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SOIL-TEST VALUES AFTER EIGHT YEARS OF TILLAGE RESEARCH ON A NORFOLK LOAMY SAND[1]

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ABSTRACT:

Long-term effects of alternate tillage systems on soil-test values for Coastal Plain soils were unknown. Therefore, soil pH, organic carbon, and Mehlich I extractable P, K, Ca, and Mg concentrations measured during an eight-year tillage study on Norfolk loamy sand (fine-loamy, silicious, thermic, Typic Paleudults) have been summarized. Yields for corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), and soybean [*Glycine max* (L.) Merr.] are also summarized to provide an indication of nutrient removal by the crops. Soil-test measurements after six years showed no significant differences in Mehlich I extractable nutrient concentrations for the 0- to 20-cm depth between disked (conventional) and nondisked (conservation) tillage treatments, but for pH, P, Ca, and Mg, the tillage by depth of sampling interaction was significant at P=0.05. Stratification did not appear to affect crop yield. Soil organic matter concentration in the Ap horizon nearly doubled after eight years of research at this site. This change occurred within both tillage treatments, apparently because high levels of management produced good crop yields, residues were not removed, and even for the disked treatment, surface tillage was not excessive. These results show that long-term average yields for corn and soybean on Norfolk soil will not be reduced by adopting reduced or conservation tillage practices. They also show that nutrient levels can be maintained at adequate levels for crop production on Coastal Plain soils by using current soil-test procedures and recommendations for lime and fertilizer application.

INTRODUCTION

Conservation tillage systems can reduce soil erosion (17,18), energy costs (19), soil compaction (5), and soil water loss (11). However, in the southeastern Coastal Plain, there are reservations concerning use of reduced or conservation tillage systems because of perceived and/or real soil fertility problems and reductions in crop yield. Sojka et al. (23) suggested that differences in soil physical and chemical properties, topography, climate, disease, weed, and insect pressures could reduce the competitive advantage of conservation tillage in this region. They concluded this after comparing initial conservation tillage results from the Coastal Plain (6,7) with results from other physiographic regions (21,22).

Water management, plant population, cultivar selection, and fertilizer placement experiments were subsequently conducted to develop conservation tillage systems that produced corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), and soybean [*Glycine max* (L.) Merr.] yields on Coastal Plain soils that were comparable to those produced using conventional tillage practices. Soil-test analyses were routinely conducted for each of those studies to determine lime and fertilizer requirements. After eight-years, data from those analyses provided an opportunity to determine if any long-term positive or negative changes were evident in the soil-test values measured for a typical Coastal Plain soil.

METHODS AND MATERIALS

Conventional and conservation tillage plots that were approximately 23 m wide and 26 m long were established on a Norfolk loamy sand (fine-loamy, silicious, thermic, Typic Paleudults) in 1979 at the Clemson University Research and Education Center near Florence, SC. Conventional tillage within this physiographic region generally consists of multiple diskings and use of field cultivators between crops to maintain a relatively weed-free soil surface and to incorporate crop residues, fertilizer, and lime. For conventional tillage in this study, the number of disking or surface tillage operations was reduced to no more than three within approximately 14 days of planting. Conservation tillage completely eliminated surface tillage. Both tillage treatments received in-row subsoiling (strip-tillage) at planting to fracture a root restrictive E horizon that reforms annually within this type of soil (5,6,7).

Corn was grown on this 2.8-ha Coastal Plain site with and without irrigation in 1979, 1980, 1981, and 1982. Each treatment was replicated five times using a stripped-split plot experimental design (14). In November 1982 wheat was planted to one-half of the site to establish a two-year rotation consisting of a wheat-soybean double crop followed by corn. This rotation was continued through corn harvest in 1986.

Corn and soybean were planted in rows spaced 0.75 m apart using John-Deere[2] Flex-71 planters that were attached to a Brown-Harden SuperSeeder. Wheat was drilled into disked and nondisked plots with a Kelley Manufacturing Company (KMC) Uni-Drill. Herbicides

TABLE 1. Cultural Practices Utilized During an Eight-Year Evaluation of Conservation and Conventional Tillage Systems on Norfolk Loamy Sand.

