
Clarion	Typic Hapludoll	38.8	39.6	21.6	14.6

Table 2. Initial soil-test data.

Soil Series	Phosphorus					Nitrogen				C:N Ratio
	Bray-P1	Mehlich-3	Olsen	WEP†	Total	NH_4-N	NO_3-N	Org.	Total	
	---------- ppm ----------									
Canisteo	4.8	22.2	7.7	3.8	740	3	10	3563	3576	14.2:1
Clarion	10.2	8.6	4.0	1.6	452	3	8	1769	1780	12.7:1

† Water-extractable phosphorus.

Table 3. Additional initial soil-test data.

Soil	Cations (Ammonium Acetate)				Mehlich-3		pH	Calcium carbonate	OM†
	K	Ca	Mg	Na	Fe	Al			
	---------- ppm ----------							-------- % --------	
Canisteo	394	6950	283	12	86	27	8.0	4.6	9.3
Clarion	93	2014	324	11	900	152	5.6	0.1	4.1

† Soil organic matter.

Table 4. Turkey litter and egg-layers manure total elemental analysis.

Manure	Nitrogen		P_2O_5	K_2O	Ca	C:N Ratio
	Ammonium	Total				
	---------- lb/ton (as is) ----------					
Egg Layer	14.6	51.9	45.6	23.5	213.4	6.7:1
Turkey	13.9	51.0	56.3	35.7	42.1	8.0:1

Table 5. Summary of treatments and nutrients applied. †

Treatments			Material Source		Total Nutrients Applied	
Code	Source	Rate	Nitrogen	Phosphorus	N	P_2O_5
					--------- lb/acre -------	
1	Control	None	None	None	0	0
2	Fertilizer	Low	Urea	Fertilizer	75	83
3		High	Urea	Fertilizer	150	166
4	Fertilizer	Low	Uric Acid	Fertilizer	75	83
5		High	Uric Acid	Fertilizer	150	166
6	Turkey	Low	Manure	Manure	75	83
7		High	Manure	Manure	150	166
8	Egg Layers	Low	Manure	Manure	75	66
9		High	Manure	Manure	150	131
10	Egg Layers	Low	Manure	Manure	106	83
11		High	Manure	Manure	212	166

† Each treatment was replicated three times. The amounts applied represent approximate field application rates derived from weights applied per unit weight of incubated soil.

