



# Effect of Five-Year Continuous Poultry Litter Use in Cotton Production on Major Soil Nutrients

K. C. Reddy,\* S. S. Reddy, R. K. Malik, J. L. Lemunyon, and D. W. Reeves

## ABSTRACT

Repeated application of poultry (*Gallus gallus*) litter to crop lands may lead to nitrates leaching and build up of P and other elements in the soil profile, which are prone to loss from runoff and erosion. A study was conducted for 5 yr at Belle Mina, AL on a Decatur silt loam (fine, kaolinitic thermic Rhodic Paleudult) during 1994 to 1998 to determine the nitrate movement and quantify the build up of P, K, Ca, and Mg due to the application of nitrification inhibitor, carboxymethyl pyrazole (CP), treated fresh and composted poultry litter and urea in conventionally tilled cotton (*Gossypium hirsutum* L.). Poultry litter maintained soil pH (0–30 cm depth) where as application of urea resulted in a pH decline. The inhibitor, CP, significantly reduced the  $\text{NO}_3^-$ -N formation in all N sources for 41 d following application. However, over the longer period of time, very minimal changes in nitrate concentrations were observed due to change in rates or sources of N. Over the experimental period, P concentration increased significantly (by 74%) in composted litter applied plots ( $17.7 \text{ mg kg}^{-1}$ ) but not in fresh litter plots ( $1.5 \text{ mg kg}^{-1}$ ). Linear increase in P accumulation was observed with increase in rate of composted litter. Concentrations of K and Mg increased significantly both in fresh (93 and  $25 \text{ mg kg}^{-1}$ , respectively) and composted litter (127 and  $36 \text{ mg kg}^{-1}$ , respectively) applied plots by the end of 5 yr period. These results indicate that a well-planned application of fresh poultry litter in soils that are not already overloaded with P is safe and treating litter with CP is advantageous from an environmental perspective.

**B**ROILER PRODUCTION is a major industry in the United States and is rapidly growing; 21% growth was recorded from 1993–2003 (USDA-National Agricultural Statistics Service, 2004). Seventy-one percent of the income generated in 2004 from the poultry industry was through broiler production. On average, each broiler produces 1.13 kg of litter (Gary et al., 2001), which results in about 10 billion kg of litter annually. Fifty-nine percent of this litter is produced in Alabama, Arkansas, Georgia, Mississippi, and North Carolina. Alabama ranks third in broiler production (12%) among states and produces about 1.19 billion kg of broiler litter annually. This enormous quantity of broiler litter poses a potential environmental pollution problem and needs to be disposed of safely.

Application of poultry litter to crop lands as a nutrient source serves as an important means of its safe disposal. Nutrients provided by poultry litter have been reported to have positive effects on crop production (Mitchell and Tu, 2005; Reddy et al., 2007). However, continuous application of poultry litter will increase levels of soil nutrients (Mitchell and Tu, 2006). There

is a growing concern that the indiscriminate disposal of poultry litter can cause nonpoint water contamination; groundwater contamination through  $\text{NO}_3^-$ -N leaching and eutrophication of lakes and water bodies with runoff P (Zhu et al., 2004).

Composting poultry litter addresses many problems associated with its use as fertilizer by lowering moisture content, reducing odor, improving texture, reducing weed seed viability, and providing uniform and stable particles that are easier to handle (Schelegel, 1992; Dao, 1999). Typically 50 to 60% of the total N in fresh manure will be mineralized and become available for crop use in the first year. Reports indicate that composting can reduce the N value by 20 to 30% (De Laune et al., 2006).

The use of nitrification inhibitors is one of several practices suggested for improving N use efficiency and reducing the potential for  $\text{NO}_3^-$ -N leaching in areas vulnerable to groundwater  $\text{NO}_3^-$ -N contamination (Central Platte Natural Resources District, 1998). Nitrification inhibitors slow the nitrification processes and thus reduce N losses from leaching and denitrification (Prasad and Power, 1995) increasing efficiency of fertilizers. Lower concentration of nitrate in soil should result in less contamination of groundwater. While benefits of nitrification inhibitor are well documented in cereals (Jay Goose and Johnson, 1999; Randall et al., 2003), there are few studies on cotton. Furthermore to our knowledge, second generation inhibitors such as CP have not been tested on cotton.

Usually poultry litter is applied to cotton based on N requirement. This may lead to overapplication of other elements in the soil. Hence a study was performed to understand the effect of treating fresh and composted poultry litter with the nitrification inhibitor, CP on nitrate movement and the

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**Abbreviations:** CP, carboxymethyl pyrazole; CPL, composted poultry litter; DAP, days after planting; FPL, fresh poultry litter.

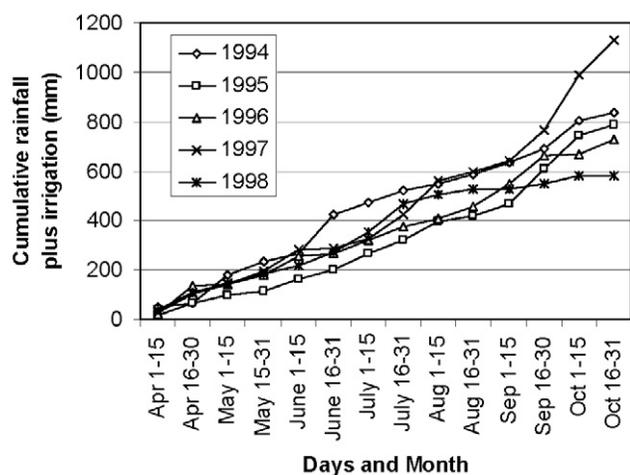


Fig. 1. Cumulative rainfall plus irrigation water applied to cotton from April through October from 1994 through 1998 at Belle Mina, AL.

accumulation of P, K, Ca, and Mg in soils after 5 yr of continuous application in cotton production.

### MATERIALS AND METHODS

The field experiment was conducted at the Alabama Agricultural Experiment Station, Belle Mina, AL, situated at 34° 41' N, 86° 52' W on a Decatur silt loam during 1994–1998 cropping seasons. The experiment was laid out in a randomized complete block design (RCBD) with 20 treatments in four replications. The treatments included a factorial combination of three sources of N: urea, fresh poultry litter, and composted poultry litter applied at three N rates, 40, 80, and 120 kg plant available N ha<sup>-1</sup>; and each of these treatments were applied with and without the nitrification inhibitor, CP. In addition, two control plots, one with 0 N and 0 CP (control) and the other with 0 N but CP soil application (CP control) were included. Plot size was 6 m wide and 9 m length with six cotton rows.