Year	Crop	Planting date	Seasonal rainfall	Water applied	Dolomitic limestone	N	P	K	Mg
			------ mm	-----	------------	kg/ha	------------		
1979	corn	12 Apr	384†	61	----	230	28	168	--
1980	corn	1 May	234	61	----	230	28	168	--
1981	corn	10 Apr	439	114	1120	224	28	168	--
1982	corn	9 Apr	460	89	----	235	28	190	22
1983	wheat	22 Nov '82	762	89	1680	106	53	90	--
	corn	26 Apr	315	196	----	202	28	190	21
	soybean	27 Jun	353	132	----	---	--	---	--
1984	wheat	9 Nov '83	894	41	1600	146	40	75	--
	corn	17 Apr	638	112	1233	196	28	112	--
	soybean	5 Jul	381	157	----	---	--	---	--
1985	wheat	27 Nov '84	427	140	1120	146	13	28	--
	corn	29 Mar	508	279	1120	247	27	50	--
	soybean	18 Jun	622	102	----	---	--	---	--
1986	wheat	10 Dec '85	206	89	----	123	25	46	--
	corn	1 Apr	254	386	1120	241	44	168	22

†Seasonal rainfall is defined as the amount received between planting and physiological maturity of the crop. Water applied refers to the amount of supplemental water applied to the irrigated blocks.

and insecticides were applied for weed and insect control using Clemson University recommendations (3). Water was applied to irrigated plots when soil-water tension, as measured with tensiometers, exceeded 20 kPa at a depth of 23 cm. Specific agronomic techniques for each crop were presented previously (6,7, 13,14,15,16) and are also summarized in Table 1.

Soil samples were collected from the Ap (0- to 20-cm depth) horizon in each plot prior to planting corn in 1979 and seven times thereafter. Except for Spring 1979 and Fall 1984 samplings, the Ap horizon was split into two samples representing the 0- to 5- and 5- to 20-cm depths. Soil samples were air dried, crushed, passed through a 2-mm sieve, and analyzed for pH and Mehlich I extractable P, K, Ca, and Mg (8). Organic matter was determined indirectly using a Leco carbon analyzer (20) to measure total carbon on samples collected in 2.5-cm increments for the top 15- to 20-cm in 1980, 1981, 1982, and 1986.

Grain yields were measured with an Almaco plot combine and adjusted to moisture contents of 155, 150, or 130 g/kg for corn, soybean, or wheat, respectively. Analysis of variance (ANOVA) was computed, and least significant difference (LSD) was calculated with appropriate error terms for each parameter (24).

RESULTS AND DISCUSSION

Soil-test changes

Soil pH and Mehlich I extractable P, K, Ca, and Mg levels measured for conventional and conservation tillage treatments are presented in Table 2. The data show that periodic additions of lime and fertilizer (Table 1), applied according to Clemson University recommendations (3), maintained soil pH and extractable nutrients at acceptable levels for corn, soybean, and wheat production.

There was no significant difference in pH or nutrient levels for the two tillage systems, when samples were analyzed for the entire Ap (0- to 20-cm) horizon. When samples were split into 0-

TABLE 2. Soil-Test Data From the Ap Horizon of a Norfolk Loamy Sand Measured During Seven Years of Conventional (disked) and Conservation (nondisked) Tillage Research.

Tillage system	Depth -cm-	Sampling Date†							
		S '79	F '79	F '80	F '81	F '82	S '84	F '84	S '86
		pH							
Conservation	0-5		5.8b	5.7b	6.0a	5.8a	5.9ab		6.5a
	5-20		5.7c	5.5c	5.5b	5.3c	5.5c		5.8c
	0-20	5.9a‡						5.6a	
Conventional	0-5		5.9a	5.8a	5.9a	5.5b	6.1a		6.3ab
	5-20		5.8b	5.6c	5.5b	5.3c	5.8b		6.2b
	0-20	5.9a						5.9a	
Interaction			ns	ns	ns	**	ns		*
		P (mg/kg)							
Conservation	0-5		52b	57ab	60a	66a	68a		72a
	5-20		43c	46b	41c	49b	36b		44c
	0-20	52a						50a	
Conventional	0-5		60a	62a	55ab	65a	70a		62ab
	5-20		51b	48b	48bc	52b	46ab		55bc
	0-20	54a						57a	
Interaction			ns	ns	ns	ns	ns		*
		K (mg/kg)							
Conservation	0-5		67a	102a	122a	108b	73b		86a
	5-20		50b	53b	62b	74c	70b		69bc
	0-20	72a						71a	
Conventional	0-5		67a	94a	111a	129a	87a		79ab
	5-20		56b	69b	65b	82c	70b		62c
	0-20	71a						85a	
Interaction			ns	ns	ns	ns	ns		ns