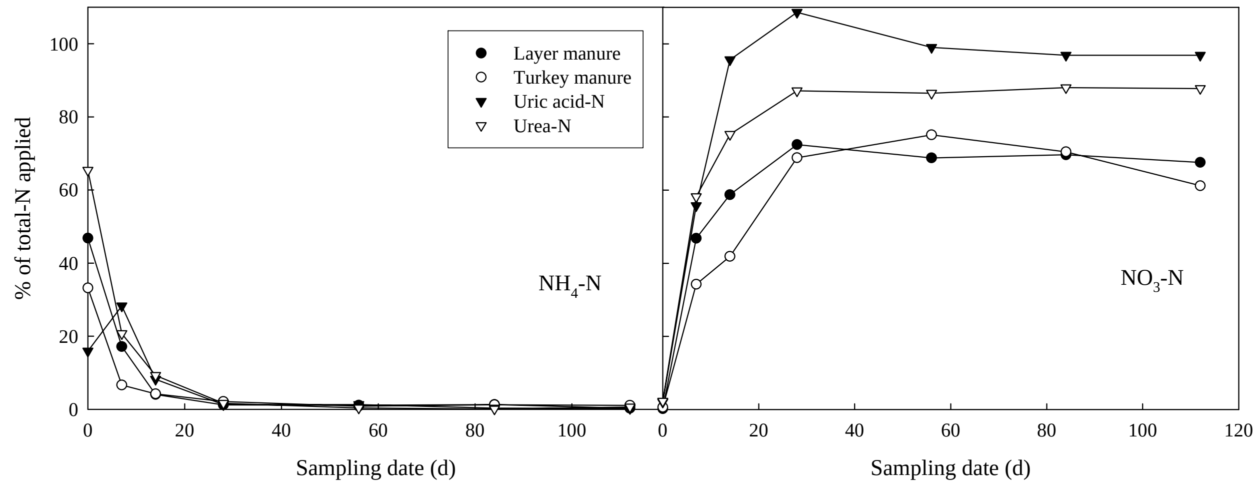

Fig.1. Inorganic N derived at each sampling date measured as extractable NH_4-N and NO_3-N. The NH_4-N and NO_3-N concentration in the control was subtracted from each sample, and then the percent of total N applied at each date was calculated for NH_4-N and NO_3-N (average of the low and high application rates).

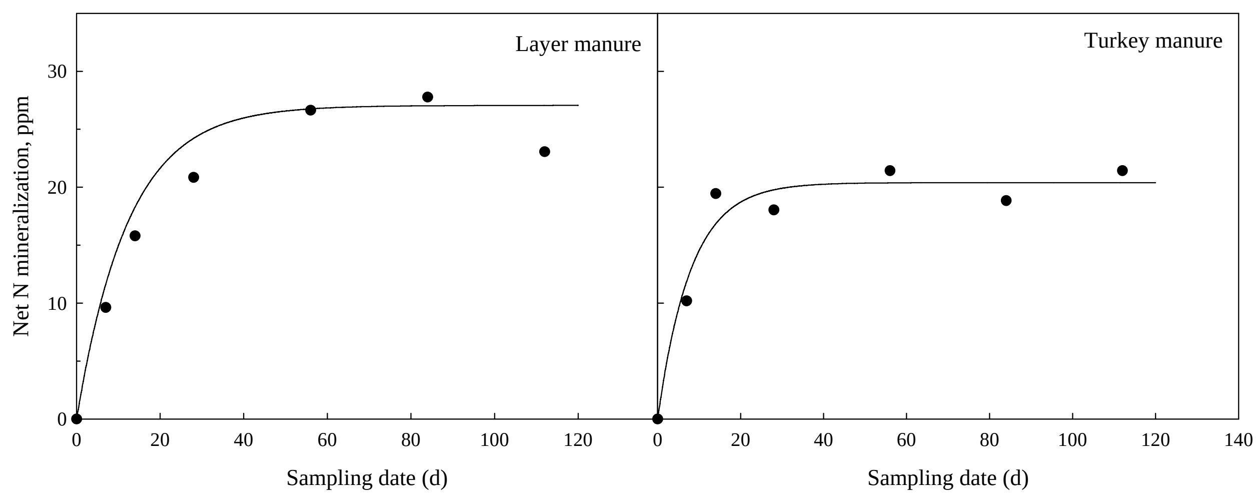

Fig.2. Net N mineralized from each poultry manure source (high application rate only), determined by subtracting the initial (day 0) inorganic-N (NH_4-N + NO_3-N) from the amount of inorganic N measured at each subsequent sampling date. This represents the amount of inorganic-N released from the manure sources over time.

