Slit-Tillage for Plow Pan Soils

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Introduction

Soil compaction in the form of plow pans, sometimes called tillage pans, is a problem on large areas of land throughout the world (DeRoo 1961, Eriksson et al., 1974. Unger et al., 1981). Plow pans are frequently a deterrent to optimum crop performance on the coarse textured soils of the Southeastern United States. The primary way in which plow pans adversely affect crop production is by reducing plant rooting into the subsoil. Often a plow pan will restrict most of a crop's roots to the plow layer. Oxygen deficiency and soil strength are the primary factors that restrict root growth in compacted soil (Barley et al.. 1967, Huck 1970, Eavis and Payne 1968, Greenwood 1969). Subsoiling is the most common management practice for promoting deep rooting on plow pan soils, however it has the disadvantages of: high power requirements; the slowing of tillage and planting operations; undesirable mixing of soil horizons; and short term benefits.

In 1979 research was begun to develop an alternative to subsoiling that would effectively promote rooting downward through plow pans but would be free of the undesirable features of subsoiling. The result was the development of a tillage method called slit-tillage and the development of various means of applying slit-tillage to crops or to individual plants. Slit-tillage is the cutting of a narrow. vertical slit through a compacted layer of soil. such as a plow pan. to promote rooting downward through the compacted layer into

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underlying soil. This paper is a review of slit-tillage research and a presentation of criteria that should be considered in developing slit-tillage implements and in applying slit-tillage

Materials and Methods

A number of field and greenhouse experiments were conducted to: 1. Evaluate the effectiveness of slit-tillage for promoting rooting downward through plow pans; 2. Evaluate the effect of slit-tillage on crop yield; 3. Establish specifications for slits; and 4. Investigate various means of cutting slits (Elkins 1980, Elkins et al., 1983, Van Sickle 1985, Reeves et al., 1988, Karlan et al., 1989. These experiments were conducted on Ultisols at Auburn, Headland, Shorter, and Crossville, Alabama and at Florence, South Carolina to compare slit-tillage to other tillage methods. Various implements such as vibratory cable-laying plows and modified subsoiler-planters as well as hand tools were used for cutting the slits. In the initial slit-till experiment slits were cut by hand with a long bladed spade (Elkins 1980.) The vibratory plows were equipped with blades that were about 5/32 inch thick and capable of cutting a slit from the soil surface to a depth of 15 inches. There was no surface tillage with these implements. A number of observation plots were planted to corn *(Zea mays* L.), grain and sweet sorghum *(Sorghum bicolor* L. Moench), okra *(Hibiscus esculentus* L.), peanuts (Arachis hypogaea L.), soybeans *(Glycine max* (L.) Merr.), and rape *(Brassica napus* L.) with a vibratory plow.

Two brands of subsoiler-planters were odified by shortening the subsoiler shanks and installing 5/32 inch thick blades that extended downward by about 7 inches from the lower end of the shanks. With these implements the subsoiler chisel point was run on top of the plow pan with the blade cutting a narrow vertical slit through the plow pan. A strip of surface soil up to 20 inches wide was tilled by the subsoiler chisel and by fluted colters attached to the shank or following the shank. Measurements of draft forces required to pull a subsoiler shank modified for slit-tillage were made in soil bins at the National Soil Machinery Tillage Laboratory (Elkins and Hendrick, 1983).

Greenhouse and field experiments were conducted to determine the optimum dimensions for the slits. Slits of various widths were formed in glass front boxes and soybeans were planted so that their roots would grow into the slits. In a companion field experiment various width slits were cut with a subsoiler shank equipped with 5/32, 1/4, 1/2, and 3/4 inch thick blades. Soybeans were grown above these slits. Observations of root growth were made in the boxes and by digging pits in the field plots.

Results and Discussion

Rooting

Roots of a variety of crop, vegetable, turf, and weed plants have been observed to grow vigorously in the slits. In fact, the roots of all plants observed responded positively to slits. Root elongation rates in slits by plants such as corn and soybeans has been observed to proceed at rates of about 2 inches per day. For example soybean roots reached the bottom of a fifteen inch deep slit while still in the cotyledon stage of growth. Rapid root growth in the slits would be expected since the two major factors that impede root growth in compacted soil, oxygen deficit and soil strength are eliminated by the slit. The walls of the slits are compacted so roots do not grow out the sides of the slits but are directed downward out the bottom of the slit into the subsoil. The tap roots or major lateral roots of tap rooted plants were observed to grow directly down the slit into underlying soil with branch roots forming a network of roots in the slit. Roots of fibrous rooted plants, such as corn and sorghum, filled the slit with a mat of roots, with the primary seminal and crown roots growing out the bottom of the slit.

Roots that grew in the slits. and residue from decomposed roots helped maintain the slits, and caused the slits to remain effective for several years. Root growth has been observed in slits that were five years old. Residue from roots that grew in slits in a Norfolk sand loam soil altered the chemical properties of soil in the walls of the slits in a way that should favor root growth. Van Sickle (1985) found increases in organic matter Ca, and Mg in the slit walls and a reduction in Al.

