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COMPARISON OF SECONDARY AND MICRO-NUTRIENT DISTRIBUTION AND AVAILABILITY IN SOIL UNDER CONSERVATION AND CONVENTIONAL MANAGEMENT FOR 17 YEARS

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Abstract

Notill management and the use of winter cover crops are cost-effective techniques for controlling erosion and minimizing the impact of cotton cultivation on the quality of nearby surface waters in the mid-South. The purpose of this study was to assess the long-term impact of these conservation practices on the distribution and availability of secondary and micronutrients through the analysis of plant and soil samples collected from a study established in 1987 to compare various tillage and cover crop systems for cotton production. Based on the various parameters measured, reductions in S availability associated with notill and winter wheat cover crops are most likely to adversely affect the performance of future cotton crops unless supplemental fertilizer is applied. Both notill and wheat covers reduced uptake of S in young cotton plants and reduced the amounts of extractable S in surface soil. Systems employing both notill and wheat covers contained an average of only 6.8 mg/kg extractable S in the surface 12" whereas values under surface tillage averaged 10.7 mg S/kg. A value <8 mg/kg is used to indicate the need for supplemental S in Louisiana. A number of other significant effects of tillage, cover crop type and N fertilizer rate were observed. Uptake of P by young (30 DAP) cotton plants and soil pH were higher under notill than under surface till. Notill also resulted in higher pH, base saturation and exchangeable K and Ca in the surface 0-3" (0-7.5 cm). Notill decreased uptake of N, S and Mg by young cotton plants and resulted in lower amounts of extractable soil NO_3, S, Fe and Mn. Winter covers of wheat significantly reduced uptake of K and S by young cotton plants and lead to slightly greater uptake of N, Cu and Mo than did surface till. Wheat covers increased base saturation and exchangeable Ca in the surface 0-3" but reduced the amounts of exchangeable K, Mg and extractable S. Increasing the amount of N (UAN) injected annually at cotton planting from 45 to 90 lbs/acre (50 to 100 kg/ha) increased plant uptake of S and the effective cation exchange capacity of soil. A higher N rate lowered soil pH, base saturation and exchangeable Ca, as would be expected. These findings suggest that conservation systems employing notill and wheat covers may require somewhat greater annual applications of N and K fertilizers, and periodic additions of S, to ensure optimal early season growth and to maintain long-term productivity.

Introduction

The use of no-till management in combination with a planted or volunteer winter cover crop has proven a cost-efficient strategy for controlling surface erosion and minimizing the impact of cultivation on nearby surface water quality in the mid-South (Boquet et al., 1997). There is concern among some growers that long-term use of notill will result in vertical partitioning of plant nutrients and possibly reduce their availability, especially during early growth when cotton roots are small.

This study was conducted to determine whether long-term use of no-till management, winter cover crop or N fertilization rates influenced early season uptake of secondary and micro-nutrients or the potential availability of these nutrients as indicated by typical pre-plant soil tests. Comparisons of test results of notill with surface tilled soils will be useful in assessing whether periodic surface tillage is needed to optimize soil fertility in long-term notill systems and whether current fertilizer recommendations derived primarily using conventional tillage merit revision to accommodate conservation tillage practices.

Methodology

Study site: Soil and plant samples were collected in Spring 2004 from plots in a long-term conservation tillage experiment established in 1987 on a Gigger silt loam soil (fine-silty, mixed, thermic Typic Fragidaulf) at the Macon

Ridge Research Station, Winnsboro LA. This study area contains a large number of tillage systems and winter cover crop combinations in a randomized complete block design. For the current study, a factorial combination of tillage (surface tillage vs. no till), winter cover crop (wheat and volunteer vegetation) and rate of N fertilizer (45 and 90 lbs N/A) was selected. Each treatment combination is replicated four times in 4-row (40" spacing) plots each 50 feet in length.

Tillage practices: The surface tilled plots are disked twice in early April and twice in late April each year. After final disking, plots are bedded with disk hippers. A reel and harrow bed conditioner is used for final seedbed preparation. No seedbed preparation is used in the no-till plots though ripple coulters are mounted ahead of each planter unit for planting.

Cover crops: Wheat seed (90 lbs/A) is broadcast into standing cotton stalks between mid-October and early-November each year. Cotton stalks are shredded with a rotary mover after seeding wheat. Stalks are shredded at the same time in plots where covers consist of volunteer winter weeds.

N fertilizers: In late May of each year since 1997, 45 or 90 lbs N/A is injected as 32% UAN solution with knife outlets positioned approximately 3 inches deep and 10 inches from the drill. Prior to 1997, all plots received annual injections of 75 lbs N/A.