Based on initial soil chemical analysis at the beginning of the experiment in 1994 (Table 1), 67.2 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O in the form of 0–20–20 fertilizer and 3359 kg ha<sup>-1</sup> of dolomite limestone were applied as a basal rate to all plots to nullify the effects of P, K, Ca, and Mg additions from the poultry litter. The experimental plots were prepared under conventional tillage which was performed using a moldboard plow in November and disking in April, followed by a field cultivator to prepare a smooth seedbed. Cotton cv. DPL-51 was planted on 20 Apr. 1994; 12 Apr. 1995; 15 Apr. 1996; and DPL-33 B was planted on 8 May 1997 and 5 May 1998. The same experimental plots and randomization was followed during the entire 5-yr period. Rainfall was supplemented with need-based irrigation (Fig. 1). All cultural practices recommended by the Alabama Extension Service for cotton cultivation were uniformly followed in all years for all treatments.

Fresh poultry litter was collected from nearby poultry farms in Alabama. Composted poultry litter was prepared at the Tennessee Valley Authority (TVA) facilities at Muscle Shoals, AL by constructing two piles, approximately 3 m in diameter and 1.5 m in height, using 2910 kg of fresh poultry litter and 1630 kg of water per pile. A front-end loader was used to construct the piles. An overhead crane with a clean bucket was used to aerate the piles. The poultry litter piles were aerated

Table 1. Initial soil chemical analysis of experimental field, Belle Mina, AL, in 1994.

Horizon	pH	Organic			K	Ca	Mg	NO <sub>3</sub> <sup>-</sup> -N
		matter	N	P				
		%			mg kg <sup>-1</sup>			
0–15 cm	6.13	1.06	0.07	23.87	64.25	932.38	84.16	15.41
16–30 cm	6.01	0.86	0.06	19.57	66.83	874.87	74.56	15.00
31–45 cm	5.92	0.41	0.06	6.71	66.80	886.49	33.12	15.91
46–75 cm	5.63	0.37	0.06	9.28	81.39	863.15	30.96	17.12
76–106 cm	5.31	0.20	0.49	14.77	92.01	622.30	29.97	31.66
106–135 cm	4.95	0.18	-	17.44	97.55	516.98	34.98	29.08

every day for the first 35 d then twice a week for the next 8 wk. During the last 6 mo the piles were aerated only when oxygen levels dropped below 5%. Oxygen levels were measured with an oxygen probe. The compost was maintained at a maximum temperature of 66°C for 30 d, thereafter it was maintained by mixing at 38°C and above for the next 6 mo. The poultry litter was composted for a total of 9 mo. The N content in fresh litter on dry weight basis was 2.8, 2.6, 2.4, 2.2, and 3.2% and in composted litter it was 1.8, 2.3, 1.9, 2.1, and 2.5% in 1994, 1995, 1996, 1997, and 1998 seasons, respectively. This was determined by digestion of 0.5-g samples using Kjeldahl wet digestion (Bremner and Mulvaney, 1982). Poultry litter applications were calculated assuming 60% of N availability from poultry litter during the first year (Bitzer and Sims, 1988; Keeling et al., 1995). Although the composting process likely reduces N availability, 60% coefficient was used for both fresh and composted litter for consistency.

The nitrification inhibitor, CP, was obtained from the Department of Botany and Plant Pathology, Purdue University and applied at 0.56 kg ha<sup>-1</sup> a.i. The inhibitor was diluted in ethanol at 50:50% (v). A volume of 116 mL of CP solution (58 mL CP + 58 mL ethanol) per plot was used. Each N source calculated per plot was put in a mixer and CP solution was dribbled on it as it mixed. Carboxymethyl pyrazole treated urea, fresh litter and composted litter were broadcasted by hand and incorporated immediately into soil with a disk harrow before planting cotton. In the control plot, the inhibitor was sprayed with a hand-held garden sprayer directly on the soil and then incorporated.

Soil samples were collected each year, except in 1996, before sowing in spring (March/April) and after harvesting in fall (October/November). In each plot, three cores (4 cm diam.) were collected to the depth of 105 cm using a tractor-mounted soil sampler and sectioned to 0–15, 16–30, 31–45, 46–75, and 76–105 cm. These samples were air-dried and ground using a mechanical grinder and passed through a 2 mm sieve and stored for analyses. In addition, during the 1994 cotton growing season, surface soil (0–15 cm) samples were collected four times; 41, 71, 102, and 111 d after planting for NO<sub>3</sub><sup>-</sup>-N estimation. NO<sub>3</sub><sup>-</sup>-N was determined by the ion chromatographic method using Dionex Model DX-100 Ion Chromatography (Dick and Tabatabai, 1997) after extraction with 2 M KCL using a 1:5 soil/extractant ratio. Samples collected before and after the experiment (March, 1994 and November, 1998, respectively) were used to determine pH and quantify available P, K, Ca, and Mg concentrations. Soil pH was measured using 1:1 soil/water ratio. The double acid (Mehlich-I extractant) method was used to extract available P, K, Ca, and Mg in soil

samples (Mehlich, 1953). Available P was determined using ascorbic acid method (Murphy and Riley, 1962); P concentration was read with a spectrophotometer set at 600 nm. Concentrations of K, Ca, and Mg were determined using Plasma 400 ICP Spectrometer.

The treatments that formed factorial arrangements were analyzed using the General Linear Model procedure of Statistical Analysis System version 9.1. Change in concentrations of K, P, Ca, and Mg were calculated by subtracting March 1994 data from November 1998. Mean separations were done using the LSD at alpha level 0.05. Soil sampling time  $\times$  treatment interaction for nitrate nitrogen concentration in soil was found significant and hence, data were presented separately for each sampling time. Nitrification inhibitor, CP, did not influence nitrate concentration in almost all sampling times except in March 1997 and therefore soil analysis data by date of sampling for CP are not presented here. Likewise, there was no effect of nitrification inhibitor on P, K, Ca, and Mg accumulation; hence, only effect of N rates and sources are discussed here. Compared to nitrates; P, K, Ca, and Mg are less mobile in soil profile and hence results for these elements are discussed here only up to 15 cm soil depth.

