Low-Till Parabolic Subsoiler: A New Design for Reduced Soil Surface Disturbance and Power Requirement

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Introduction

Soil compaction has long been known to cause root restrictions and yield reductions in many crops, with cotton being particularly susceptible (Cooper et al., 1969). Two primary techniques were developed concerning the evaluation and management of soil compaction. The first method was subsoiling. Early research showed that the subsoiling produced significantly higher cotton yields than the conventional middle buster (Grissom et al., 1956). Lint yield increases with subsoiling have been reported, especially on sandy loam and silt loam soils, where subsoil compaction is a serious problem (Tupper, 1977).

The second method was to restrict wheel traffic in the same trafficked area between the rows each trip across the field, thus not allowing wheel traffic to occur over the growing zone (Williford, 1980). Raper (et al., 1994) reported no significant benefit to completely eliminating wheel traffic when in-row subsoiling occurred annually and traffic was restricted to row middles.

Subsoiling tools are designed to open up dense or impervious layers of soil for improved aeration, water infiltration, and root penetration. Research on the shape of subsoiler shanks was conducted at the National Tillage Machinery Laboratory in the 1950's (Nichols and Reaves, 1958). They found draft requirements with curved shaped shanks to be 7 to 20 percent less than with straight shanks. Draft was relatively insensitive to approach angles between 20" and 50" but increased very rapidly as the approach angle exceeded 50" (Payne and Tanner, 1959). Additional work further defined draft requirements and vertical forces on tillage tools with approach angles from 20 to 132º (Tanner, 1960).

The basic information developed by the research described above was incorporated into the Stoneviile parabolic subsoiler designed at the MAFES Delta Branch in 1972 (Tupper, 1974). Evaluations of the parabolic subsoiler revealed increased lint yields, lower horsepower requirements and reduced wheel slippage (43.4%) when compared to the straighter shank conventional subsoiler (Tupper, 1977). The parabolic subsoiler required 30.2% less fuel per acre than the conventional subsoiler, while working 2 inches deeper. Compared with the conventional and triplex subsoilers, the parabolic had the lowest draft, applied the highest vertical forces upon the soil, and had the lowest wheel slippage (Smith and Williford, 1988). Fewer than one percent of the Mississippi Delta cotton producers were subsoiling in 1975 (Cooke et al., 1975), but in 1992, more than 71% of Mississippi Delta cotton producers were subsoiling (Martin and Hamill, 1992).

New Federal legislation will require some changes in land preparation methods to meet requirements for reduced soil losses from fields. Residue cover on soil is recognized as a major factor affecting soil erosion (Meyer et al., 1970). Special subsoilers have been developed to reduce surface disturbance like the Paratill (The Tye Company or Bigham Brothers, Inc.) commonly referred to as "bent legged" or "L-shaped" shanks. These types of subsoilers are effective in reducing **soil** surface disturbance and maintaining ground cover but producers have noted high horsepower requirements.

The objective of this research was to meet the current needs of producers with interest in reduced tillage by designing a new parabolic subsoiler that would reduce soil surface disturbance and have lower draft requirements for in-row or across the row subsoiling.

Low-Till Parabolic Subsoiler Design

The low-till parabolic subsoiler was designed at the MAFES Delta Branch in the spring of 1993 (Tupper, 1994). The shank had a parabolic curve, with a long gradual increase in slope from an approach angle of 22.5" at the foot to 55" approach angle at the soil surface when running at the normal operating depth of 16 inches. The shanks were cut with an electric eye torch from 1%-inch T-1 steel plate with 321 Brinnel Hardness Number (BHN). Shanks were designed to provide a 17-inch ground clearance at operating depth or a total height of 33 inches.

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When soil is dry enough to shatter, rupture planes usually develop along a 45° plane up from the foot. Under less than ideal fracturing conditions, this angle tends to be less than 45° providing a narrower fractured zone. One of the design criteria used to reduce the power requirements was to keep the shank away from the fracture plane (less than 45° angle) *so* that it would always run in fractured soil. This design allowed only the subsoiler foot to run in hard unfractured soil. Another design criterion was to reposition the shank from following directly behind the foot, which minimizes the lifting of clods fractured by the foot to the soil surface like the original parabolic subsoiler. Reducing the lifting of clods through the topsoil layer would also reduce the power requirement and the amount of surface disturbance. Another design criterion was to sharpen the leading edge of the shank to reduce the lifting ability of the shank, also reducing the power requirement.