Sampling: Plant samples were collected on June 11, 2004 30 days after planting (DAP). Each sample consisted of the above ground portions of ten plants randomly selected from the center two rows of each plot. Samples were dried in a greenhouse, finely ground (100 mesh) and re-dried in a fan-forced oven (65 ^{o}C; 24 h). Soil samples were collected immediately prior to planting. Each sample consisted of two composite samples (0-3", 3-6", or 6-12") of 5 cores each collected at 8" intervals along transects perpendicular to rows. Soil samples were air-dried, crushed, and re-dried in a fan-forced oven (105 ^{o}C; 48 h). Subsamples were taken before final drying for determination of inorganic N before final drying. Additional cores were collected at 0-3", 3-6" and 6-12" for bulk density measurements using a 12" AMS core sampler fitted with four brass rings (3" x 2" dia.) for removal of largely undisturbed soil cores.

Analyses: Elemental composition of plant samples was determined by inductively coupled plasma emission spectrophotometery (ICP) analysis of HNO3:HCl digests except for N which was determined using a CE Model 1300 CNS analyzer.

Soil pH was determined in 2:1 soil:water suspensions. Effective CEC was measured by a NH_4-saturation technique using ammonium acetate (pH 7.0). Exchangeable cations and extractable S and B were determined by ICP analysis of ammonium acetate extract. Extractable Cu, Fe, Mn and Zn were determined by ICP analysis of soil samples extracted with DPTA-TEA-$CaCl_2$ (pH 7.3) . Ammonium (NH4) and nitrate (NO3) were measured in 2 M KCl extracts of air-dried soils using an automated inorganic N analyzer (Timberline Instruments, Bolder CO).

Statistical analyses were performed using the GLM procedure of Statistica (StatSoft, 2003). Tables 1, 3 and 5 show the probability (p) of a greater F for main effects and interactions derived from ANOVA with assumption of normality. Tables of means include Newman-Kuel's LSD (p = 0.05) values as an aid in identifying significant effects.

Results and Discussion

Nutrient uptake

Plant samples were collected just prior to 1st square on the supposition young plants would provide a more sensitive assay of micronutrient and secondary nutrient availability because of limited root development. Moreover, there is concern that early season deficiencies could possibly delay normal development during the critical early growth period.

Conservation management practices significantly ($p<0.05$) influenced the uptake of all three of the principal plant nutrients (N, P, and K), though these effects were generally small. Average N uptake was slightly greater with surface tillage (24.0 g N/kg) than under notill (23.2 g N/kg) and slightly greater (2%) following a wheat cover than following a cover of volunteer vegetation. P uptake was about 8% greater with notill than with surface tillage. K uptake was about 8% greater following a winter cover of volunteer vegetation than following a planted wheat cover. Tissue concentrations suggest that adequate amounts of N, P and K were taken up by young cotton plants under all management regimes.

Tillage significantly influenced the uptake of several secondary nutrients, including S, Ca and Mg though the tissue concentrations of these elements did not indicate deficiency. Surface tillage caused greater uptake of S (34%) compared to notill. S uptake was also significantly greater following a winter cover of volunteer vegetation and in plots receiving higher annual rates of N (90 lbs N/acre). Combinations of surface tillage following volunteer cover and surface tillage with high rates of N led to significantly greater uptake of Ca. Mg uptake was also greater with surface tillage than with notill.

Zn uptake was substantially greater (24%) with surface tillage than with notill. Cu uptake was somewhat greater following a wheat cover than volunteer winter weeds but adequate for crop growth in all management systems. This effect was most evident in plots where cotton received the higher rate of N fertilizer. No significant effects on the uptake of Fe, Mn, B, Mo or Ni were observed.

pH and Cation Exchange Capacity

Notill resulted in significantly higher soil pH values than surface till. This effect was most evident in the surface 0-3", but occurred at lower depths as well (Table 1). Higher rates of N fertilization resulted in lower soil pH, as would be expected. No main effect of cover type was evident, though pH was much lower when combining wheat covers (pH 5.6) with surface tillage than with notill (pH 6.1). This effect was less evident in systems employing a volunteer cover crop.

Effects of management on effective CEC were generally slight, but a few statistically significant differences were observed. Higher soil CEC was associated with a higher rate of N fertilizer; and CEC in soil under a surface till-wheat system was slightly higher than under notill wheat. Base saturation correlated with pH as would be expected. Base saturation varied significantly with depth and this effect was modified by tillage. Lowest base saturations were observed in the surface 0-3" in surface tilled soil, and in the underlying soil in notill. The influence of management on base saturation appeared to be due primarily to loss of Ca and Mg. The ratio of Ca:Mg was significantly higher with wheat (9.7) than with volunteer covers (7.7), suggesting that wheat placed greater demands on soil Mg reserves. Use of wheat cover crops also reduced exch. K by 24%. This reduction undoubtedly contributed to the reduced uptake of K observed in young cotton plants (Table 1).

Table 1. Main effects of tillage, cover crop type and N rate on soil pH, effective CEC, base saturation and exchangeable cations.