Tillage system	Depth -cm-	S '79	F '79	F '80	F '81	F '82	S '84	F '84	S '86
		Sampling Date							
		Ca (mg/kg)							
Conservation	0-5		194a	180a	368a	384a	420a		963a
	5-20		142b	145b	235c	228c	253b		338b
	0-20	175a						393a	
Conventional	0-5		197a	187a	326b	301b	380a		462b
	5-20		150b	149b	269c	258bc	275b		342b
	0-20	182a						395a	
Interaction			ns	ns	**	**	ns		**
		Mg (mg/kg)							
Conservation	0-5		43a	34a	77a	95a	106a		245a
	5-20		28b	23b	24c	34b	44b		72c
	0-20	36a						92a	
Conventional	0-5		46a	37a	49b	51b	97a		112b
	5-20		30b	28b	32c	39b	62b		84c
	0-20	35a						106a	
Interaction			ns	ns	**	**	ns		**

†Sampling date--S refers to spring and F to fall for the year indicated.

‡Means within a column for a single year for a single nutrient followed by the same letter are not significantly different at P=0.05 using least significant difference values for mean separation.

to 5-cm and 5- to 20-cm increments, there were some significant tillage by sampling depth interactions for pH, P, Ca, and Mg. The values measured for the 0- to 5-cm depth from conservation tillage samples were generally equal to or significantly higher than the values for samples from conventional treatments, but for the 5- to 20-cm depth, values for samples from conservation treatments were generally equal to or significantly lower than values for samples from conventional treatments.

Tillage differences in soil-test values presumably occurred because of stratification in the top 5-cm of the nondisked plots. This occurred because lime and fertilizer materials were not incorporated with surface tillage, but as reported for other soils (21,22), this stratification had no apparent effect on crop yield.

Potassium concentrations did not show a significant tillage by depth of sampling interaction. This finding after seven years is consistent with short-term soil-test results (14), presumably because cation exchange capacity for this Coastal Plain soil is low and K is relatively more mobile than P, Ca, or Mg. This finding confirms that surface tillage is not necessary for downward movement of K in Norfolk soils.

Soil organic matter concentrations measured after two, three, four, and eight years of tillage research at this site are presented in Table 3. Average concentrations in the Ap horizon for both conventional and conservation tillage treatments doubled after eight years. Part of the total carbon increase measured in the fall of 1986 may reflect soluble organic carbon being added by decomposing corn stover. However, analysis of soil samples collected from the 0- to 15-cm depth after 14 months (October 1986 through November 1987) of chemical fallow at this site confirmed that the soil organic matter concentrations had increased to at least 18 and 15 g/kg for conservation and conventional tillage treatments. There was no significant difference between the two tillage treatments, but organic matter concentrations were 1 to 5 g/kg higher than for conventional tillage treatments. There were

TABLE 3. Soil Organic Matter Concentration in the Ap Horizon of Norfolk Loamy Sand After Two, Three, Four, and Eight Years of Conventional or Conservation Tillage Research.

Depth	Year							
-- cm --	1980		1981		1982		1986	
	Conv.	Cons.	Conv.	Cons.	Conv.	Cons.	Conv.	Cons.
	g/kg							
0 - 2.5	11	14	17	19	17	18	23	38
2.5 - 5.0	10	12	16	17	14	14	22	30
5.0 - 7.5	11	13	12	13	13	13	21	25
7.5 - 10.0	9	14	12	13	12	12	21	22
10.0 - 12.5	8	12	11	12	9	11	19	21
12.5 - 15.0	8	10	10	10	8	9	17	20
15.0 - 20.0	--	--	--	--	--	--	15	20
LSD(0.05)	ns		ns		ns		1.2	

Tillage effect	1980	1981	1982	1983
	g/kg			
Conservation	12	14	13	25
Conventional	10	13	12	20
LSD(0.05)	ns	ns	ns	ns

Depth effect	1980	1981	1982	1986
-- cm --	g/kg			
0 - 2.5	12	18	17	30
2.5 - 5.0	11	16	14	26
5.0 - 7.5	12	13	13	23
7.5 - 10.0	12	12	12	22
10.0 - 12.5	10	11	10	20
12.5 - 15.0	9	10	9	19
15.0 - 20.0	--	--	--	18
LSD(0.05)	2	2	2	1

significant differences among depth increments, but the depth by tillage interaction for soil organic matter was significant only for the 1986 sampling.