## RESULTS AND DISCUSSION

### Soil pH

Continuous application of fresh and composted poultry litter for 5 yr did not bring significant changes in soil pH at the two depths (0–15 and 16–30 cm) at all N levels, whereas urea application reduced soil pH at higher N levels (Fig. 2). Similar results with broiler litter were observed by Mitchell and Tu (2006) in similar types of soils. It was proved that poultry litter is as effective as  $\text{Ca}(\text{OH})_2$  in raising the pH of acidic soils (Hue, 1992). No-N control plots maintained soil pH. Application of dolomite at the beginning of the experiment in 1994 may be responsible for maintaining soil pH in urea applied plots up to 40 kg N ha<sup>-1</sup> and further increase in N rate

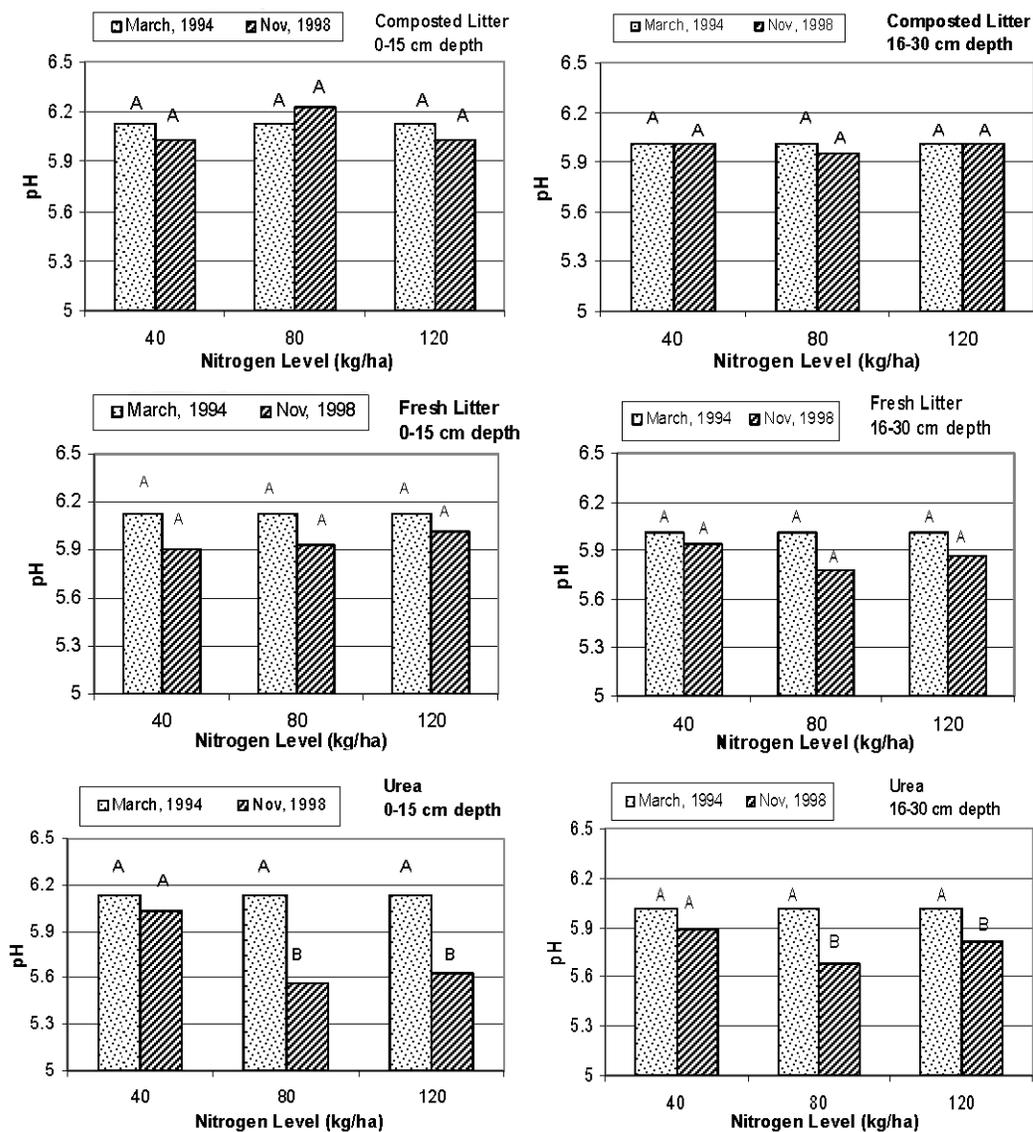
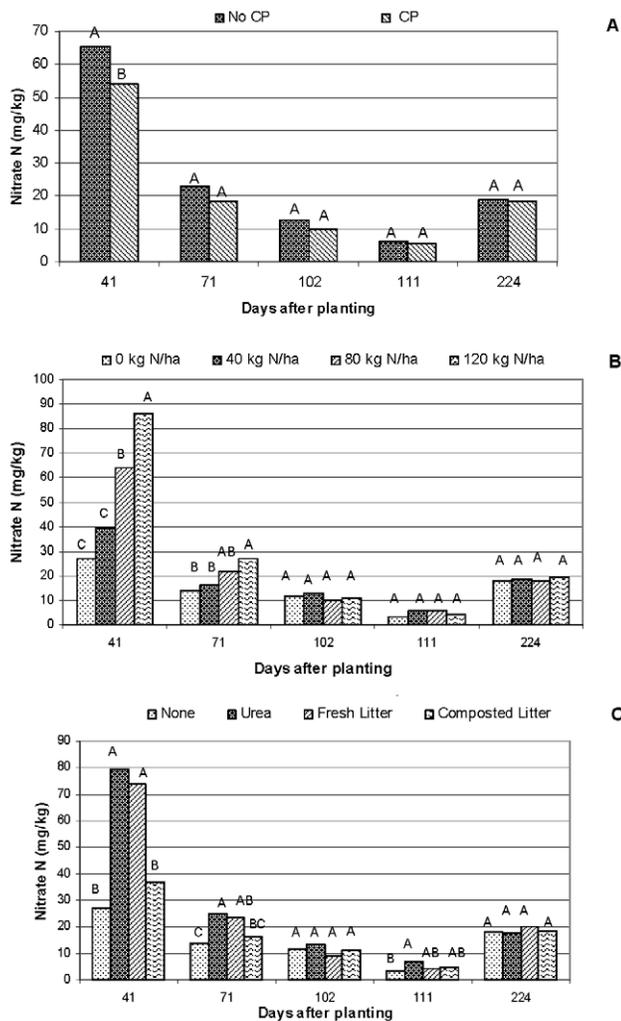


