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NUTRIENT MOVEMENT UNDER LONG-TERM BROILER LITTER FERTILIZATION

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Abstract

Poultry broiler litter (BL) has been applied to crops of cotton and corn on a Coastal Plain soil (fine-loamy, siliceous, thermic Typic Kandiudults) since 1991 in Central Alabama and to a Tennessee Valley soil in North Alabama (clayey, kaolinitic, thermic, Rhodic Paleudults) in 1990-1992 . Variable N rates from 0 to 240 lb. N per acre were applied based upon the total N content of BL and compared to fertilizer N rates as ammonium nitrate. Periodically, during the experiments deep soil samples were taken to a 1 m depth in 15-cm (6-inch) increments in selected treatments in order to evaluate the effect of treatments on nutrient accumulation and movement. The results indicated that BL applications maintained surface soil pH whereas, as expected, pH and Mehlich-1 extractable Ca levels dropped dramatically when ammonium nitrate was used as an N source. Long-term application of BL resulted in accumulation of total C, total N, Ca, Mg, P, K, B, Zn, and Cu as the rates of BL increased. No significant accumulation of heavy metals was observed in the soil tested during the experiment. Nitrogen mineralization and leeching below the rooting zone was similar with BL and ammonium nitrate.

Introduction

Alabama produces almost 3 times more poultry broiler litter (by weight) as commercial fertilizers used. In regions of intensive poultry production, most broiler litter is over applied to pastures and hayfields creating potential nutrient enrichment of surface and ground waters. Row crop farmers have been reluctant to use broiler litter on their crops, especially cotton. Reasons may include: (1) perception among cotton producers that manure-N sources would produce excessive vegetative growth and late maturity of cotton; (2) suspicion that animal manures may introduce weed seed into prime cotton land; (3) lack of extensive published, applied research with manures on cotton; (4) most cotton land is often remote from the smaller farms where poultry is produced; (5) availability of broiler litter may not coincide with optimum time of fertilizing cotton at planting in the spring; and (6) reluctance of cotton producers to change successful production practices.

In 1990 and 1991, experiments were begun to address some of these concerns. The Central Alabama experiment has been continued with some modification since then. Today, it is one of the oldest, continuous experiments in the U.S. with poultry manure on crops.

Objectives

The objectives of these experiments were to (1) evaluate broiler litter as a source of N for cotton and corn; (2) determine the availability of N in broiler litter compared to ammonium nitrate fertilizer; (3) determine if plant growth regulators would be needed to control excessive vegetative growth of cotton fertilized with broiler litter; (4) determine the residual effects of broiler litter on cotton and corn production and soil properties; and (5) demonstrate to area producers the practicality of using broiler litter as an alternative fertilizer for cotton. This phase of the study addresses only objective no. 4, to determine the residual effects of broiler litter on cotton and corn production and soil properties. Other objectives have been addressed in previous papers (Mitchell et a., 1993, 1995; Mitchell and Tu, 2001; Mitchell and Birdsong, 2002)

Methods

Experiments began in 1990 in the Tennessee Valley of North Alabama and in 1991 in the Coastal Plain of Central Alabama with 11 treatments replicated 4 times in a RBD (Table 1). Soil at the Tennessee Valley site is a Decatur silt loam on the Tennessee Valley Research and Extension Center in Belle Mina, Alabama. The Tennessee Valley experiment was discontinued after 3 years. The Central Alabama site is in the Coastal Plain physiographic region on a Norfolk fine sandy loam on the E.V. Smith Research Center near Shorter, Alabama. This site has been continued from 1991 through 2002. Plot size at both sites is 25 feet long and 24 feed wide which accommodates eight, 36-inch rows of cotton or corn. All broiler litter has been broadcast just prior to planting at a rate based upon the TOTAL N concentration in the litter. Ammonium nitrate rate is split with 1/2 applied at planting and 1/2 applied as a sidedress. All treatments except the broiler litter treatments receive 30 kg P ha^{-1} and 56 kg K ha^{-1} as concentrated superphosphate and muriate of potash, respectively, at planting.

