IN-ROW TILLAGE METHODS FOR SUBSOIL AMENDMENT AND STARTER FERTILIZER APPLICATION TO STRIP-TILLED GRAIN SORGHUM

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ABSTRACT

Acid subsoils and tillage pans limit crop yields on sandy soils of the Southern Coastal Plain of the USA. Studies were conducted for 3 years at 2 locations with acid subsoils and tillage pans to determine the effect of starter fertilizer (22 kg N, 10 kg P/ha) and liquid lime (1350 kg/ha) placement with in-row tillage methods on growth and yield of grain sorghum (*Sorghum bicolor* (L.) Moench) grown in a conservation-tillage system . The starter fertilizer and lime were applied in factorial combinations in the in-row subsoil channel, in a narrow (4 mm) slit 18 cm below the tillage pan (slit-tillage), or 7 cm to the side of the row incorporated 7 cm deep. Starter placement was not critical, but response to starter occurred only when deep tillage, either in-row subsoiling or slit-tillage, was used in conjunction with the fertilizer. There was no benefit from injecting lime.

INTRODUCTION

In many Ultisols of the southeastern USA, yield-limiting water stress is induced by restriction of root growth to the surface soil as a result of subsoil acidity (Adams, 1984) and the presence of genetic or traffic-produced pans (Campbell et al., 1974; Kashirad et al., 1967). Subsoiling is frequently used to disrupt root-restricting pans in these soils and planters are available that incorporate in-row subsoilers in their design. Although subsoiling can increase yields (Touchton et al., 1986; Reeves and Touchton, 1986; Reeves et al., 1986), the practice requires large amounts of energy, reduces planting speed, often results in erratic stands, and can cause undesirable mixing of soil horizons. An energy saving alternative to subsoiling has been developed that promotes root growth through hardpans so that crops can access water and nutrients in the subsoil (Elkins and Hendrick, 1983). Slit-tillage, as it is called, results in a surface-tilled, 20-cm wide seedbed and a 4 mm wide vertical slit through the hardpan.

Application of N-P starter fertilizers with in-row subsoiling has proved beneficial for cotton (Touchton et al., 1986), and corn (Reeves et al., 1986) grown on easily-compacted, coarse-textured soils. Crops grown with conservation tillage may especially benefit from starter fertilizer applications. The acid subsoils of the southeastern United States can restrict root growth through Al toxicity and Ca deficiency (Adams, 1984). Root growth through the opening in the hardpan of acid subsoils provided by slit-tillage might be enhanced by the injection of amendments such as starter fertilizers and liquid lime.

The objectives of these field studies were to: 1) compare slit-tillage to the more common practice of in-row subsoiling as a means of improving crop performance in compacted soils; 2) determine if deep placement of lime is of benefit in improving crop growth and yield in soils with acid subsoils; and 3) determine the effect of starter fertilizer on growth and yield of conservation-tilled grain sorghum as influenced by in-row tillage/placement method.

MATERIALS AND METHODS

Tests were conducted for 3 years (1985-1987) on a Hartsells fine sandy loam (fine-loamy,siliceous, thermic Typic Hapludults) in northeastern Alabama (USA) and for 2 years (1986-1987) on a Norfolk sandy loam (fine-loamy, siliceous, thermic Typic Paleudults) in west central Alabama. A different site was used in 1985 than in 1986-87 at the Hartsells location. Soils at both locations had a 4-8-cm tillage or traffic pan located 25-35 cm below the surface. Initial soil pH averaged 6.5, and 5.3 for the 0-25 and 25-45 cm depths, respectively, on the Hartsells soil sites, and 5.7 and 4.5 for respective depths on the Norfolk soil. On the Norfolk soil, an application of 2.2 t/ha dolomitic limestone in the winter of 1986 raised the pH in the top 20 cm to 6.1 prior to planting in 1987. Ammonium nitrate to supply 134 kg-N/ha was banded beside each row 4-5 weeks after planting in all tests.

