Paper No. 961044
An ASAE Meeting Presentation

VERTICAL TRENCHING OF CELLULOSE WASTE TO HINDER HARDPAN RECONSOLIDATION

by

R. L. Raper
Agricultural Engineer

J.H. Edwards
Soil Scientist

T.R Way, B.H. Washington, E.C. Burt
Agricultural Engineers
USDA, ARS, National Soil Dynamics Laboratory
P.O. Box 3439, Auburn, AL 36831-3439 USA

D.T. Hill
Professor
Alabama Agricultural Experiment Station and Agricultural Engineering Department
Auburn University, Auburn, AL 36849 USA

Written for presentation at the
1996 ASAE Annual International Meeting
sponsored by ASAE

Phoenix Civic Plaza
Phoenix, Arizona
July 16, 1996

Summary

Trenches placed midway between rows were filled with a mixture of soil, cellulose material, and poultry litter. Soybeans and grain sorghum were grown in rows adjacent to the trenched areas for multiple years. Results showed that a trenching effect, with or without the presence of cellulose, significantly increased plant yields, particularly in dry years. Cone index measurements taken three years after the trenches were created showed no sign of hardpan consolidation from natural forces.

Keywords:

Subsoil, soil compaction, implement. soybean, grain sorghum, cone index, vertical mulching

ASAE, 2950 Niles Rd., St. Joseph. MI 49085-9659 USA
Voice: 616.429.0300 FAX: 616.429.3852 E-Mail: <hq@asae.org>

VERTICAL TRENCHING OF CELLULOSE WASTE TO HINDER HARDPAN RECONSOLIDATION

INTRODUCTION

Soil compaction problems are evident to farmers throughout the United States, but problems are often acute, particularly in the Southeastern United States (Cooper et al., 1969; McConnell et al., 1989; Mullins et al., 1992). Here, Coastal Plains soils exhibit layers of extreme compaction from both natural causes and wheel traffic. These compact layers impede root growth, thereby reducing the plant's capacity to obtain water during drought. These problems are especially severe in the Southeastern United States because of the low organic matter content and low water holding capacity of Coastal Plains soils, coupled with frequent short-term drought.

The most common method of alleviating layers of extreme soil compaction is subsoiling (Garner et al., 1984; Reid, 1978; Campbell et al., 1974). This process of moving a tillage tool through the soil requires a large amount of energy. Disruption of soil horizons down to depths of almost 0.7 m are not uncommon, but the practice is not a permanent solution. Due to natural reconsolidation and surface forces of uncontrolled traffic, the soil tends to recompact and requires periodic subsoiling.

One method that has been proposed to lengthen the time between periodic subsoiling is to incorporate some type of non-soil, foreign material into the subsoiled zone to keep the soil particles from cohering to each other and to provide extra pore space for water infiltration and storage. Crop residue was plowed into the soil by Spain and McCune (1956) as a method of alleviating heavy straw concentrations left on the soil surface after large yields. This heavy straw concentration was interfering with planting operations and preventing timely field operations. Curley et al. (1958) investigated burial of organic materials, including hay and corn cobs, as a method of deepening the plant root zone. They found that large increases in crop yield were achieved in the first year of the experiment. Yields were variable in later years, however, due to heavy winter rains which provided adequate moisture to all plots. A Canadian experiment (Clark and Hore, 1965) found that vertical mulching (as it came to be called) had little effect on crop yields or on soil moisture distribution.

Saxton (1980) hypothesized that one reason for the failure of the vertical mulching system developed in the 1950's is that trench surfaces were sealed during subsequent plowing operations. Saxton (1980) proposed a system by which the crop residue was not completely buried but was allowed to protrude above the soil surface and intercept free water.' The subsoiled zone would then have a longer lifespan, infiltration would be increased, and the problems associated with surface sealing would be alleviated.

An implement was developed to vertically mulch residue cover in the Pacific Northwest of the United States (Hyde et al., 1986; Hyde et al., 1989). Vertical shanks, parabolic shanks, and rotary slot cutting devices were compared to determine the best method of creating a vertical trench for depositing residue cover. It was found that a vertical shank operating to a depth of 26 cm with a 22-degree lift angle minimized draft requirements and formed the best slot when combined with a pair of preceding coulters that cut to about half the depth of the slot. A machinery system similar to the one developed in the Pacific Northwest was developed to handle corn *(Zea mays* L.) residue (Edwards and Rumsey, 1989).