The sites were in conventionally tilled cotton through 1993 (moldboard plow, disk, field cultivate, and cultivate to control weeds; winter fallow; nutrients were incorporated just prior to planting under conventional tillage). In 1994, treatments at the Central Alabama site were slightly modified to include residual broiler litter treatments. The experiment was planted to conservation-tilled corn from 1994-1997 (winter rye planted as a cover crop; nutrients surface applied just prior to planting into rye residue after spraying with glyphosate; in-row subsoiled to 35 cm every spring just prior to planting; no cultivation.). From 1998 through 2002, the experiment has been in conservation tilled cotton (Table 1).

Residual broiler litter plots in 1994-2001 received no additional fertilization the year after application. Soil samples were taken periodically during the experiment in incremental depths to 1 m. Samples were analyzed for Mehlich-1 extractable nutrients and KCl extractable nitrates and ammonium. Soil organic C was determined by combustion on surface soils.

Results and Discussion

Broiler Litter Analysis

Broiler litter used in the experiments varied from year to year depending upon the source and age of the litter (Table 2). However, the mean N concentration in the litter, 2.98 percent or about 60 pounds per ton, is exactly what Alabama Cooperative Extension System literature claims as the average concentration in poultry broiler litter (Mitchell and Donald, 1999). When the experiments were started, the base rate of BL was 120 pounds total N per acre or about the equivalent of 2 tons BL per acre. At the time, we thought this was about the lowest rate most growers would apply.

Soil pH

Application of broiler litter either increased soil pH or maintained the existing pH depending upon rate applied in both the 0 to 2-inch depth and in the 2 to 8-inch depth (data not shown). However, long-term application of ammonium nitrate (AN) resulted in a decease in soil pH. Surface soil pH (0-2 inches) at the Central Alabama decreased by 0.12 to 0.95 units as N rate of AN increased from 60 pounds per acre to 240 pounds per acre over the period from 1993 to 2000. Regression relation analysis showed a simple linear relationship existed between soil pH and N rates of AN. At the Tennessee Valley location, there was no significant change of soil pH in 3-yr experiment., Kingery et al. (1994) reported that long-term application of BL in pastures in sand mountain region of northern Alabama caused an increase of approximately 0.5 units over the 0- to 60 cm depth interval. Same results were reported by Sharpley et al. (1993) in 12 soils in Oklahoma under coastal burmudagrass (*Cynodon dactylon*) to which litter had been continually applied for 12 to 35 years.

Nitrogen and Carbon

After 11 years in Central Alabama and 32 tons broiler litter per acre were applied, significant increases in both total N and total C were found in the upper 20 cm of soil (Fig. 1). These differences were not significant at the lower rates of broiler litter application. They were reflected in the residual yields of cotton (Mitchell and Tu, 2002). Nitrate-N was always low throughout the soil profile at both locations (Fig. 2). From 1994 through 1997, soil nitrate-N was measured to 16 inches at sidedressing time for the corn (late May in Central Alabama) in an attempt to evaluate the presidedress soil nitrate test for corn. Rarely did soil nitrate-N exceed 10 mg N/kg in the surface horizons even after heavy BL applications at planting. Research in the northeastern U.S. and midwestern U.S. suggest that nitrate-N in the upper 24 inches of soil should exceed 20 to 25 mg N/kg in order to avoid sidedressing corn. We never found levels this high in this relatively sandy, Coastal Plain soil (data not shown) although BL applications at planting of 120 to 240 pounds N per acre were often adequate to achieve maximum cotton and/or corn yields (Mitchell and Tu, 2002). Research reported by Jackson (1998) also showed rapid nitrate-N leaching from long-term N fertilization on cotton on similar Coastal Plain soils in Alabama.