Fig. 2. Soil pH at 0 to 15 and 16 to 30 cm depth in March 1994 and November 1998 as influenced by poultry litter and urea application at different N levels calculated across nitrification inhibitor treatment. Means under each level of N followed by different uppercase letter are significantly different from each other at  $P \leq 0.05$ .

resulted in decline in pH. Nitrification inhibitor, CP, did not significantly influence the soil pH.

### Nitrates

In 1994 at 41 d after planting,  $\text{NO}_3^-$ -N concentration within the 0 to 15 cm depth ranged from 26.8 mg kg<sup>-1</sup> in the 0 kg N ha<sup>-1</sup> to 86.3 mg kg<sup>-1</sup> with 120 kg N ha<sup>-1</sup>. At 71 d after planting,  $\text{NO}_3^-$ -N concentration dramatically decreased in the 0 to 15 cm depth in all the treatments (Fig. 3). This drastic change could be attributed to plant uptake and accumulation of N for vegetative growth. Boquet and Breitenbeck (2000) observed that maximum N uptake by cotton plants occur between 49 and 71 d after planting. At 102 d after planting,  $\text{NO}_3^-$ -N concentration continued to decrease albeit at a slower rate. The need for N by the plant at this stage was low. In general, at 111 d after planting;  $\text{NO}_3^-$ -N concentration was at its lowest. The final soil analyses at 224 d after planting showed that the  $\text{NO}_3^-$ -N concentration was higher in all treatments as compared to 102 and 111 d after planting. It was likely that



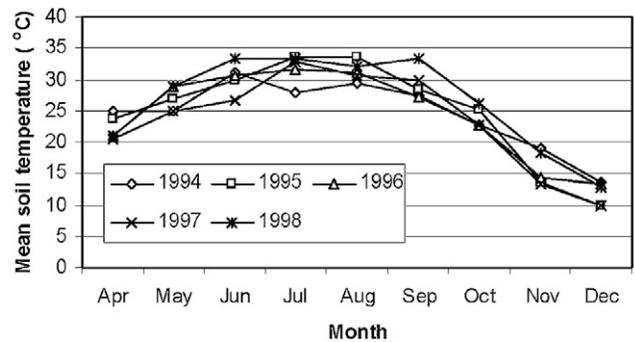
**Fig. 3. Effect of CP, N source and rates on surface soil (0–15 cm) nitrate N dynamics during 1994 cotton growing season, Belle Mina, AL. (Means were calculated across the treatments).**

tillage operations conducted in November after the harvest (October) increased aeration and consequent mineralization of N. Significant differences between different treatments existed only at 41 d after planting. Later, the treatment differences disappeared which prompted us to discontinue expensive soil nitrate measurements during the following years.

#### Effect of Carboxymethyl Pyrazole on Nitrate-Nitrogen

Nitrification inhibitors are able to slow conversion of  $\text{NH}_4^+\text{-N}$  to  $\text{NO}_3^-\text{-N}$  and thus reduce N losses from leaching and denitrification (Rao, 1996). In this experiment, application of CP influenced nitrate concentration in surface soil (0–15 cm) significantly only for a short period of time. During 1994, CP treated plots showed significantly lower  $\text{NO}_3^-\text{-N}$  at 41 d after planting ( $53 \text{ mg kg}^{-1}$ ) compared to no-CP plots ( $65 \text{ mg kg}^{-1}$ ). However, the differences disappeared and became non-significant in later samplings (Fig. 3).

Effectiveness of CP for only such a short term might be due to this location's warm soil temperatures. Warm soil in the fall tends to reduce the effectiveness of surface applied nitrification inhibitors (Gerik et al., 1994). Sawyer (1984) observed that nitrapyrin application at soil temperature below  $10^\circ\text{C}$  resulted in 26% of  $\text{NH}_4\text{-N}$  remaining even 4 mo after application of