Preliminary studies have been conducted in the Southeastern United States using cotton *(Gossypium hirsutum L.)* as an indicator crop (Edwards et al., 1992a; Edwards et al., 1992b; Edwards et al., 1995) where trenches were dug and filled with a mixture of soil, cellulose, and poultry litter. Results indicated that cotton yields increased when the waste cellulose material was applied in a vertical trench between plant rows.

A potential benefit of this system is its ability to use virtually any organic material as the non-soil foreign substance. Because an abundance of waste cellulose materials are currently available and are filling up valuable landfill space (Rathje, 1991) the potential exists for farmers to offset machinery and energy costs by potential payments from municipalities for disposal of a portion of their solid waste. This would be in addition to any yield increases that farmers might achieve. According to Burt et al. (1992) waste disposal costs for municipal landfills vary from $44 - $154 per Mg, depending upon location. They reported that if waste could be applied to agricultural soil at a rate of 27 Mg/ha with a 1 -m spacing between trenches, landfill costs of $1188 - $4158 per ha could be avoided.

Commercialization of this process has not been successful, primarily because yield increases have been insufficient to overcome machinery and tillage energy costs. More experiments are needed in the Southeastern portion of the United States where hardpan problems are prevalent to determine potential benefits from this process on various crops. This research requires a substantial amount of labor to place the cellulose materials into the subsoiled zone. For this reason, an implement was needed to create a subsoiled zone and apply waste materials in one pass before additional experiments can be performed.

The objectives of this study were to:

- design an implement to subsoil and apply waste material in one pass,
- determine the effect of waste cellulose material applied in trenches on crop response, and
- determine the effect of cellulose waste on hardpan reconsolidation in Coastal Plains soils.

METHODS AND MATERIALS

An implement was developed at the USDA-ARS National Soil Dynamics Laboratory (U.S. Patent #5,401,119) for subsoiling and applying waste cellulose material in one pass (Figure 1). The implement consists of a 15-cm wide shank which is used to subsoil to a 61-cm depth. The shank is similar to a polyurethane wedge being passed through the soil. The sides of the shank are covered in polyurethane to minimize frictional forces from the sides of the subsoiled zone. The sides of the shank also tend to stabilize the subsoiled trench and keep it open so that the deposited cellulose waste material can flow freely to the bottom.

The cellulose-disposal implement also contains a large hopper which holds the waste materials to be applied. Flexible fingers mounted inside the hopper and powered by a hydraulic motor rotate and dispense the waste cellulose material directly into the soil behind the subsoiler shank. Soil is then brought back into the subsoiled zone by rotating spider wheels which run to the rear of the shank. A mixing wheel is located at the very rear of the machine to enhance mixing of soil and waste cellulose material. Excavations performed during initial trials showed that a uniform mixture was being obtained along the depth of the trench.

The implement was used in two investigations of vertical mulching at the Alabama Agricultural Experiment Station E.V. Smith Research Center near Shorter, AL. Because waste cellulose material had to be manually shredded and varied in consistency, the decision was made to obtain shredded newspaper that is used for insulation (CEL-PAK[1], Decatur, AL). This material was passed through a 9.5-mm screen before being packaged into 11.4 kg bundles. Analysis of the shredded newspaper showed it to contain 48% carbon and less than 0.5% nitrogen,

One of the objectives of the experiment was to determine if the application of the cellulose materials affected plant growth. Therefore, obtaining a correct C:N relationship was important and three treatments of this factor were included. The first treatment consisted of applying the cellulose material directly to the subsoiled zone without any modifications. In this treatment, the cellulose material had a C:N ratio of approximately 125:1. The second and third treatments consisted of adjusting the C:N ratio to approximately 25:1 by adding either a urea ammonium nitrate solution (32% N) or poultry litter to the shredded newspaper prior to application. Analysis of the poultry litter a few days prior to the experiment showed it to contain 22% carbon and 3% nitrogen.