Extractable P

Increases in Mehlich 1extractable P from BL were dramatic at both Tennessee Valley and Central Alabama (Fig. 3). At the highest BL rate (approx. 4 tons per acre every other year since 1994), 1254 pounds P_2O_5 per acre were applied over 11 years. The ammonium nitrate treatments and the no-N control received 658 pounds P_2O_5 per acre as concentrated superphosphate. P applied as concentrated superphosphate at an annual rate of 60 pounds P_2O_5 per acre maintained Mehlich-1 extractable P in the surface horizon near 25 mg P/kg. This is the level that would be considered as "high" by the Auburn University soil testing laboratory and no additional P would be recommended. However, at the highest broiler litter rate, Mehlich-1 extractable P exceeded 125 mg P/kg, a level that would be rated "extremely high". Although the highest rates of broiler litter did not result in cotton or corn yield reductions in these studies (Mitchell and Tu, 2002), over-application could result in restrictions on future broiler litter applications due to excessive P buildup.

Extractable K, Ca and Mg

When BL is used as a source of N for crops, dramatic increases in extractable K can be expected and additional K fertilization is not needed for cotton and corn (Fig. 4). Similar trends were observed with Ca and Mg (data not shown).

Extractable Metals

Mehlich-1 extractable Cu, B, Zn, Fe, Mn, Mo, Na, Si, Pb, Al, Ba, Co, and Cr, were determined at each sampling depth. Only Cu, Zn, and B had accumulated significantly in littered soils to a depth of 20cm (Table 3). Kingery et al.(1994) found that Cu and Zn accumulated near soil surface of pastures in long-term application of BL. The BL used in this study had a mean Cu and Zn concentration of 508 and 401 mg/kg, respectively (Table 2). Boron and Zn are the only micronutrients routinely recommended for cotton and corn, respectively, in most southeastern U.S. States. In Alabama, 0.3 lb. B per acre is routinely recommended for all cotton and 3 lb. Zn per acre are recommended for corn on sandy soils (Adams et al., 1994). An average ton of the BL used in this study would apply 0.1 lb. B and about 0.8 lb. Zn. Thus application of BL may decrease the demand of chemical B and Zn fertilizer. However, accumulation of Zn from long-term application is a concern especially in Coastal Plain soils where peanuts may be grown. Peanuts are particularly susceptible to Zn toxicity. Keisling et al. (1977) reported a critical Mehlich-1 extractable Zn level for toxicity in peanuts to be around 12 mg Zn/kg. Davis-Carter et al. (1993) showed that the critical value was dependent upon soil texture and pH with a critical value around 10 mg Zn/kg at a pH of 6.0. After 11 years of very high BL application, these soils were approaching a critical extractable Zn level. This should not be a problem for most crops but it would be a concern if peanuts are grown in a rotation.

Copper accumulation was significant from BL applications but was far below reported Cu toxicity levels in soils. Rhoads and Olson (1990) reported toxicity in oats from soil from Mehlich-1 extractable Cu levels of 96 mg Cu/kg, many times higher than we observed after 11 years of very high BL application. Copper accumulation does not appear to be a major concern.

Conclusions

Three years of BL application in the Tennessee Valley and 11 years application in a Central Alabama Coastal Plain soil dramatically increased extractable P, K, Ca, Mg, Zn, and Cu in surface soils in proportion to that applied in the BL. There was also a slight but significant accumulation of surface soil organic C and N after 11 years in Central Alabama at the highest BL rate (240 lb. N/acre as BL or approximately 4 tons BL/acre every two years). When BL is used as a source of N, soil pH is maintained or slightly increased depending upon the rate used (data not shown). Rapid nitrate leaching in these soils results in generally low measurable levels of soil nitrate-N. The presidedress soil nitrate test does not predict crop response to sidedress N regardless of N source at planting.

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Table 1. Treatments used in experiments with broiler litter on cotton and corn at two locations.