The low-till parabolic subsoiler was designed with the shanks positioned at a 28° angle from a vertical plane in the direction of travel. The top of each shank was directed away from the center of the tool bar. Placing the shanks at a 28" angle allows the shanks to always run inside the rupture planes developed by the foot, even when soil conditions are less than ideal for good fracture. Each shank was positioned on the tool bar *so* that the foot (row spacing width) can run directly under the drill row. The angle of the shank moves the top of the shank away from being directly over the drill. The shank's position prevents the leading edge from lifting large clods to the surface. Also, it provides more clearance for trash to minimize plugging under minimum till/high debris conditions. This design allows a producer to subsoil in the row direction prior to shredding cotton stalks, whereas, the conventional parabolic subsoiler plugs with stalks. A 45 º angle was cut on the upper side of the leading edge of the shank to provide a sharp leading edge. This sharp leading edge reduces the lifting ability of the shank thus reducing soil lift or surface disturbance and the power requirements of the shank. The reduced surface disturbance helps maintain ground cover for erosion control.

The subsoiler foot is 3 inches wide and has a 22.5" approach angle for minimum draft (Tanner, 1960), and a minimum of 360 BHN on the upper and lower surfaces for wear resistance. The foot runs in a position similar to the original parabolic subsoiler foot. This position is obtained by cutting an opposite 28° angle to the lean of the shank in a horizontal plane on the upper and lower edge of the point of the shank where the foot attaches to the shank. Side plates on the foot are leaned at a 28" angle parallel to the shank and a roll-pin is used to attach the foot to the shank.

A four-shank low-till parabolic subsoiler was constructed at Stoneville using a 5 x 7 **x** 1/2-inch tool bar. A category III three-point hitch was mounted on a shorter second 5 **X** 7 x 1/2-inch tool bar, which was mounted 17 inches ahead of the long tool bar on which the shanks are mounted. Two gage wheels were attached to the long tool bar and mounted to run behind the subsoiler in the row middles.

Field Tests

Field tests began in the fall of 1993. The studies were arranged in split plot experiments with two main plots: (1) check and (2) conventional parabolic subsoiler at a 45° angle to the row in the fall. The subplots consisted of five treatments: (I) check; (2) paratill in-row, fall; (3) paratill in-row, spring; (4) low-till parabolic in-row, fall; and (5) low-till in-row, spring. Each of the five treatments had (1) check or (2) alternate middle chisel operated 12 inches deep in nontraffic middles after emergence. The studies were 2 x *5* x 2 factorial experiments for 20 total treatments with six replications on two soil types: Bosket very sandy loam soil and Forestdale silty clay loam soil. The research was supported in part by the Mississippi Cotton Incorporated State Support Program (MCISSP) and by Cotton Incorporated.

First-year preliminary results showed the conventional parabolic subsoiler, operated at 45" to the row direction in the fall, was best on the Bosket very fine sandy loam soil type. Fall in-row subsoiling tended to produce higher yields than spring in-row subsoiling on the sandy soil type and the alternate middle chisel did not increase lint yield. On the Forestdale silty clay loam soil spring in-row subsoiling produce higher yields than fall-in row subsoiling.

A field performance test was run on Forestdale silty clay loam soil with the two in-row subsoilers set to run 16 inches deep. A 195-PTO Hp Case IH® 7240 tractor was used to pull the subsoilers. The criteria used in the study were to run the tractor at full throttle and maintain 2,100 to 2,200 engine RPM by shifting down or up a gear, respectively, to vary draft load to maintain engine RPM within this range. Alternate four-row plots were subsoiled with each subsoiler across a field with rows 480 feet long. The 7240 was able to pull the Paratill at a field performance rate of 8.16 A/hour and the low-till parabolic subsoiler at a rate of 9.09 A/hour, for an 11.4% increase in performance rate. Both in-row subsoilers were run without busters. Additional research will be conducted and reported as data are available.

Note: The use of trade names in this publication is solely to provide specific information and does not imply their approval or recommendation by the Mississippi Agricultural and Forestry Experiment Station to the exclusion of other products.

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