An arrangement of rows and trenches provided a plot area which could be used to observe both C:N effects and trench effects. Eight-row plots with a row spacing of 0.76 m were used with trenches placed halfway between rows 2 and 3 and rows 6 and 7 (Figure 2). Each plot was 18.3 m in length with a 6-m buffer zone between plots. The experimental layout consisted of placing a trench with the cellulose material mixture on one side of the plot (between rows 2 and 3) and placing a trench with no cellulose material on the other side of the plot (between rows 6 and 7). The trench between rows 6 and 7 with no cellulose material was constructed with the cellulose disposal implement, but with nothing applied in the trench area. It was assumed that rows 2 and 3 would benefit from the trench with the cellulose material, and rows 6 and 7 would benefit from the trench alone. Rows 4 and 5 would receive no trenching benefit and should provide a useful control. Rows 1 and 8 were used as buffer rows.

Each of the two experiments contained four replicates. A Cahaba-Wickham-Bassfield sandy loam soil *(fine-loamy, siliceous, thermic Typic Hapludults - fine-loamy, mixed, thermic Typic Hapludults - coarse-loamy, siliceous, thermic Typic Hapludults)* with a predominant hardpan which is prone to reconsolidation was used to grow grain

---

[1] The use of tradenames or company names does not imply endorsement by USDA-ARS or Auburn University.

sorghum *(Sorghum bicolor (L.) Moench).* A similar experiment was performed in a Norfolk sandy loam soil *(fine-loamy, siliceous, thermic Typic Kandindults)* with soybeans *(Glycine max (L.) Merr.).* The soybean experiment received no poultry litter treatment because it was thought that this treatment would be of little benefit because soybeans fix nitrogen.

The trenches were formed and the shredded newspaper applications were made in June 1993. Application of fertilizer (based on soil test recommendations) was made to all plots at time of planting. Because very little rain fell, a small amount of water (≈ 2.5 cm) was used to irrigate both sets of plots early in the growing season to prevent loss of crop. Throughout the growing season, grain sorghum plants in rows 4 and 5 were noted to contain plants with reduced height and immature heads as compared to those plants in rows 2 and 3 or rows 6 and 7. At the conclusion of the growing season, the center 9.1 m of each plot along the plot length was harvested for crop yield. These harvests placed rows 2 and 3 together, as well as rows 4 and 5, and rows 6 and 7.

No shallow or deep tillage was conducted on the plots during the period that the experiments were being conducted other than the initial trenching operation which was only performed the first year. The row locations were not moved from year to year because no tillage was performed to disturb old row locations, The only traffic that was allowed in the plots was for planting, spraying herbicide, and harvesting.

The soil condition at the end of each growing season was determined by recording the force required to push a soil cone penetrometer (ASAE, 1993) vertically into the soil at depth increments of approximately every 3 mm. The soil cone penetrometer is an indicator of soil strength and simulates the force that roots encounter when growing in a particular soil condition. The forces recorded are then divided by the cross-sectional base area of the cone to calculate cone index.

Several profiles were taken in the first replication of the sorghum experiment across the plot area both inside the trench and in nearby untrenched areas in October 1993, to assess the effect of trenching on soil condition. A series of seventeen measurements were made across plots in the 3 C:N treatments (Raper et al., 1995). A complete set of soil cone penetrometer measurements in the soybean plots were taken in March 1996 to determine the resulting soil condition after 3 consecutive years of crops. At six locations in each plot, penetrometer measurements were taken both in the trench that contained cellulose and in the trench that did not contain cellulose. Measurements were also taken halfway between the trench and the row as well as in adjacent rows.

In each plot in the grain sorghum experiment, two ceramic cup lysimeters with 0.4 micron pore size (Soil Moisture Equipment, Inc., Santa Barbara, CA) were installed midway between the plant row and the trench at depths of 0.6 m and 1.2 m (Hill et al., 1995). Water samples were taken monthly in 1993 to determine if any nitrogen leaching could be detected, particularly in the plots that received the added nitrogen. The limited data available for these months indicated that none of the applied nitrogren in the trenches leached below the 1.2-m depth (Hill et al., 1995). However, the trench that contained only cellulose material and had a C:N ratio of 125:l caused direct vertical movement of NO_3-N to below the rooting depth. This could allow nitrate from fertilizer to become a potential ground water contaminant.

Grain yield data were analyzed for each year using C:N ratio and row positions as the independent variables. Analyses of variance and multiple comparisons were made using SAS statistical software (Cary, NC).

RESULTS AND DISCUSSION

Grain yield results varied greatly with year but tended to show similar results for both soybean and sorghum. In 1993, after stand establishment was aided by irrigation, the crops weathered brief droughts but received adequate rainfall periodically throughout the growing season (36.6 cm from May-August). In 1994, rainfall was excessive for most of the growing season resulting in poorer yields (63.0 cm from May-August). Rainfall was again sparse in 1995, with frequent short-term droughts a common occurrence (21.9 cm from May-August). The grain sorghum experiment was discontinued after the second year due to a lack of response from the trenched areas.