Both locations Cotton - Conventional tillage 1990-1993			**Central Alabama location only Corn - Conservation tillage 1994-1997 Cotton - Conservation tillage 1998-2002**		
Source of N	**N rate (lb/acre)**	**Growth regulator**[†]	**Source of N**	**N rate (lb/acre)**	**Other factors**
None	0	no	None	0	
Am. nitrate	60	no	Am. nitrate	60	
Am. nitrate	60	yes	Am. nitrate	120	
Am. nitrate	120	no	Am. nitrate	180	
Am. nitrate	120	yes	Am. nitrate	240	
Broiler litter	120	no	Broiler litter	120	
Broiler litter	120	yes	Broiler litter	120	Residual[‡]
Broiler litter	180	no	Broiler litter	180	
Broiler litter	180	yes	Broiler litter	180	Residual[‡]
Broiler litter	240	no	Broiler litter	240	
Broiler litter	240	yes	Broiler litter	240	Residual[‡]

[†]Pix (mepiquot chloride) applied at rate of 8 oz./acre in multiple applications.
[‡]Broiler litter and resiudal plots were alternated each year such that each year there was a residual treatment which did not received an N source.

Table 2. Analysis of 11 broiler litter samples used in experiments from 1991-2002

Analysis	**Mean**	**Std. deviation**	**Maximum**	**Minimum**
Moisture, %	24.4	9.2	38.5	14.4
Ash, %	27.3	6.7	37.4	20.5
Total N, %	2.98	0.63	4.14	2.04
P_sO_5, %	3.92	0.40	4.75	3.37
K_2O, %	2.80	0.53	3.56	1.80
Ca, %	2.43	0.24	2.89	2.01
Mg, %	0.54	0.05	0.60	0.47
Cu, mg/kg	508	154	751	300
Zn, mg/kg	401	86	562	250
Mn, mg/kg	439	138	669	310
Pb, mg/kg	14	6	21	9
B, mg/kg	51	10	71	39

Table 3. Accumulation of copper and zinc over an 11-yr period of treatment with ammonium nitrate (AN) and broiler litter (BL) as sources of N at the Central Alabama location.

Treatment	**1993 Copper**	**2001 Zinc**	**1993 Copper**	**2001 Zinc**
	.----mg/kg----		**.----mg/kg----**	
No N	0.31	0.70	0.85	1.40
AN @ 60 lb. N/acre	--	0.53	--	1.23
AN @ 120 lb. N/acre	0.40	0.53	1.03	1.40
AN @ 180 lb. N/acre	--	0.58	--	1.90
AN @ 240 lb. N/acre	--	0.58	--	1.40
BL @ 120 lb. N/acre	--	1.28	--	3.55
BL @ 180 lb. N/acre	--	1.38	--	5.30
BL @ 240 lb. N/acre	1.21	2.20	2.79	7.58
L.S.D. (P<0.05)	*0.21*	*0.35*	*0.45*	*0.86*