Grain sorghum (*Sorghum bicolor* (L.) Moench) was planted into a winter cover crop of rye (*Secale cereale* L.) at the Hartsells location on 22 May 1985, 14 May 1986, and 29 May 1987. Planting dates at the Norfolk location were 24 April 1986, and 5 June 1987. A 4-row no-till planter was used to seed 250,000 seed/ha in 75-cm row widths. Four-row plots, 9.1-m long, were used in all tests. The front tool bar of the planter was equipped with smooth coulters for cutting through residue, straight-shank subsoilers to subsoil in-row, and a pair of angled, fluted coulters to close the subsoil channel and till a narrow (20-cm wide) seedbed. Planter units, each consisting of a double-disk opener, seed hopper, and angled, hard-rubber press wheels, were attached to the rear tool bar. Subsoiler shanks were removed to plant no-till. Modified subsoiler shanks were used to perform slit-tillage. Shortened shanks were fitted with a 4-mm thick X 18-cm long triangular bladelike fin beneath the foot of each shank. A detailed description of this tool has been described (Elkins and Hendrick, 1983). Depth of tillage for subsoiled and slit-till treatments was the same (40 cm). The foot of the modified slit-till shank was pulled through the soil above the pan, at a depth of 22-24 cm; the slit blade extended through the pan, an additional 18 cm below the foot of the subsoiler. In appropriate treatments, solution fertilizer to supply 22 kg-N and 10 kg-P/ha was displaced with an electric pump into: 1) the bottom 10-15 cm of the subsoil channel; 2) into the slit channel; or 3) 7-cm beside the row, incorporated 7-cm deep with fluted coulters. Liquid-lime suspension was displaced with a PTO driven pump to supply 1350 kg/ha lime in a similar manner.

In 1985 on the Hartsells soil, the experimental design was a factorial arrangement of 3 tillage methods X 4 amendments in a randomized block of 4 replications. Tillage treatments were: 1) slit-till; 2) no-till (amendments incorporated 7-cm beside the row and 7 cm deep with fluted coulters); and 3) subsoiling. Amendment treatments were: 1) N-P starter fertilizer; 2) lime; 3) starter + lime; and 4) no amendment check. In 1986 and 1987, on all tests, the design was an incomplete factorial of 4 replications; treatments expanded from those used in 1985 to include 7 X 7 cm placement of amendments with deep tillage treatments (subsoil and slit-till) and deep-placed lime with 7 X 7 cm placed starter fertilizer.

Whole plant samples for dry weight determinations were taken from 1-m of row 5-6 weeks after planting. At maturity, grain yields were taken from the middle 2 rows and adjusted to 130 g/kg moisture.

Data were subjected to appropriate analysis of variance for each design model. Fisher's protected least significant difference ($P \leq 0.10$) and single degree of freedom tests were used for mean separation of preplanned comparisons.

RESULTS AND DISCUSSION

Hartsells Location

In 1985, substantial increases in early-season plant growth occurred only when starter fertilizer or starter + lime was applied in conjunction with some form of deep in-row tillage (Table I). Treatment effects on grain yield generally followed the same trend as for plant growth (Table I). Maximum grain yield (5175 kg/ha) occurred when starter fertilizer was applied in the subsoil channel. Averaged over amendments, yields were 4302, 4053, and 3741 kg/ha ($LSD_{0.10}$ =230 kg/ha) for subsoiling, slit-till, and no-till, respectively.

In 1986 there were no treatment effects on early-season plant growth or grain yield other than an increase in yield from subsoiling compared to no-till plots (5239 vs. 4943 kg/ha, $P \leq 0.11$).

In 1987, subsoiling resulted in reductions in early-season plant growth compared to no-till and slit-tillage (Table II). However, this reduction did not result in differences in grain yield between subsoiled plots and no-till plots (Table II). Slit-tillage significantly increased yield compared to no-till and subsoiling. Starter fertilizer and lime had no effect on early-season plant growth or yield. Elkins et al. (1983) reported that root growth into slits maintained the integrity of slits, resulting in an increased effect on crop performance with successive growing seasons. The superior performance of slit-till in this, the second year on this tier, is compatible with results previously reported (Elkins et al., 1983).

Norfolk Location

In 1986, rainfall during the period extending 84 days after planting totaled 6 cm, 22 cm below the 30-year norm. Although early-season plant growth was improved by subsoiling and slit-tillage (Table III), an outbreak of anthracnose (<u>Colletotrichum graminicola</u>) resulted in extremely low yields, with no differences in yield due to treatments (Tables III and IV). Starter fertilizer increased early-season growth only when applied with some form of deep tillage, either subsoiling or slit-till (Table IV).