No overall differences were detected in grain yield of the soybeans or the grain sorghum due to differences in the original establishment of the C:N ratio of the waste cellulose material mixture (Figures 3 and 4). This lack of a trend indicates treating the cellulose mixture with additional nitrogen is probably unnecessary. It also suggests that if another waste material rich in nitrogen is available (such as poultry litter) it neither inhibits nor increases plant growth when placed in the subsoiled zone.

One of the most interesting results is the benefit afforded plants placed in rows alongside the trenches. Grain yields of grain sorghum and soybeans in rows adjacent to trenches (rows 2, 3, 6, and 7) were significantly greater than those of rows not adjacent to a trench (rows 4 and 5) (Figures 5 and 6). The improved rooting depth afforded by the trench allowed plants adjacent to this zone to take advantage of loose soil conditions and obtain moisture throughout the growing season. The benefits offered by the trench to the plants were substantial except in 1994 when grain sorghum yields were equivalent throughout the entire plot. These results tend to indicate that the trenched zone in these plots had closed up and did not benefit the grain sorghum during this growing season.

An effort was made to excavate and visually inspect the trenches for rooting activity near the end of the first growing season, Only a small amount of cellulose remained visible in the trenched area, but rooting activity was abundant to the bottom of the trench. Cone index measurements were taken across the plot width to determine the effect of the trench. These were taken at 19-cm increments across the 76-cm rows. The soil was extremely dry and gave extremely high cone index measurements, but the results clearly showed that the effect of the trench was much broader than the 15-cm width of the tillage tool (Figure 7). This was evident in trenches with and without cellulose.

After three annual soybean crops had been raised on the trenched zones with cellulose addition, we decided to obtain a full set of cone index measurements inside and adjacent to both sets of trenches (Figures 8 and 9). The trenched area in each figure contains the minimum values of cone index compared to those taken in the row and those obtained halfway between, Also, there is no indication that the trenched areas not receiving waste cellulose were recompacting. The cone index in this zone is still mostly below the 2 MPa limit that researchers have determined is important for proper root growth (primarily for cotton plants) (Taylor and Gardner, 1963).

CONCLUSIONS

- An agricultural implement was successfully developed for subsoiling and applying waste materials in one pass. This machine was successfully used to install experiments to examine the feasibility of applying waste cellulose materials in a traditional agricultural field situation.
- Crops were shown not to be detrimentally affected by the application of cellulose materials in a nearby trenched area. Soybeans and grain sorghum both showed positive responses when placed adjacent to trenched areas as compared to plants placed adjacent to untrenched areas. Plants placed adjacent to a trench containing the waste cellulose mixture grew equally well to those placed adjacent to a trench containing only soil.
- Recompaction of the trenched area has not occurred in plots that contained either the waste cellulose mixture or only soil after 3 years. Without any-surface traffic to reconsolidate these trenched areas, the soil condition in this Coastal Plains soil may be able to withstand natural recompactive forces for several years.

REFERENCES

Burt, E.C., J.H. Edwards, R.L. Raper, and D.T. Hill. 1992. Cellulose as a soil conditioner. ASAE Paper No. 921560, ASAE, St. Joseph, MI.

Campbell, R.B., D.C. Reicosky, and C.W. Doty. 1974. Physical properties and tillage of Paleudults in the southeastern Coastal Plains. J. Soil and Water Cons., Sept-Oct., pp. 220-227.

Clark, D.E. and F.R. Hore. 1965. Vertical and horizontal mulch on Haldimand clay Trans. ASAE 8(4):592-593.

Cooper, A.W., A.C. Trouse, and W.T. Dumas. 1969. Controlled traffic in row crop production. Proc., 7th International Congress of Agricultural Engineering, Baden-Baden, W. Germany, Theme 1, pp. 1-6.

Curley, R.G., B.A. Krantz, J.A. Vomicil, and W.J. Chancellor. 1958. Vertical mulching; one possible solution to soil compaction problems. Western Grower and Shipper, November.

Edwards, B.A., and J.W. Rumsey. 1989. Development of a vertical mulching implement. ASAE Paper No. 891503. ASAE, St. Joseph, MI.