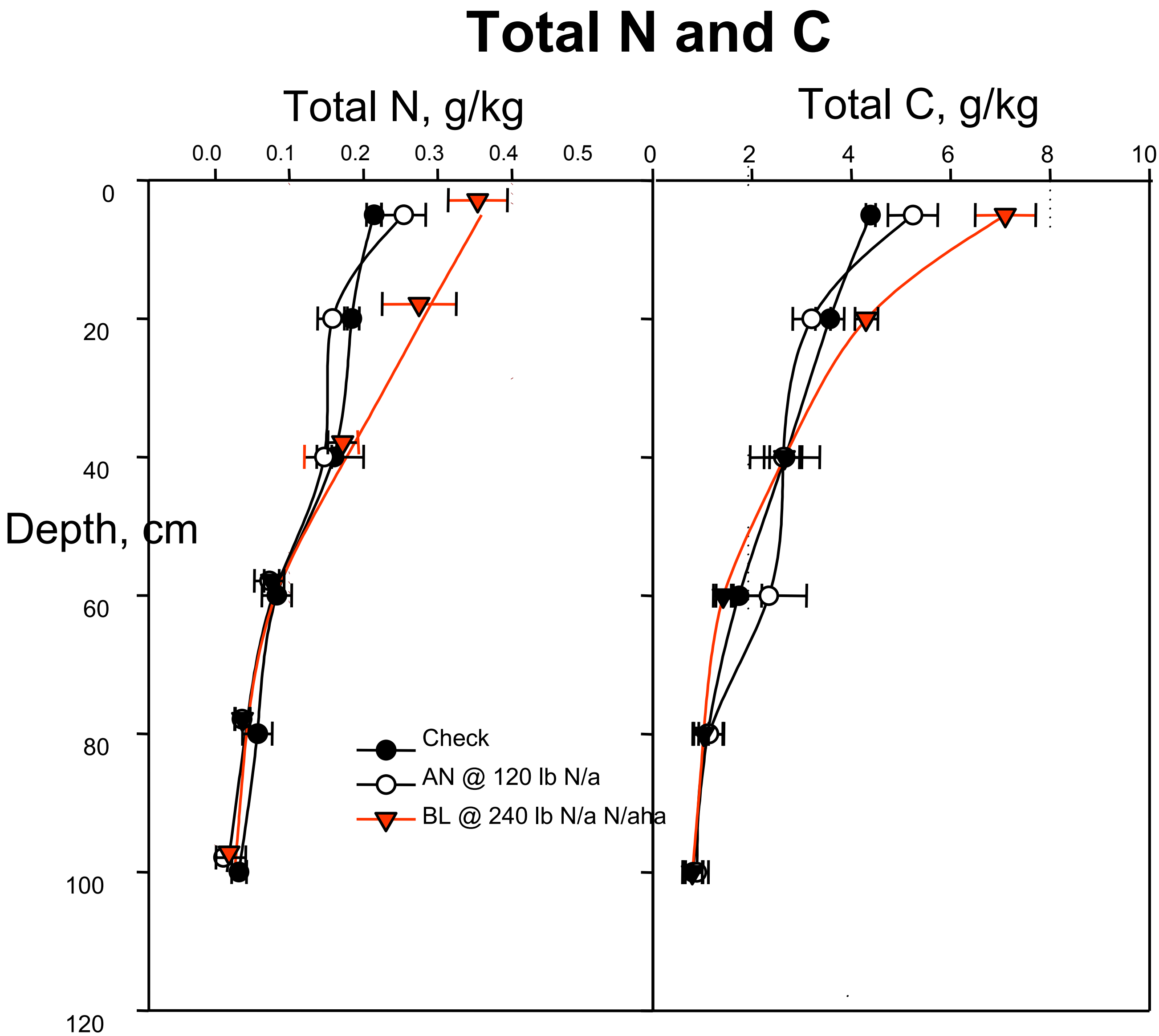

Figure 1. After 11 years in Central Alabama and 72 Mg BL/ha (32 tons/acre) were applied, significant increases in both total N and total C were found in the upper 20 cm of soil.

