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Evaluation of the Stoneville Parabolic Subsoiler

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Highlights and Conclusions

Cotton yields were increased by subsoiling, with most of the increase obtained at second harvest. Average taproot length was increased by subsoiling and average residual soil strength was still lower for subsoiled treatments about 11 months after subsoiling.

Lint yield and taproot length were positively correlated in all treatments, lint yield and residual soil strength were negatively correlated in all treatments and taproot length and residual soil strength

were negatively correlated in all treatments except subsoiling with the Stoneville Parabolic Subsoiler.

The two most important facts established by the trials are: residual soil strength and taproot length did not limit lint yields significantly on plots subsoiled with the Stoneville Parabolic Subsoiler and tractor wheel slippage was 43.4 percent less in pulling the parabolic subsoiler than in pulling the conventional subsoiler.

Subsoiling has increased cotton yields, especially on sandy loam and silt loam soils where soil compaction is a problem. Deep tillage has resulted in significant increases in cotton yields where soil compaction problems limit water intake and storage and root development (5, 9, 12, 18 and 20). Subsoiling a fine sandy loam soil with a hard pan increased cotton yields over 100 percent in the Mississippi Delta in a 1954 test (7). Precision tillage, subsoiling under the drill row, and bedding in the same operation have increased cotton yields in sandy and fine sandy loam soils (2). Cotton yields were shown to be proportional to the decrease in soil strength in the fall resulting from precision

tillage (3). Research indicated that roots could penetrate 90 to 95 percent of a fine sandy loam soil where a precision tillage system was used but could penetrate only about 30 percent of the soil when a conventional system was used (4).

Greacen (6) studied the interactions of soil strength, moisture tension, and the porosity of clay soils. Soil strength and moisture tension increased as soil compaction increased and porosity of soil decreased as compaction increased. Thus, increasing soil compaction resulted in limited plant growth because it produced undesirable changes in these three important soil characteristics.

Vomocil, *et al* (19) measured the rate at which water infiltrated soil

before and after a tractor had been in operation on the soil. Increasing drawbar pull was used to increase wheel slippage and compaction. The infiltration rate was reduced when soil compaction was increased by wheel slippage. A decrease in water-infiltration rate of soil usually increases water runoff and erosion; thus, excessive compaction presents water and soil conservation problems. Sievers, *et al* (13) concluded from their work that losses of fertilizers and organic insecticides could be partially controlled by reducing runoff and controlling erosion.

Osman (10) found that moving an inclined plane through soil compressed it until its maximum shear strength was reached. A

wedge-shaped mass of soil was sheared from the soil bulk when failure occurred. Tanner (16) found that the approach angle of an inclined plane affects both the normal pressure on the tool and the amount of soil disturbed by the tool. He found that average normal pressure decreased as approach angle¹ of the tool decreased and that this relationship was associated with reduced draft.

Payne and Tanner (11) concluded that tines narrower than two inches tend to slice through the soil rather than lift it. Distance of soil disturbance beyond the sides of a tool was relatively insensitive for tines two or more inches wide. They concluded that draft was relatively insensitive to approach angles of 20° to 50° but increased very rapidly as approach angles exceeded 50°. They also found that soil provided a component force that assisted tool penetration when tines were inclined at less than 50° to 55°---at greater approach angles the component force opposed penetration. Tanner's work at the National Tillage Machinery Laboratory confirmed these conclusions (Table 1). A tool operated with an approach angle less than 55° usually resulted in a greater upheaval of the soil than a tool operated with an approach angle greater than 55°.

Table 1. A summary of D. W. Tanner's work using a chisel tine¹ in three soils at the USDA National Tillage Machinery Laboratory, Auburn, Alabama.

Approach angle	Average draft	Average vertical forces ²	Resultant forces
deg.	-----lbs-----		
20	63	-41	75
48	100	-15	101
76	181	37	185
90	224	76	237
104	260	113	283
132	306	205	368

¹Rectangular plate tines 2 inches wide, 6 inches deep, covering the range of inclination to the horizontal of 20°-132° were drawn through Lakeland sand, Hiwassee sandy loam, and Lloyd clay in soil bins at the N.T.M.L., Auburn, Alabama.

²A negative sign denotes a downdraft on the tool and a positive sign denotes updraft.

Source: Tanner, D. W., "Further work on the relationship between rake angle and the performance of simple cultivation implements", *Journal of Agricultural Engineering Research*, Vol. 5, 1960, pages 307-315.

Sohne (14) found that concavely-curved tines were more effective than straight tines in breaking soil into smaller elements. Osmon (10) found that draft of curved tines in

soils for a particular rake angle increased with the amount of curvature and lies between the maximum and minimum limits at the approach angles.