Edwards, J.H., E.C. Burt, R.L. Raper, and D.T. Hill. 1992a. Effects of deep placement of nutrients, broiler litter, and newsprint on cotton yield and rooting depth. Proceedings of the Beltwide Cotton Conference, National Cotton Council, Memphis, TN.

Edwards, J.H., E.C. Burt, R.L. Raper, and D.T. Hill. 1992b. Recycling newsprint on agricultural land with the aid of broiler litter. Compost Sci. and Utilization 1(2):79-92. 1993.

Edwards, J.H., R.H. Walker, E.C. Burt, and R.L. Raper. 1995. Issues affecting application of noncomposted organic waste to agricultural land. Chapter 11 of ASA-CSSA-SSSA Special Publication Agricultural Utilization of Urban and Industrial By-Products. Editor: D. Karlen.

Garner, T.H., W.R. Reynolds, H.L. Musen, G.E. Miles, J.W. Davis, D. Wolf, and U.M. Peiper. 1984. Energy requirement for subsoiling Costal Plain soils. ASAE Paper 84-1025, ASAE, St. Joseph, Ml.

Hill, D.T., R.L. Raper, E.C. Burt, and T.R. Way. 1995. Root-zone water quality as affected by incorporation of shredded newsprint. Ecological Engineering 4:45-52.

Hyde, G.M., J.E. George, K.E. Saxton, and J.B. Simpson. 1986. A slot-mulch implement design. Trans. ASAE 29(1): 20-25.

Hyde, G.M., J.E. George, K.E. Saxton, and J.B. Simpson. 1989. Slot-mulch insertion machine: design and performance. ASAE Paper No. 891502. ASAE, St. Joseph, MI.

McConnell, J.S., B.S. Frizzell, and M.H. Wilkerson. 1989. Effects of soil compaction and subsoil tillage of two alfisols on the growth and yield of cotton. J. Prod. Agric., Vol. 2, no. 2, pp. 140-146.

Mullins, G.L., D.W. Reeves, C.H. Burmester, and H.H. Bryant. 1992. Effect of subsoiling and the deep placement of K on root growth and soil water depletion by cotton. Proceedings of the 1992 Beltwide Cotton Conference, Volume 3, pp. 1134-1138, National Cotton Council of America, Memphis, TN.

Raper, R.L., T.R. Way, E.C. Burt, D.T. Hill, J.H. Edwards, D.W. Reeves, A.A. Trotman. 1995. Hindering hardpan reformation with cellulose waste. Chapter 12 of ASA-CSSA-SSSA Special Publication Agricultural Utilization of Urban and Industrial By-Products. Editor: D. Karlen.

Rathje, W.L. 1991. Once and future landfills. National Geographic, May, pp. 116-134.

Reid, J.T. 1978. A comparison of the energy input of some tillage tools. ASAE Paper 78-1039, ASAE, St. Joseph, Ml.

Saxton, K.E. 1980. Slot mulch tillage for water management and reduced erosion. Proceedings of the Conference on Crop Production with Conservation in the 80’s ASAE, St. Joseph, Ml.

Spain, J.M. and D.L. McCune. 1956. Something new in subsoiling. Agronomy Journal 48:192-193.

Taylor, H.M., and H.R. Gardner. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content, and strength of soil. Soil Sci 96(3):153-156.