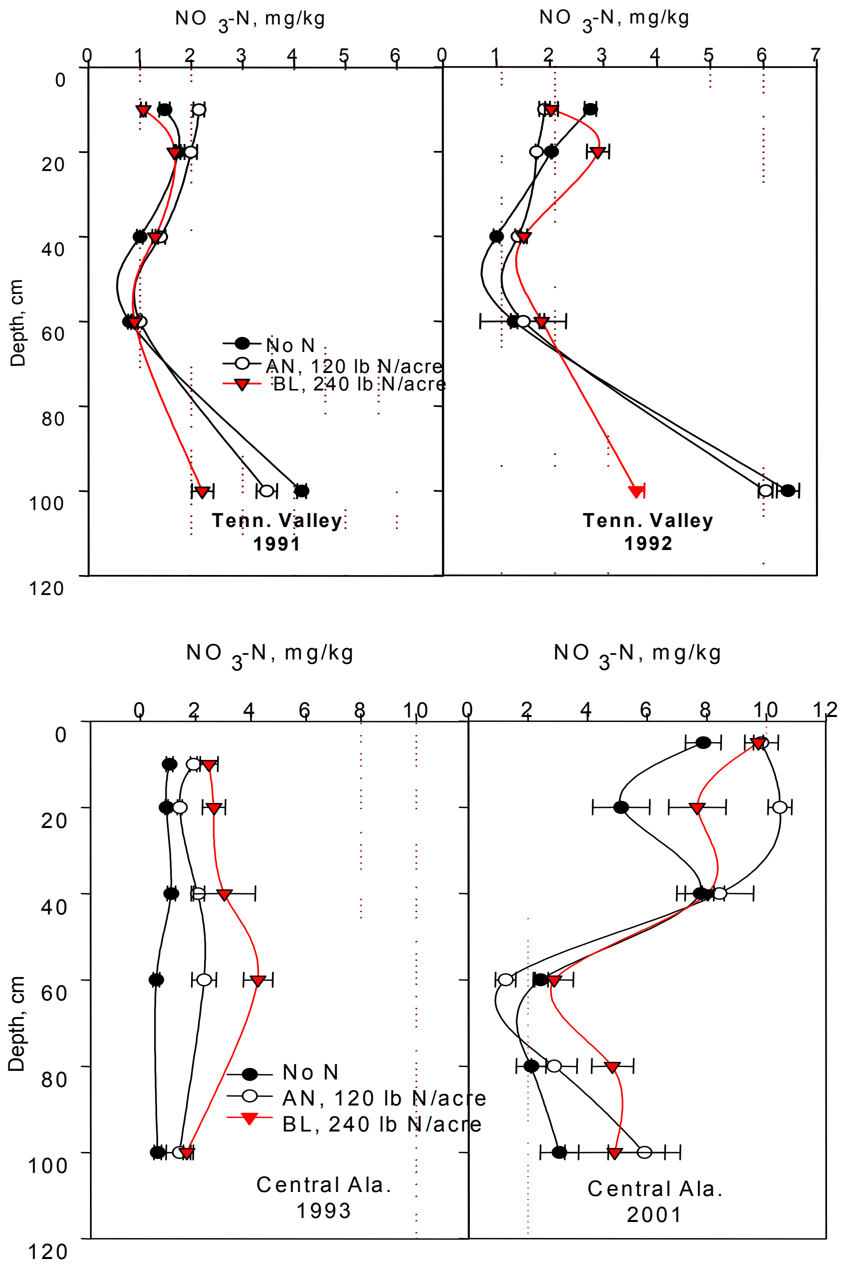

Figure 2. Nitrate movement to 100 cm in the Tenn. Valley and Central Alabama locations following N applications as ammonium nitrate (AN) and broiler litter (BL).