Yields

In the initial experiment soybean yields were 29, 25, and 18 bu/A for slit-tillage, complete surface tillage, and no-till respectively (Elkins 1980). Root observations from a pit dug across the rows showed that roots in the no-till plots were restricted to the surface soil by a plow pan but roots in the slit-tilled plots grew down the slit and proliferated throughout the subsoil to a depth of more than three and one-half feet. On plots where the surface was completely tilled rooting was more dense in the surface soil than on the no-till and slit-tillage plots, but few roots grew into the subsoil. During periods of low rainfall plants on plots with no slits wilted and on still, clear days leaf temperature of plants growing on slit-tilled plots was 4 to 5^{o} F cooler than plants growing without slits.

In general, yields of soybeans and grain sorghum grown with slit-tillage have been greater than yields of these crops grown no-till or with complete surface tillage. In the first year of experiments, yields with slit-tillage were about the same as, but in some cases lower or higher than yields with in-row subsoiling. In the second year of experiments yields with slit-tillage equalled or exceeded yields with in-row subsoiling. By the third year yield with slit-tillage exceeded yields with in-row subsoiling (Elkins 1980, Van Sickleet al., 1984, Reeves et al., 1988, Karlan et al., 1989). The improved performance of slit-tillage with time is attributed to the cumulative effect of introducing additional, functioning slits each time slit-tillage is applied.

Slit Specifications

The roots of soybeans grown in slits in glass front boxes grew normally only in slits narrow enough so that the roots made good contact with both walls of the slits. Roots growing into wide slits ceased to elongate, sometimes producing many fine branches. This phenomena was verified in a field experiment where soybeans were grown over slits of varying widths. Contact with slit walls is essential for adequate water uptake. The ideal width for slits is one that is approximately the thickness of the root tip. For common tap-rooted plants this would be about 3/100 inch. The ideal width would vary with fibrous-rooted plants such as corn, sorghum, and millet.

From a practical standpoint a slit of acceptable width for both tap-rooted and fibrous-rooted plants can be obtained by cutting the slit with a blade ranging from 1/8 to 5/32 inch thick. In some cases a 3/16 inch thick blade may produce acceptable results, but caution should be exercised as thickness of the blade is increased. A blade thicker than that required for the slit can be used because elasticity ofthe soil and overburden weight ofthe soil tends to close the slit following passage of the blade.

Blades for cutting slits should be sharpened on the leading edge and **must be sharpened on the lower edge. A** sharpened or tapered lower blade edge is essential so that the bottom of the slit will be tapered. Upon reaching the slit bottom roots wedge themselves into the taper and can thus grow readily into the underlying soil. If slits have a flat or rounded bottom roots tend to grow along the slit bottom rather than penetrating into underlying soil.

An objective of slit-tillage is to establish stable slits. This can best be accomplished by cutting slits when the soil layer into which the slits are cut is wet (good plowing moisture content) so that the blade passing through the soil smears the slit walls. From a practical standpoint slits can be successfully cut only when the soil is wet because of increasing soil strength with drying and because of rapid wear of blades drawn through dry soil. As for blade length, blades should obviously reach through the plow pan and blades should initially be about 2 inches longer than required to allow for wear before replacement is necessary.

Implements

Effective slits have been cut through plow pans with a variety of implements ranging from a machete to four-row modified subsoiler-planters. Draft requirements for applying slit-tillage with a modified subsoiler shank was 12 to 43 percent lower than for subsoiling depending on operating speed and soil type. The 43 percent reduction was in Norfolk soil material with a speed near that of field operations. It appears that practical implements can be devised for application of slit-tillage with hand power, animal power, and with tractors ranging from small garden tractors to large farm tractors. The modified subsoiler-planter implements that have been used to experimentally apply slit-tillage are too heavy. The design and development of a slit-tillage-planter type implement is needed for successful application of slit-tillage to production agriculture. Implement development should also be considered for low power applications of slit-tillage, as with hand tools, garden tractors. and animal power.

Summary

Slit-tillage is a tillage procedure that installs narrow, vertical slits in compacted soil. The slits, if of proper dimensions, serve as substitutes for the macropores that are generally missing in compacted soil. The slits alleviate the oxygen deficiency and soil strength constraints on root growth that normally exist in compacted soils. A wide variety of fibrous and tap rooted plants responded favorably to slit-tillage. Roots grew in the slits at near maximum rates. On several experiments on southeastern soils (Ultisols), yields with slit-tillage were equal to, or exceeded yields with in-row subsoiling, complete surface tillage, and no-till. In the first year of some experiments yields with slit-tillage were slightly lower than yields with in-row subsoiling. Less power is required to slit*till than to subsoil to the same depth. Slit-tillage does not mix soil from different soil horizons as does subsoiling. The effect of slit-tillage last for several years in contrast to the usual short-term effects of subsoiling. Slit-tillage can he applied with a variety of implements, ranging from hand tools to large multi-row farm implements.

Conclusions

Slit-tillage is a useful procedure for ameliorating plow pans to promote rooting into the subsoil. In several ways slit-tillage is superior to other types of deep tillage. Implements should be developed specifically for slit-tillage so that it can be applied to production agriculture, to gardening, and to other plant growing enterprises.

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