In 1987, subsoiling and slit-tillage resulted in equivalent increases in early-season growth over no-till (Table III). Although yields were low due to a severe drought from bloom through physiological maturity, the increased growth from deep tillage was mirrored in commensurate yield increases (Table III). As in 1986 at this location, application of N-P starter in conjunction with some form of deep tillage (either subsoiling or slit-tillage) resulted in increased early-season plant growth (Table IV). Amendments had no effect on grain yield, however.

CONCLUSIONS

1. There was no benefit to plant growth or grain yield from injecting lime below the tillage pan in any location-year.
2. In years when early-season growth and grain yield responded to in-row deep tillage, slit-tillage was as effective as subsoiling. At the Hartsells location, which was not subjected to severe drought stress in any year, slit-till resulted in improved crop performance compared to subsoiling in the second year of the test on the same site.
3. Applying N-P starter fertilizer in conjunction with deep tillage, either subsoiling or slit-till, increased early-season growth in 3 of 5 location-years. A nonsignificant trend occurred in the remaining 2. Placing the N-P in the subsoil channel or slit was no more effective than incorporating it beside the row.
4. Although early-season growth responded consistently to starter fertilizer applied in conjunction with deep tillage, yield response was highly dependent on rainfall. Yield response to starter fertilizer occurred in only 1 location-year.

TABLE I

Early season growth and grain yield of sorghum grown on a Hartsells soil in 1985 as affected by amendment and in-row tillage/placement.

Tillage/ Placement	Amendment			
	None	Lime	Starter	Starter + Lime
	--plant growth, g dry matter/ 1-m row --			
Slit	18.7	22.0	43.6	39.0
Subsoil	19.4	21.0	65.0	36.4
7 X 7	14.4	14.4	24.6	21.7
LSD (0.10)=9.84				
	------------grain yield, kg/ha-----------			
Slit	3640	3837	4354	4628
Subsoil	4385	4088	5175	4172
7 X 7	3648	3655	4126	3579
LSD (0.10)=518				

TABLE II

Early-season growth and grain yield of sorghum grown on a Hartsells soil in 1987 as affected by in-row tillage methods.

Comparison	Dry Wt.	P <	Grain Yield	P <
	g/m row		kg/ha	
Subsoil	48.1		3984	
No-till	57.3	0.02	3962	0.91
Slit-till	55.8		4307	
No-till	57.3	0.66	3962	0.08
Slit-till	55.8		4307	
Subsoil	48.1	0.02	3984	0.04

TABLE III

Effect of tillage on early-season growth and grain yield of sorghum grown on a Norfolk soil in 1986 and 1987.

Comparison	1986				1987			
	Dry Wt.	P<	Yield	P<	Dry Wt.	P<	Yield	P<
	g/m row		kg/ha		g/m row		kg/ha	
Subsoil	14.3		481		19.7		1240	
No-till	6.2	0.001	399	0.36	9.6	0.001	706	0.001
Slit-till	12.7		460		18.3		1232	
No-till	6.2	0.001	399	0.49	9.6	0.001	706	0.001
Slit-till	12.7		460		18.3		1232	
Subsoil	14.3	0.15	481	0.76	19.7	0.47	1240	0.99

TABLE IV

Effect of amendments on early-season growth and grain yield of sorghum grown on a Norfolk soil in 1986 and 1987.

Comparison	1986				1987			
	Dry Wt.	P<	Yield	P<	Dry Wt.	P<	Yield	P<
	g/m row		kg/ha		g/m row		kg/ha	
Lime Deep	7.6		388		16.1		1399	
No Lime	7.4	0.92	502	0.44	16.5	0.88	1195	0.26
N-P + deep till	17.6		493		21.6		1221	
No N-P + deep till	7.4	0.001	502	0.94	16.1	0.03	1166	0.76
N-P + no-till	7.2		247		9.4		829	
No N-P + no-till	4.5	0.42	344	0.64	8.3	0.78	641	0.53
N-P deep	18.8		551		23.5		1186	
N-P 7 X 7	16.5	0.32	436	0.44	20.0	0.21	1255	0.74

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