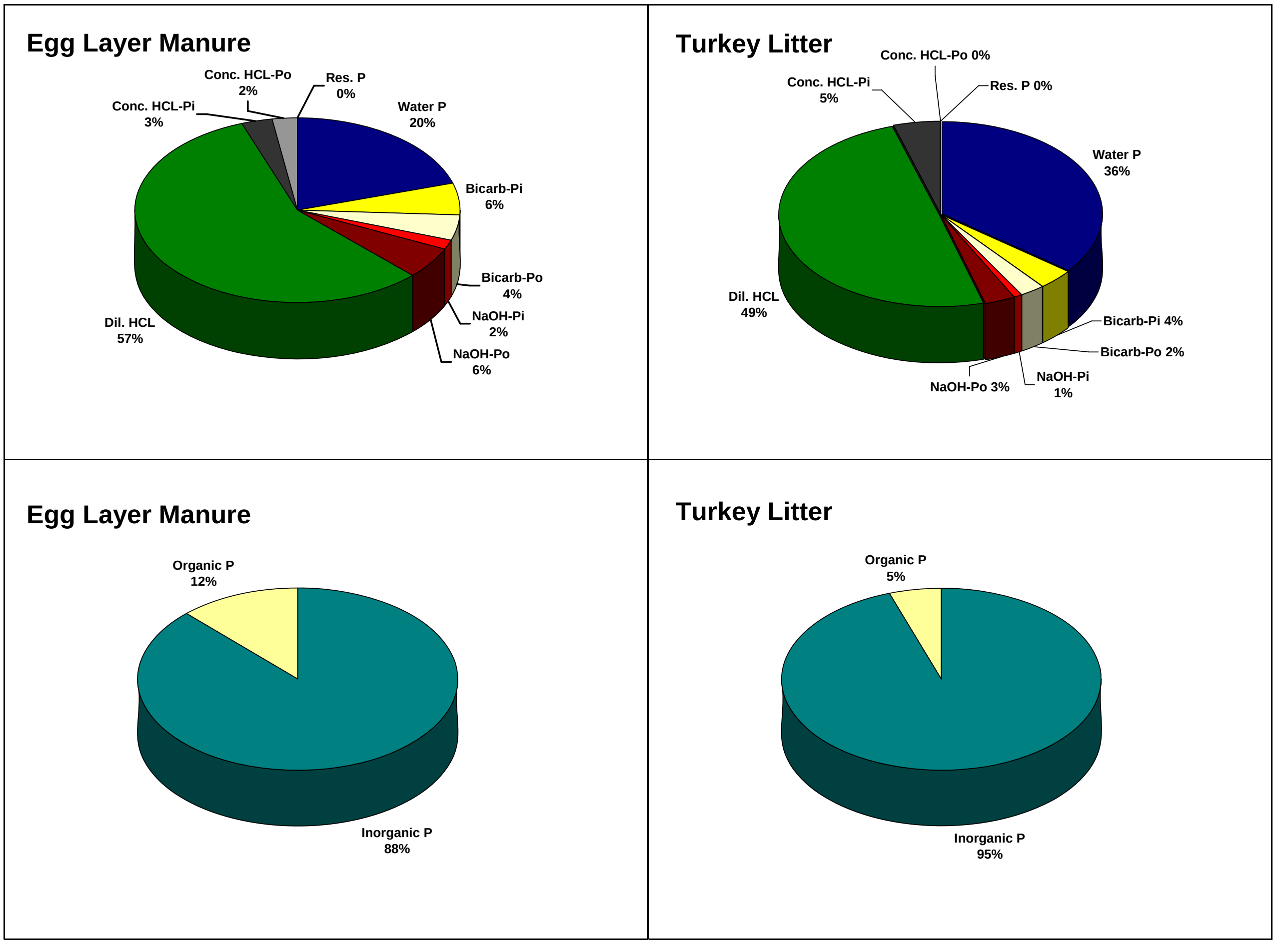

Fig. 3. Results of P fractionation analyses for turkey litter and egg-layers manure used in the study. Abbreviations: water-extractable P (Water P), weak alkaline-soluble inorganic P (Bicarb-Pi) and organic P (Bicarb-Po), alkaline-soluble inorganic P (NaOH-Pi) and organic P (NaOH-Po), weak acid-soluble P (Diluted. HCl-P), strong acid-soluble inorganic P (Conc. HCl-Pi) and organic P (Conc.HCl-Po), and recalcitrant residual P (Res. P).