**Fig. 4. Mean surface soil temperature from April through December, 1994 to 1998 at Belle Mina, AL.**

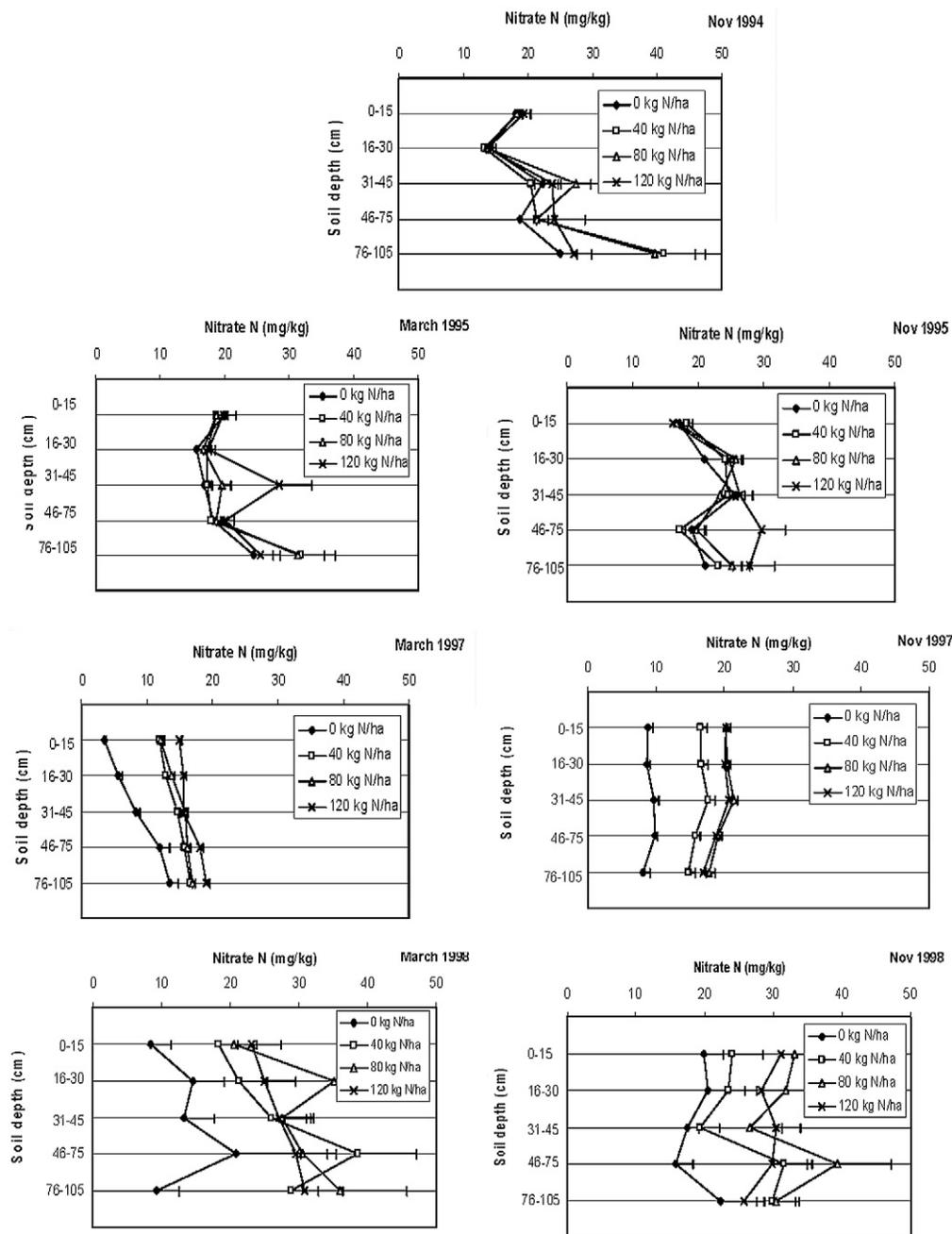
anhydrous ammonia against 17% of  $\text{NH}_4\text{-N}$  when nitrapyrin was applied at above  $10^\circ\text{C}$  of soil temperature. Brundy and Bremner (1973) found that most nitrification inhibitors are more effective at  $15^\circ\text{C}$  than at  $30^\circ\text{C}$  soil temperature. Guiraud and Marol (1992) studied the nitrification inhibition ability of dicyandiamide ( $\text{C}_2\text{H}_4\text{N}_4$ ), which was  $>80\%$  as long as the soil temperature did not exceed  $15^\circ\text{C}$ , and decreased to 10% after 6 mo. Furthermore when the soil temperature was maintained at  $10^\circ\text{C}$ , it took a year to decrease the efficiency to 10%. These results clearly indicate that soil temperature plays a vital role in efficiency of nitrification inhibitors. In our study, in all the 5 yr, surface soil temperatures were between  $25$  and  $35^\circ\text{C}$  during May to September (Fig. 4), perhaps explaining the short-term performance of CP. However, maximum N uptake by cotton plants occurs between 49 and 71 d after planting (Boquet and Breitenbeck, 2000) and hence, the ability of the CP to prevent nitrification in the initial plant growth period is a great help in reducing nitrate leaching.

Soil analysis by date of sampling showed that the  $\text{NO}_3^-\text{-N}$  concentrations in soil at all depths were not affected by CP treatment except in March 1997 where it actually decreased  $\text{NO}_3^-\text{-N}$  concentration. These results are expected as soil samples were collected and analyzed every year in March, before application of CP, and in October/November, 7 to 8 mo after application of CP.

#### Effect of Nitrogen Rate on Nitrate-Nitrogen

During 1994, an increase in N application rates increased the surface soil (0–15 cm)  $\text{NO}_3^-\text{-N}$  concentration at all sampling days but differences were significant only on 41 d after planting (Fig. 3). The  $40 \text{ kg N ha}^{-1}$  rate did not influence surface soil  $\text{NO}_3^-\text{-N}$  concentration throughout the crop period. The  $80 \text{ kg N ha}^{-1}$  recorded significantly higher  $\text{NO}_3^-\text{-N}$  concentration over the control only at 41 d after planting and differences disappeared in later dates. The  $120 \text{ kg N ha}^{-1}$  resulted in significantly higher  $\text{NO}_3^-\text{-N}$  concentration over the control until 71 d after planting (Fig. 3).

Soil analysis by date of sampling showed very minimal changes in nitrate concentration due to changes in N rates (Fig. 5). This might be due to absorption of  $\text{NO}_3^-\text{-N}$  by the plants even at higher N application rates and it was evidenced from yield data of this same experiment (Reddy et al., 2007). However the effect of N levels on nitrate concentration in soil profile (0–105 cm) was very apparent during 1997 (Fig. 5). In both fall and spring sampling in 1997 all N levels recorded significantly higher  $\text{NO}_3^-\text{-N}$  concentration compared to the



**Fig. 5. Nitrate N concentration in soil at different depths as affected by N rates calculated across N sources and nitrification inhibitor from November 1994 through November 1998, Belle Mina, AL (vertical bars = SE).**