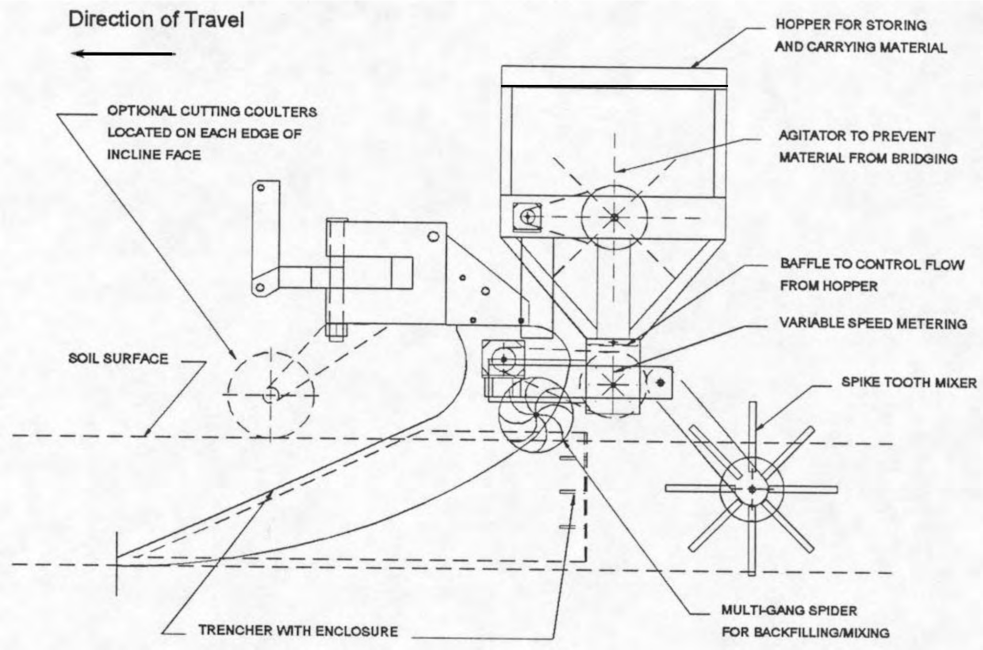

Figure 1. Left side view of implement to subsoil and deposit waste cellulose material in a narrow trench.

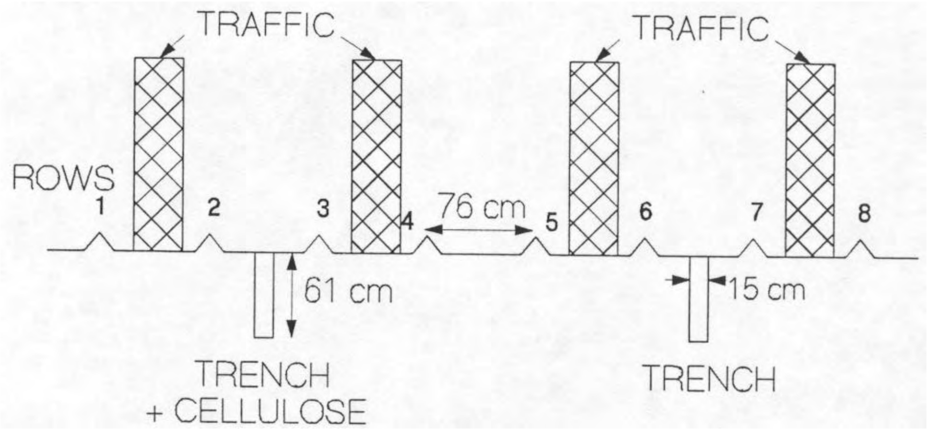

Figure 2. Position of trenches relative to rows and wheel traffic.

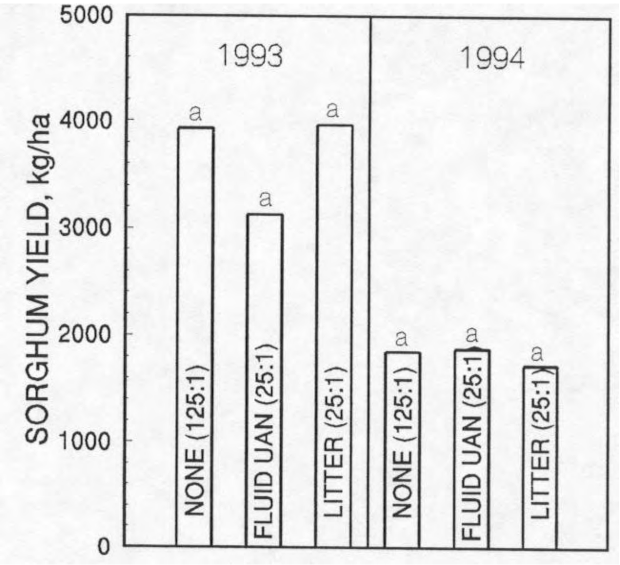

Figure 3. Grain sorghum yields in rows 2 and 3 adjacent to trenches filled with cellulose material that had C:N ratios balanced. Within each year, means with the same letter are not significantly different at α = 0.05 (LSD test).