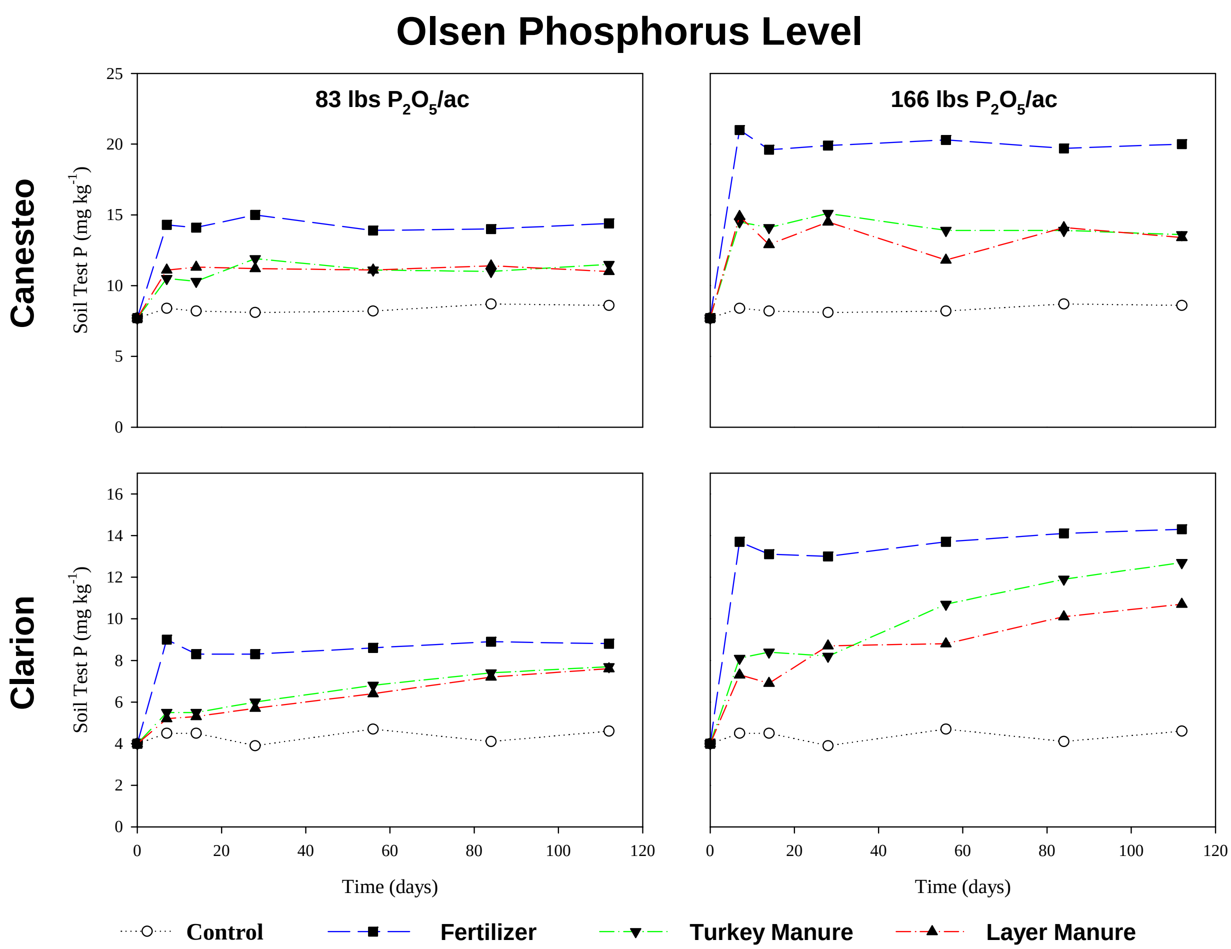

Fig. 4. Estimated plant-available soil P by the Olsen test after incubating fertilizer and manure P sources with soil for 0, 7, 14, 28, 56, 84, and 112 days.