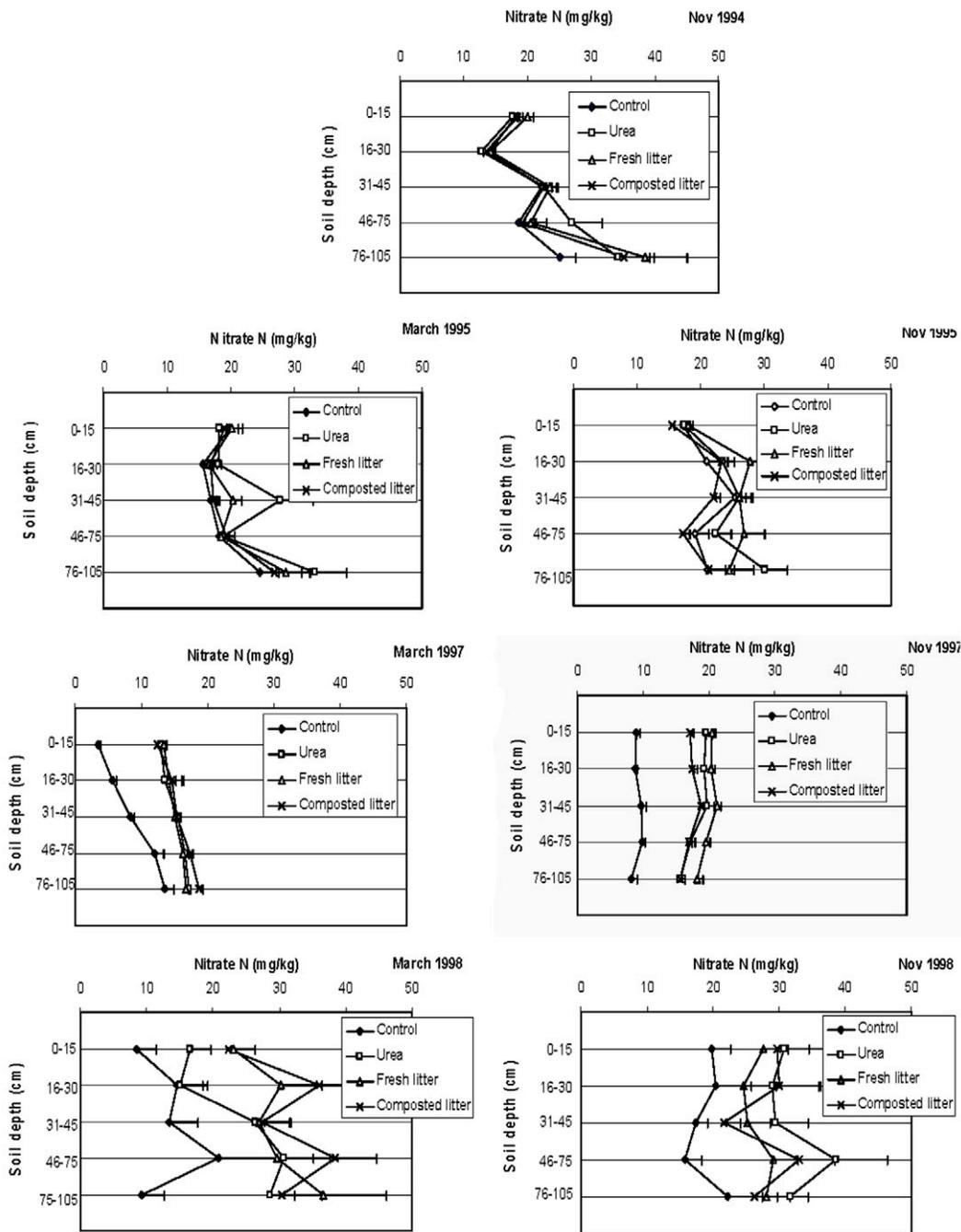
0-N control. The 120 kg N/ha recorded significantly higher  $\text{NO}_3^-$ -N concentration compared to all other N levels in March and compared to 0 and 40 kg N/ha in November. These results are in accordance with the findings of Evans et al. (1977) and Gagnon et al. (1998) where high fertilizer rates resulted in high soil and groundwater  $\text{NO}_3^-$ -N levels.

#### Effect of Nitrogen Source on Nitrate-Nitrogen

In 1994 urea application resulted in significantly higher surface soil (0–15 cm)  $\text{NO}_3^-$ -N concentration compared to composted litter application at 41, 71, and 111 d after planting, but these differences became insignificant at the end of the season (Fig. 3). Urea application resulted in significantly higher  $\text{NO}_3^-$ -N concentration compared to fresh litter at 102 and 111 d after planting. However fresh poultry litter application

recorded significantly higher  $\text{NO}_3^-$ -N concentration ( $19.9 \text{ mg kg}^{-1}$ ) compared with urea ( $17.6 \text{ mg kg}^{-1}$ ) application at the end of the season. Fresh litter application resulted in significantly higher surface soil  $\text{NO}_3^-$ -N concentration over composted litter application till 71 d after planting and these differences disappeared later.

Sampling time specific analysis showed that majority of times all three N sources showed similar  $\text{NO}_3^-$ -N concentration at all observed depths (Fig. 6). There is a general opinion that application of poultry litter is responsible for nitrate accumulation in the soil that may leach to groundwater (Edwards et al., 1992; Sharpley et al., 1996). However, our results suggest that nitrate concentrations resulting from application of fresh and composted poultry litter were similar to that of commercial fertilizer, urea (Fig. 6). Similar results