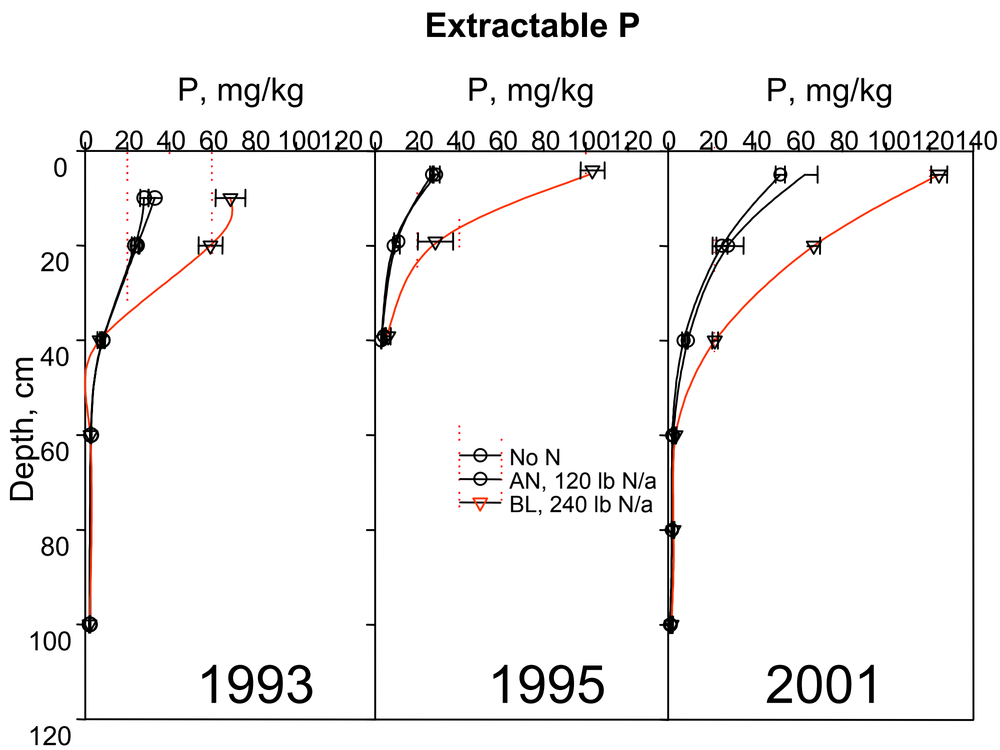

Figure 3. Mehlich- 1 extractable P with depth at the Central Alabama location.

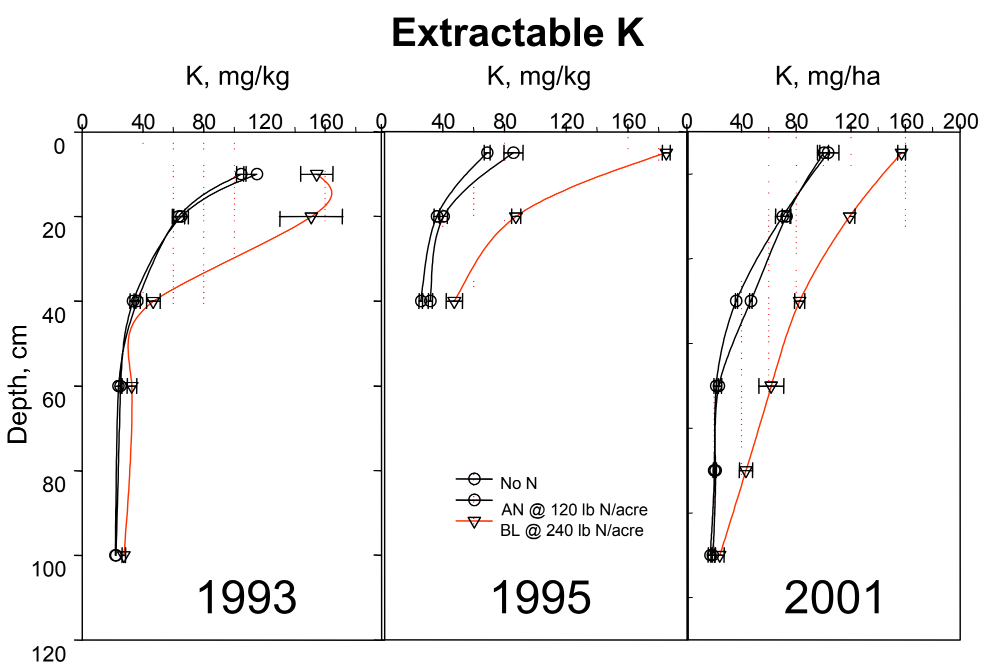

Figure 4. Mehlich- 1 extractable K with depth at the Central Alabama location.