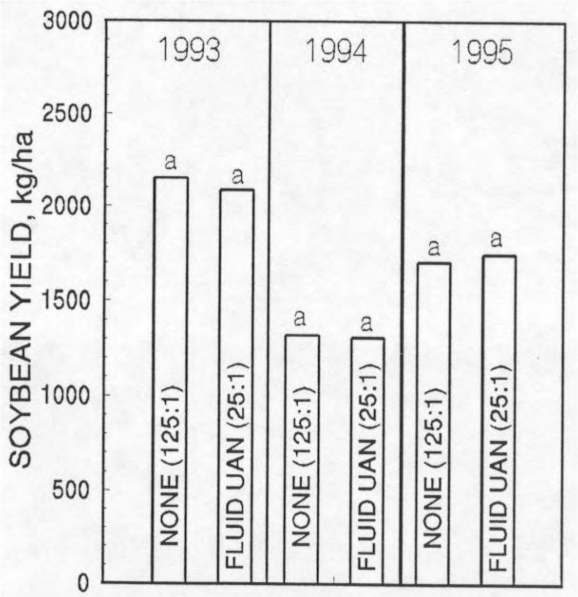

Figure 4. Soybean yields in rows 2 and 3 adjacent to trenches filled with cellulose material that had C:N ratios balanced. Within each year, means with the same letter are not significantly different at α = 0.05 (LSD test).

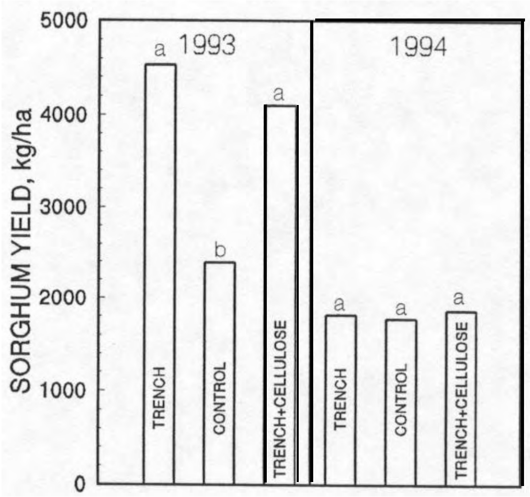

Figure 5. Grain sorghum yield in rows adjacent to trenches (rows 2 and 3 for trench + cellulose and rows 6 and 7 for trench alone) and in control rows (rows 4 and 5). Within each year, means with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

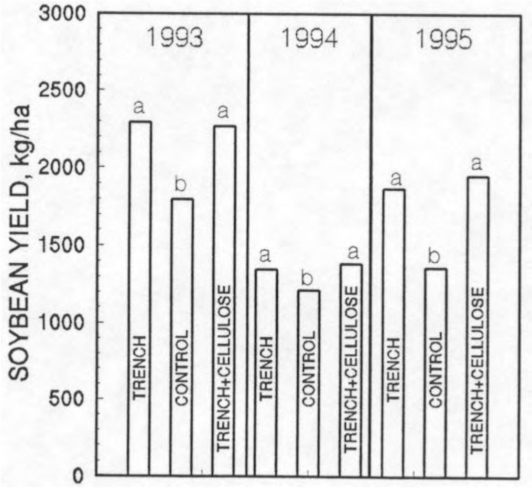

Figure 6. Soybean yields in rows adjacent to trenches (rows 2 and 3 for trench + cellulose and rows 6 and 7 for trench alone) and in control rows (rows 4 and 5). Within each year, means with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