Increases in soil organic matter concentration occurred for both tillage systems, presumably because high levels of crop management resulted in good yields and most of the crop residues were returned to the site. Increases measured for conventional tillage plots may have been slightly greater than normally expected, because the number of surface tillage operations used to prepare a seedbed was less than many farmers use. Frequently, surface tillage operations are conducted during winter months to maintain a weed-free surface, but this excessive pulverization of the soil is not necessary. Tillage approximately two weeks before planting appears to be desirable only to prevent depletion of seedbed water by weeds (6,7) if winter rainfall is limiting.

The slight additional increase in soil organic matter content with conservation tillage probably occurred because without surface disking, soil aeration would be decreased, microbial populations would be altered (9), and therefore rates of crop residue oxidation would be decreased. Decreases in soil organic matter during a period of chemical fallow emphasizes the importance of returning of crop residues or other carbon sources such as manure to this type of soil each year.

Identifying an increase in soil organic matter after a period of only eight years is the most important finding of this soil-test evaluation. The reason for this is that Coastal Plain soils generally have very low organic matter content and small changes in organic matter can substantially change soil properties such as nutrient and water retention. Furthermore, Hue et al. (10) have shown that organic acids can reduce activity of Al which can be a root-limiting factor in Coastal Plain soils. Leachates from the additional organic matter may actually complex subsoil Al, thus extending the depth to which plant roots can penetrate and extract nutrients and water during periods of short-term drought.

TABLE 4. Crop Yields Produced With Conventional and Conservation Tillage Practices Between 1979 and 1986 on a Norfolk Loamy Sand Near Florence, SC.

Tillage system	Year								
	1979	1980	1981	1982	1983	1984	1985	1986	Average
	Mg/ha								
Corn at 15.5% moisture									
Conservation	9.0	6.5	9.3	10.3	8.9	9.1	7.6	3.9	8.0
Conventional	8.7	7.1	8.3	11.0	9.5	9.9	8.3	2.8	8.3
LSD(0.05)	ns	ns	ns	ns	0.6	ns	ns	ns	ns
Wheat at 13.0% moisture									
Conservation	--	--	--	--	1.9	3.2	2.4	2.6	2.6
Conventional	--	--	--	--	2.4	3.4	2.4	2.8	2.8
LSD(0.05)	--	--	--	--	0.2	ns	ns	0.1	0.1
Soybean at 15.0% moisture									
Conservation	--	--	--	--	2.4	2.0	2.5	--	2.3
Conventional	--	--	--	--	2.4	2.6	2.3	--	2.4
LSD(0.05)	--	--	--	--	ns	0.2	ns	--	ns

Crop Yields

Crop yields averaged for irrigated and nonirrigated treatments for conventional and conservation tillage treatments are presented in Table 4 to show the yield levels associated with the soil-test results. Specific treatment effects on crop yield at this site are available in other publications (6,7,12,13,14,15,16).

For corn, there was no significant difference in grain yield for seven of the eight years. For wheat, conventional tillage significantly increased grain yields in 1983 and 1986, but in 1984 and 1985 when higher rates of N fertilizer were applied (13), the conservation tillage yields were not significantly lower. Soybean yield with conservation tillage was significantly lower than with conventional tillage in 1984, but not in 1985 or 1986. There was no significant tillage effect when averaged for three years. This was consistent with previous soybean studies (7) in this region.

Summary and Conclusions

An improved understanding of conservation tillage production practices for Coastal Plain soils evolved during eight years of study on Norfolk loamy sand. This resulted in little or no tillage system difference, when yield of corn, wheat, or soybean was averaged across years. Soil pH, P, Ca, and Mg concentrations showed stratification in the upper 20 cm, but surface application of K did not result in stratification on this soil. The most important soil-test finding was that soil organic matter increased during the course of this study. This is very important because of the effect that organic matter can have on the long-term productivity of many Coastal Plain soils.

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2. Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA or the SC Agric. Exp. Stn. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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