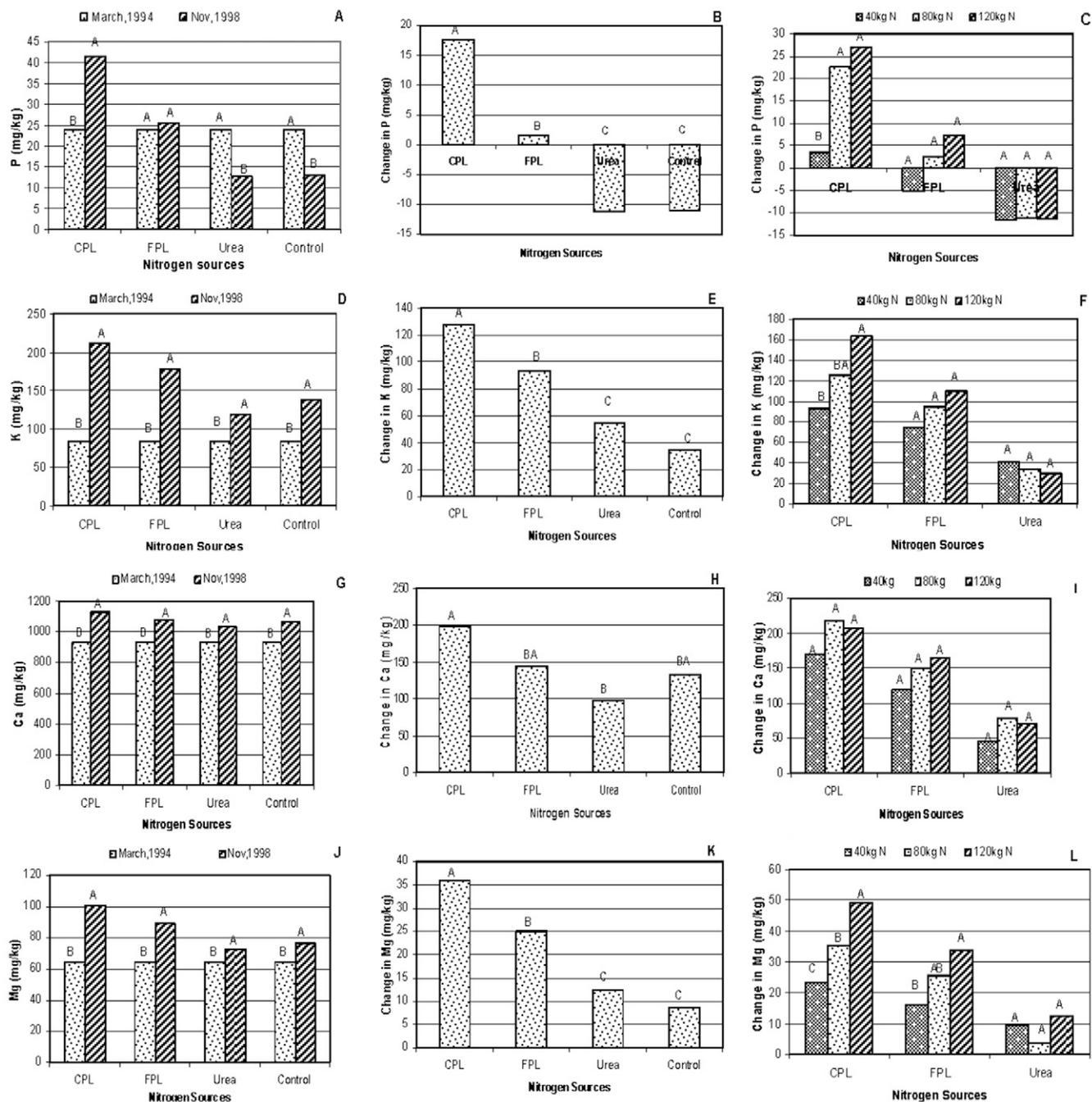
**Fig. 6.** Nitrate N concentration in soil at different depths as affected by N sources calculated across N rates and nitrification inhibitor, from November 1994 through November 1998, Belle Mina, AL (vertical bars = SE).

were reported by Cabrera et al. (1999). All three N sources did not differ significantly from the control (0-N source) in nitrate concentration in soil except in November 1997. This might have been the result of utilization of nitrates by cotton plants, as was reflected in terms of lint yield where all three N sources recorded significantly higher yield compared to control (Reddy et al., 2007). Occasionally interactions between N rates and N sources were observed but they were inconsistent from one sampling time to another.

### Phosphorus

Over the 5-yr period, extractable soil P concentration in the top layer (0–15 cm) of poultry litter applied plots (average of all poultry litter applied treatments) increased significantly

by 33% from 23.9 mg kg<sup>-1</sup> in March 1994 to 31.7 mg kg<sup>-1</sup> in November 1998. Among N sources, application of composted litter for 5 yr resulted in significantly higher P accumulation (+17.7 mg kg<sup>-1</sup>) in the top layer of the soil (0–15cm) (Fig. 7A). Phosphorus concentration in fresh litter applied plots did not change significantly but significant reduction was observed in urea (–11.3 mg kg<sup>-1</sup>) and control plots (–11.0 mg kg<sup>-1</sup>) from 1994. The increase in P concentration in the 0 to 15 cm depth over the 5-yr period in composted litter applied plots was 11 times higher than in fresh litter applied plots. However, Mitchell and Tu (2006) found that fresh litter application for 10 yr increased P concentration by five times. Higher accumulation of P with composted litter compared to fresh litter was attributed to application of both litters on a plant N use rate



**Fig. 7.** Influence of N sources on soil P, K, Ca, and Mg concentrations in March 1994 and November 1998 and change in soil P, K, Ca, and Mg due to sources and rates of N. Means under each N source followed by same uppercase letter are not significantly different from each other at  $P \leq 0.05$ . (CPL, composted poultry litter; FPL, fresh poultry litter). Values for graphs A, B, D, E, G, H, J, and K were averaged across N rates and nitrification inhibitor treatments; values for graphs C, F, I, and L were averaged across nitrification inhibitor treatment.

which resulted in higher dosage of composted litter and over application of P. For 5 yr, on an average, composted litter was applied at the rate of 3.2, 6.4 and 9.6 t/ha compared to 2.6, 5.2, and 7.8 t/ha in case of fresh litter to supply 40, 80, and 120 kg N/ha, respectively. On an average, 24% higher quantity of composted litter than fresh litter was applied every year for each level of N. The composting process does not reduce plant available P and P can be as available in composted poultry litter as in fresh poultry litter (Preusch et al., 2002). Our results confirmed the opinion that applying composted litter on plant N use rate may contribute to over application of P (Preusch et al., 2002). Depending on soil type and extractant used, previously

published critical levels of soil P for cotton include 6 to 12 mg kg<sup>-1</sup> with Mehlich-1 extractant (Bingham, 1966; Cope, 1984), 12 mg kg<sup>-1</sup> with Mehlich-3 extractant (Cox and Barnes, 2002), and 14 to 32 mg kg<sup>-1</sup> with a bicarbonate extractant (Duggan et al., 2003). In the present study, plant available P concentration before the experiment in March 1994 was 23.9 mg kg<sup>-1</sup> with Mehlich-1 extractant; and it was much higher than the above reported critical limits. Application of poultry litter based on N requirement further increased the P concentration significantly and it reached to 31.7 mg kg<sup>-1</sup> in November 1998. These results corroborate findings that applying compost at N-based rates could lead to excess P of which may buildup in the soil,

be lost to run-off or leaching, or absorbed by plants (Preusch et al., 2002; Preusch and Tworowski, 2003). Sharpley et al. (1986) demonstrated a positive relationship between soil P level, particularly at or near the soil surface, and dissolved P in runoff.