Subsoiler Design

The basic information developed by the research described above was incorporated into the Stoneville Parabolic Subsoiler designed at the MAFES Delta Branch in 1972 (17). The subsoiler standard (Figure 1) was designed as a parabolic curve with a long and gradual increase in slope, from 22° at the foot to 50° at the soil surface, when operating at a 16-inch depth. The foot was a conventional three-inch design with a 22°

approach angle and hard upper and lower surfaces. Tool bar clearance from the bottom of the foot was 32½ inches. The standards were cut from 1½-inch mild steel plate.

Tractor-mounted implements with a steeper line of draft are advantageous because greater weight transfer to the rear wheels reduces wheel slippage (Heitshu, 1952). The foot of the parabolic subsoiler standard is further

forward in the operating position than is the foot of a conventional subsoiler. The subsoiler was designed with the center standard moved forward 12 inches. The two design factors were incorporated into the Stoneville Parabolic Subsoiler to obtain a steeper line of draft required for greater weight transfer to the tractor wheels needed to reduce wheel slippage.

¹A 90° approach angle represents a tool operated in a vertical position.



Figure 1. The Stoneville Parabolic Subsoiler.

Field Tests

Tests on Bosket fine sandy loam soil were conducted at the MAFES Delta Branch in 1974 and 1975. Three treatments were arranged in a randomized complete block design with four replications. Plot size for each treatment was six rows 40 inches wide and 100 feet long. Treatment of each plot in 1974 was repeated in 1975. Cultural practices on plots were identical except for treatment differences.

Treatments were: (1) no subsoiling, (2) subsoiling with a conventional subsoiler---16 inches deep in the drill (Figure 2), and (3)

subsoiling with the Stoneville Parabolic Subsoiler---16 inches deep in the drill. Subsoiling was done on February 28, 1974 and January 30, 1975.

Seedbed preparation consisted of subsoiling (as required by treatments) and hipping twice over the old stubble (15). Nitrogen, as a 32 percent urea-ammonium nitrate solution, was applied at the rate of 80 lb/A after the first hipping. The seedbed was knocked down with a bed conditioner (Do-all) ahead of the planter.

Twenty pounds per acre of

'Stoneville 213' acid delinted seed were planted on April 26, 1974 and April 28, 1975. Diuron was applied for preemergence weed control. Conventional cultivation and postemergence weed control practices were used on all plots. Insecticides were applied by air as needed. The tests were defoliated at maturity and the two center rows of each plot were spindle picked twice each year. Samples were ginned on a 20-saw gin with a standard equipment sequence (1)².

Results and Discussion

Seed cotton yields in 1974 were higher ($P < .05$) on plots subsoiled with the parabolic subsoiler than on plots that were not subsoiled. This difference more than offset the smaller difference in 1975 and the two-year average yield of plots subsoiled with the parabolic subsoiler were higher than yields for plots that were not subsoiled (Table 2). The only significant difference between subsoilers was in 1974 when total lint yield was higher on plots subsoiled with the parabolic subsoiler.

Earliness, expressed as the percentage of lint harvested at first pick, generally was delayed by subsoiling but differences in time from first harvest did not differ significantly by treatment in either year. Total lint yield in 1974 was highest from plots subsoiled with the parabolic subsoiler and the two-year average was higher for both types of subsoilers than for no subsoiling.

Taproots were longer on cotton from plots subsoiled with both the conventional and parabolic subsoilers. Differences between subsoiling treatments were not significant.



Figure 2. The conventional subsoiler used in this test.

²Cotton was ginned at the U. S. Cotton Ginning Research Laboratory at Stoneville, Mississippi.



Figure 3. Taproots of cotton plants from the 1975 trials: (left) from plots not subsoiled in 1974 and 1975; (center) from plots not subsoiled in 1975; (right) from plots subsoiled in 1974 and 1975. All plots had been subsoiled each year for many years before the trial was started in 1974.

ent but taproots of plants from plots subsoiled with the parabolic soiler were slightly longer and straighter (Figure 3). Residual soil strength (measured about 11 months after subsoiling and when soil moisture was high) was not significantly lower

($P < .05$) for subsoiled plots in 1974. However, significant differences in 1975 more than offset the smaller differences in 1974 and the two-year averages were significantly lower for subsoiled plots than for plots that were not subsoiled. Differences between type of sub-

soiler were not significant. Computed relationships of (1) lint yield and taproot length, (2) lint yield and residual soil strength and (3) taproot length and residual soil strength reveal a positive correlation of taproot length and lint yield for all treatments, a

Table 2. Effect of subsoiling method on yield, earliness and tap root length of cotton and on residual soil strength, MAFES Delta Branch, 1974 and 1975.