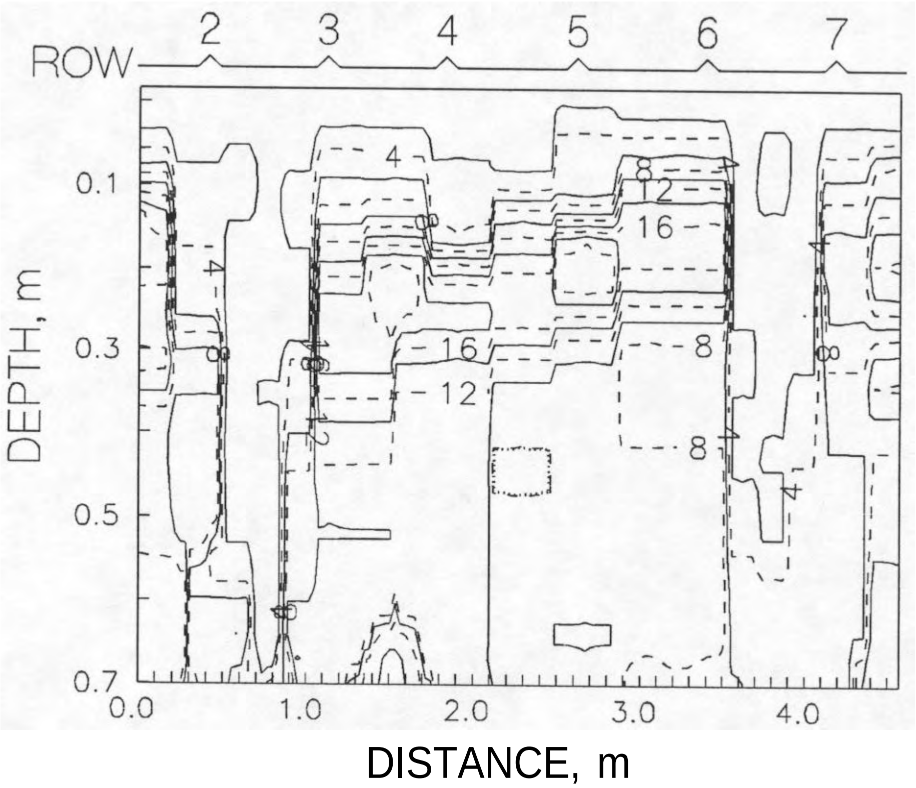

Figure 7. Cone index (MPa) profile taken at end of growing season 1993 across the grain sorghum experiment with the cellulose trench between rows 2 and 3 and the non-cellulose trench between rows 6 and 7. Fluid urea ammonium nitrate was mixed with the cellulose on this plot to achieve a C:N ratio of 25:1.

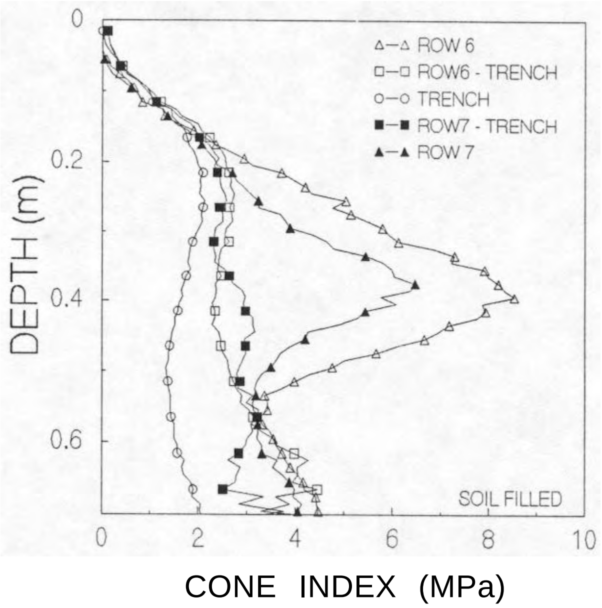

Figure 8. Cone index measurements taken in plots where trenches were created midway between rows 2 and 3. These measurements were taken 3 years after the subsoiled zones were created.

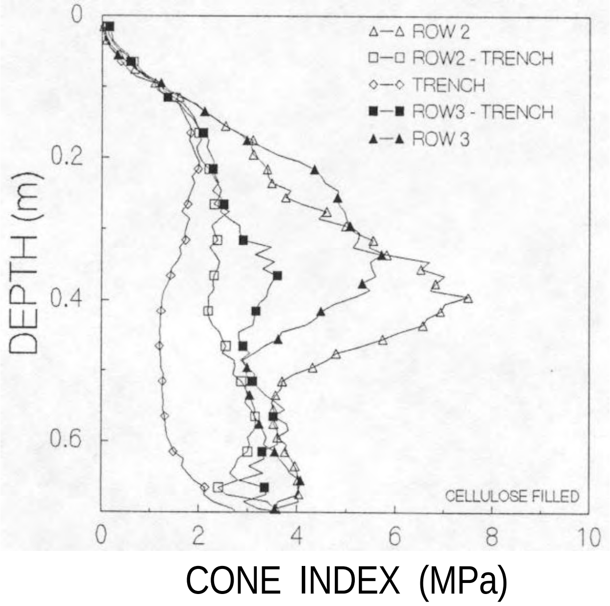

Figure 9. Cone index measurements taken in plots where trenches midway between rows 2 and 3 were partially filled with cellulose material. These measurements were taken 3 years after the subsoiled zones were created.