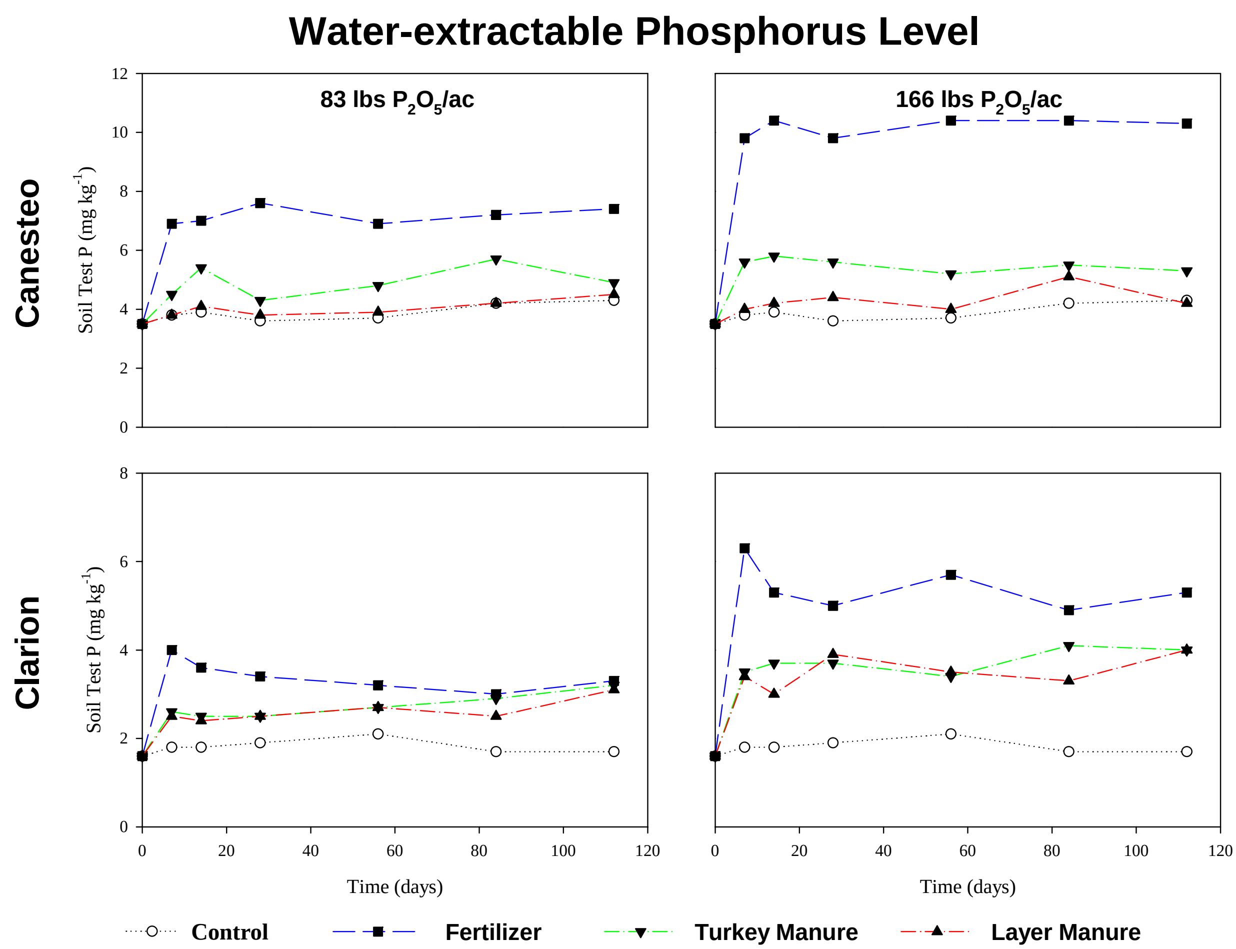

Fig. 5. Water-extractable soil P after incubating fertilizer and manure P sources with soil for 0, 7, 14, 28, 56, 84, and 112 days.