Phosphorus concentration in urea and control plots declined significantly and reached above said critical level in 5 yr. Reduction in P concentration in urea and 0-N control plots can be attributed to continuous uptake of P by plants and no addition of P for 5 yr. The lower pH in urea plots (Fig. 2) must have also played a role in lowering bioavailability of P level. In the present study average lint yield in urea-applied plots was similar to that of composted litter applied plots (Reddy et al., 2007). Hence, stopping poultry litter application in P-rich soils for few years and fertilizing only with inorganic N sources until the P concentration reaches its critical level and then resuming poultry litter application should be a vital strategy to control P accumulation.

Among the N sources only composted litter differed significantly in P accumulation at different N rates (Fig. 7B). Regression analysis showed that extractable P was related to rate of composted litter application (Fig. 8). Application of composted litter at the rate of 80 and 120 kg N/ha recorded significantly higher P accumulation (22.7 and 26.9 mg kg<sup>-1</sup>, respectively) compared to 40 kg N/ha (3.4 mg kg<sup>-1</sup>). Though fresh litter did not differ significantly in P accumulation at different N based litter application rates, it resulted in a reduction in P concentration at the 40 kg N/ha (-5.1 mg kg<sup>-1</sup>) based application. During 5-yr period, approximately a total of 580 and 720 kg P/ha were added as fresh and composted poultry litter, respectively at highest N rate. In urea-treated plots P concentration declined at all N rates.

Approximately 2.6 kg P is required to produce 100 kg of seedcotton (Potash and Phosphorus Institute and Potash and Phosphate Institute of Canada, 2003). In the present study over 5 yr, average seed cotton yields in fresh and composted poultry litter applied plots were 3825 and 3569 kg/ha, respectively (Reddy et al., 2007) and to produce this approximately 100 and 93 kg P/ha is required, respectively. Phosphorus concentration of broiler litters in Alabama ranges between 0.6 to 3.8% on dry weight basis with an average of 1.5% (Mitchell et al., 2007). In the present study on average the highest applied dosages of fresh and composted litter were 7.7 and 9.6 t/ha, respectively which can approximately supply 116 and 144 kg P/ha, respectively (assuming 1.5% P concentration). Plant available P would be much lower than this applied total P and it can be concluded that P application rates in the present study were within the range of crop requirement. Further applica-

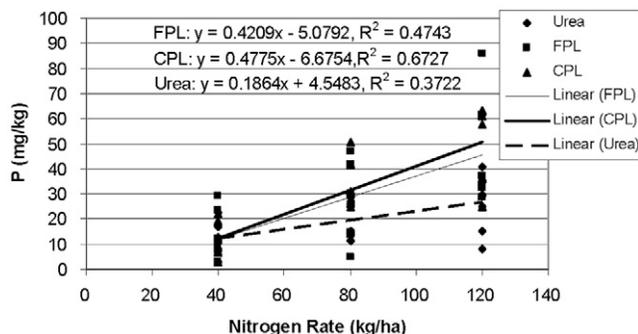


Fig. 8. Soil P concentrations as influenced by sources of N regressed on N equivalent litter application rates in 1998.

tion of poultry litter over years may result in excess application and build up of P in soil and lead to potential loss in to the environment.

### Potassium, Calcium, and Magnesium

In 5 yr of experimentation, K, Ca, and Mg concentrations increased in all treatments including in control plots, significantly (Fig. 7D, 7G, and 7J). This could be due to application of 0-20-20 (N-P-K) fertilizer and dolomite application in 1994, before starting up the experiment and incorporation of plant residue after each harvest.

Both forms of poultry litter showed significantly higher K accumulation in the soil compared to urea and control (Fig. 7E). Among N sources, composted litter resulted in significantly higher K accumulation (127 mg kg<sup>-1</sup>) compared to fresh litter (93 mg kg<sup>-1</sup>), urea (54 mg kg<sup>-1</sup>) and 0-N control (35 mg kg<sup>-1</sup>). Among N sources, only composted litter differed significantly in accumulation of soil K with N-based rates of fertilizer (Fig. 7F). The increase in K concentration was greater in composted litter plots with 120 kg N/ha (163.5 mg kg<sup>-1</sup>) compared to 80 kg N/ha (125.3 mg kg<sup>-1</sup>) and 40 kg N/ha (93.3 mg kg<sup>-1</sup>). Application of poultry litter based on N requirement resulted in application of higher quantity of composted litter than fresh litter which resulted in higher accumulation of K in composted litter plots.

The differences in Ca accumulation by different sources of N were somewhat similar except that composted litter plots accumulated significantly higher Ca than urea applied plots (Fig. 7H). This was attributed to extra application of Ca through composted litter compared to urea. Similar increase in Ca concentration in composted poultry litter, fresh poultry litter, and control plots showed that the increase in Ca concentration is attributed to application of dolomite in 1994 before starting of the experiment but not due to poultry litter application. All N sources did not differ significantly in Ca concentration at different N levels (Fig. 7I).

Over 5 yr, change in Mg concentration was significantly higher in composted litter (36 mg kg<sup>-1</sup>) and fresh litter (25 mg kg<sup>-1</sup>) applied plots compared to urea (12 mg kg<sup>-1</sup>) and control (9 mg kg<sup>-1</sup>) plots (Fig. 7K). Between these two poultry litter forms composted litter recorded significantly higher Mg accumulation. Application of both litters at higher N rates resulted in significantly higher Mg accumulation (Fig. 7L). Urea-treated plots did not differ significantly in Ca accumulation at different N rates.

### CONCLUSION

Results from our 5-yr study indicate that application of fresh and composted poultry litter maintained soil pH whereas urea reduced soil pH. Nitrate concentration levels of plots that received fresh poultry litter and composted poultry litter were similar to that of urea. The Nitrification inhibitor, carboxymethyl pyrazole, significantly reduced the NO<sub>3</sub><sup>-</sup>-N formation during the first 41 d of its application in which period demand for N is less from cotton plants and nitrates are easily subjected to leaching if the nitrification inhibitor is absent. A linear increase in soil P occurred with application rates of composted litter. Fresh poultry litter did not increase P concentration even at higher rates of application. Both forms of poultry litter

increased soil K and Mg concentrations in the top soil. It can be concluded that poultry litter or poultry litter treated with nitrification inhibitor present no more risk of nitrate leaching than commercial fertilizer when managed properly.

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