Year	Subsoiling method	Seed Cotton			Lint			Percent of Lint Harvested at first pick	Avg. taproot length (in.)	Residual soil strength ¹ (lbs/sq in)
		1st	2nd	Total	1st	2nd	Total			
-----lbs/Acre-----										
1974	none	2250	542b ²	2792b	723	164b	887b	81.1a	6.7b	530
	conventional	2357	630ab	2987ab	737	187ab	924b	79.1ab	8.9a	463
	parabolic	2235	736a	3071a	759	226a	985a	76.0b	10.5a	413
1975	none	2500	697b	3197	790	236b	1026	76.7a	7.2b	482b
	conventional	2431	908a	3339	768	325a	1093	70.1b	9.8a	339a
	parabolic	2541	882a	3423	771	322a	1093	70.6b	9.9a	320a
2 yr avg	none	2375	620b	2995b	757	200b	957b	78.9a	6.9b	506b
	conventional	2394	769a	3163a	752	256a	1009a	74.6b	9.3a	401a
	parabolic	2438	809a	3247a	765	274a	1039a	73.3b	10.2a	367a

¹Measurements made about 11 months after subsoiling and when soil moisture was high.

²Values in each column followed by the same letter are not significantly different ($P < .05$) as determined by Duncan's New Multiple Range Test.

negative correlation of residual soil strength and lint yield for all treatments and a negative correlation of residual soil strength and taproot length for all treatments except subsoiling with the parabolic subsoiler (Table 3). Correlations of (1) lint yield and taproot length, (2) lint yield and residual soil strength and (3) taproot length and residual soil strength were not significant for plots subsoiled with the parabolic subsoiler.

Taproot length was a significant-

ly limiting factor in lint yields from the non-subsoiled plots and soil strength was a significantly limiting factor in taproot length. Soil strength was a significantly limiting factor in lint yield and in taproot length on plots subsoiled with the conventional subsoiler. *Taproot length and soil strength were not significantly limiting factors in total lint yield from plots subsoiled with the parabolic subsoiler, and soil strength did not limit taproot length.*

Horsepower requirements are

reduced with the lower approach angle of the parabolic subsoiler shank because the shank exerts an upward shearing force on the soil rather than the forward compressive force exerted by the conventional approach angle of the conventional subsoiler shank.

Wheel slippage of the tractor pulling a three-shank conventional subsoiler 16 inches deep was 13.6 percent; for the same tractor pulling the parabolic subsoiler at this depth, 7.7 percent (a reduction of 43.4 percent).

Limitations of Study

Results reported in this publication are based on data from only two years of observation on the one soil type. The years were relatively

wet and maximum benefits from subsoiling were not anticipated. The parabolic subsoiler will be tested further, on other soil types

and under moisture conditions more conducive to benefits from subsoiling.

Table 3. Relationship of (1) lint yield and taproot length, (2) lint yield and residual soil strength and (3) taproot length and residual soil strength, cotton grown on plots of Bosket fine sandy loam soil, without subsoiling or subsoiled with conventional or the Stoneville Parabolic Subsoiler, MAFES Delta Branch, 1974 and 1975.

Number of observations	Regression equation	Correlation coefficient	(r ² X 100) ¹	Level of significance
Treatments Combined				
48	L = 788 + 24.2 R	0.405	16.4	1%
48	L = 1180 - .42 S	-0.409	16.7	1%
48	R = 12.9 - .0095 S	-0.554	30.7	0.1%
No Subsoiling				
16	L = 683 + 39.6 R	0.489	23.9	10%
16	L = 1018 - .12 S	-0.100	1.0	N.S.
16	R = 10.5 - .0070 S	-0.467	21.8	10%
Conventional Subsoiler				
16	L = 825 + 19.7 R	0.265	7.0	N.S.
16	L = 1267 - .65 S	-0.598	35.8	2%
16	R = 12.2 - .0071 S	-0.491	24.1	10%
Stoneville Parabolic Subsoiler				
16	L = 940 + 9.7 R	0.121	1.5	N.S.
16	L = 1139 - .27 S	-0.244	6.0	N.S.
16	R = 9.9 + .0007 S	0.049	0.2	N.S.

¹Percent of dependent variable explained by the independent variable.

L = total lint yield harvested (lbs/A).

R = average taproot length (inches).

S = residual soil strength (lbs/sq in).

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