Effect	pH	CEC	Base Sat.	Sum of bases	Exch. Cations Ca	K	Mg	Na
		cmol(+)/100g	%	cmol(+)/100g	-------- mg/kg ---------			
0-3"	6.03	6.97	57.4%	3.99	590	184	66	6
3-6"	5.68	6.93	48.4%	3.36	520	94	59	9
6-12"	5.81	6.99	63.1%	4.41	677	63	99	12
lsd ($p<0.05$)	*0.15*	*ns*	*13.4%*	*0.28*	*38*	*8*	*8*	*3*
ST	5.64	7.01	55.5%	3.89	587	114	77	9
NT	6.04	6.91	57.1%	3.94	605	113	73	9
lsd ($p<0.05$)	*0.12*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Wheat	5.85	6.97	56.2%	3.91	608	101	70	9
Vol.	5.83	6.95	56.4%	3.92	583	126	79	9
lsd (p<0.05)	*ns*	*ns*	*ns*	*ns*	*ns*	*7*	*7*	*ns*

Table 2. Main effects of surface till (ST) and notill (NT), cover crop type and N rate on extractable soil nutrients.

	KCl-Extractable		NH4OAc-Extract		DTPA-Extractable			
Effect	NH4	NO3	S	B	Cu	Fe	Mn	Zn
	-- mg/Kg (ppm) -----------------------------------							
0-3"	5.0	12.9	7.6	7.9	0.72	25.3	65.5	3.2
3-6"	3.1	11.1	8.7	8.0	0.94	27.0	74.6	3.5
6-12"	2.4	3.9	11.7	8.7	0.86	26.5	49.4	2.6
lsd (p<0.05)	0.4	1.6	0.2	0.4	ns	ns	ns	ns
ST	3.5	10.0	10.7	8.1	0.73	28.5	67.0	2.9
NT	3.5	8.5	8.0	8.3	0.94	24.0	59.3	3.3
lsd (p<0.05)	ns	1.3	0.9	ns	ns	1.4	4.6	ns
Wheat	3.5	9.2	8.8	8.3	0.91	26.0	63.7	3.0
Vol	3.5	9.4	9.9	8.1	0.76	26.6	62.7	3.2
lsd (p<0.05)	ns	ns	0.9	ns	ns	ns	ns	ns
45 lbs N	3.3	9.1	8.7	8.2	0.92	25.5	59.3	2.7
90 lbs N	3.7	9.5	9.9	8.2	0.76	27.1	67.1	3.5
lsd (p<0.05)	0.3	ns	0.9	ns	ns	1.4	4.6	0.6

Soluble nutrients

Ammonium (NH_4) and nitrate (NO_3) were significantly higher in the surface soil than at underlying depths despite the fact that fertilizers are annually injected at a depth of ~4-6” (Table 2). Vertical distribution of available N was more pronounced with notill. N fertilizer rate had a slight impact on the amounts of exchangeable NH_4, but no significant influence on soil NO_3 levels. Note that samples were collected prior to annual N fertilization. Overall, spring NO_3 levels were higher under surface tillage than notill and were not greatly influenced by type of cover crop. These findings are consistent with a number of studies indicating that N availability is less with notill than with surface tillage (Bronson et al., 2004; Boquet et al., 2004a, 2004b).

Readily available S was strongly influenced by tillage, type of cover and N fertilization rate and these effects were modified by a number of interactions. Overall, extractable S increased with depth and higher rates of N, and decreased with notill and wheat cover crops. The average S level in the surface 3” of notill plots was below the 8 ppm level typically used to recommend S addition for cotton grown in Louisiana. The average extractable S levels in the profiles of notill plots with a wheat cover also fell below this level. These findings indicate that producers using notill systems, especially in combination with a winter wheat cover, should be wary of possible S deficiencies and apply supplemental S before crop yields are adversely impacted.

DTPA-extractable Fe and Mn were somewhat higher with surface tillage. This effect was most evident in the surface 0-6” were Fe and Mn were lower in soils under notill. Fe, Mn and Zn were higher where a higher N rate (90 lbs/A) had been applied, presumably because this higher resulted in lower soil pH. The amounts of all DTPA-extractable metals in these experiments were well within the sufficiency range. No significant effects of management on B were observed other than a slight increase in concentration with depth.

Conclusions

Long-term conservation management practices exerted a number of modest effects on the distribution and availability of nutrients in this silt loam soil. Reduction in available S associated with notill and wheat cover crops is the effect most likely to influence the future performance of cotton in this study unless supplemental S is added. To briefly summarize the effects of management practices, notill increased plant uptake of P and resulted in higher soil pH, base saturation and exchangeable K and Ca in the surface 3". Notill decreased plant uptake of N, S and Mg and extractable NO3, S, Fe and Mn. Routine planting of a winter wheat cover rather than relying on volunteer weed cover resulted in increased uptake of N, Cu and Mo by cotton plants and led to higher base saturation and Ca at the soil surface. Wheat covers reduced uptake of K and S by cotton and caused lower amounts of exchangeable K and Mg and extractable S. Applying a higher rate of N (90 lbs/a) to cotton increased plant uptake of S and increased soil CEC and extractable S, Fe, Mn, Zn and NH4. Higher rates of N resulted in lower soil pH, base saturation and exchangeable Ca.

Citations

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