12 Hindering Hardpan Reformation with Cellulose Waste

R. L. Raper, T. R. Way, E. C. Burt, J. H. Edwards, and D. W. Reeves

USDA-ARS
National Soil Dynamics Laboratory
Auburn, Alabama

D. T. Hill

Auburn University
Auburn, Alabama

A. A. Trotman

Tuskegee University
Tuskegee, Alabama

Disposal of solid wastes in the USA is becoming increasingly challenging. Our 5500 landfills are filling up at an alarming rate and few new ones are being approved (Rathje, 1991). The nation's annual trash bill now exceeds $15 billion and new ways of handling waste materials are sorely needed.

According to Rathje (1991), misperceptions must be dealt with before a reduction in trash can be achieved. He reports that most people believe that landfills are filled with fast-food packaging, polystyrene foam and disposable diapers. His research has showed that these components add up to only about 2% of the total solid waste.

The largest component of landfill waste is paper. Waste paper now occupies some 50% of the waste stream, and newspapers themselves occupy between 10 to 15%, even though many are now being recycled or exported. Rathje (1991) reports that paper does not decompose as rapidly as once believed. His research has found legible copies that have been buried for 40 yr. Alternative methods for disposal of waste paper should be investigated before our expensive landfill space is filled to capacity.

An alternative paper disposal method that has been investigated at the USDA-ARS National Soil Dynamics Laboratory is to use shredded newspaper as a soil amendment for crop production (Burt et al., 1992; Edwards et al., 1992a, b, 1994). Experiments have been conducted on both surface incorpo-

Copyright © 1995 American Society of Agronomy, Crap Science Society of America, Soil Science Society of America, 677 S. Segoe Rd., Madison, WI 53711, USA. *Agricultural Utilization of Urban and Industrial By-Products.* ASA Special Publication no. 58.

ration of the waste paper and on burying this material in vertical trenches. Preliminary results have indicated that increased cotton *(Gossypium hirsuturn* L.) yields have resulted when the waste paper was applied in a vertical trench between plant rows. The trenches alleviated the shallow rooting problems associated with a hardpan and the waste paper may decrease the rate at which the hardpan reconsolidates. The cellulose waste offers the benefit of keeping the hardpan from reforming and offers a disposal alternative to landfills.

Vertical mulching of agricultural crop residue was investigated as a method of alleviating heavy straw concentrations left on the soil surface after large yields (Spain & McCune, 1956). 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 increasing water availability and deepening the plant root zone. They found that in the 1st yr of the experiment, large differences in crop yield were achieved due to the benefits afforded by vertical mulching. In later years, however, yields were variable due to heavy winter rains which provided adequate moisture for all plots. A Canadian experiment (Clark & Hore, 1965) found that vertical mulching had little effect on crop yields, soil moisture distribution, unit draft or watertable levels.

Saxton (1980) hypothesized that one reason for the failure of the vertical mulching system developed in the 1950s is that the experimental plots were plowed following the vertical mulching treatment, which sealed the trench surfaces. Saxton (1980) proposed a system by which the mulch was allowed to penetrate the soil surface and intercept free water. The trench would then have a longer lifespan, infiltration would be increased, and the problems associated with surface sealing would be alleviated.

An implement was developed for this application to vertically mulch residue cover in the Pacific Northwest of the USA (Hyde et al., 1986, 1989). Several methods were tested to establish the vertical trenches necessary for the vertical mulch operation. These included vertical shanks, parabolic shanks, and rotary slot cutting devices. They determined that a vertical shank with a 22^o lift angle minimized draft requirements and formed the best slot when combined with a pair of preceding coulters that cut to about one-half the depth of the slot. The slot depth was 26 cm. A machinery system similar to the one developed in the Pacific Northwest region was developed to handle corn *(Zea mays* L.) residue (Edwards & Rumsey, 1989).

Despite successful attempts by researchers to incorporate crop residue into a vertical trench, commercialization of this process has not been successful. Apparently, the potential yield increases have been insufficient to overcome the significant machinery and tillage energy costs. If waste cellulose materials are applied, these machinery and energy costs may be offset by potential payments from municipalities to farmers for disposal of a portion of their solid waste. This would be in addition to any potential yield increases that farmers might achieve. According to Burt et al. (1992) waste disposal costs for municipal landfills very from $44 to $154/Mg, depending on location. They reported that if waste could be applied to agricultural soil at a rate of 27 Mg/ha with a I-m spacing between trenches, landfill costs of $1188 to $4158/ha could be avoided.

To facilitate experiments of this nature, an implement was designed and built at the USDA-ARS National Soil Dynamics Laboratory to disrupt the hardpan and incorporate cellulose material into the trench in one pass. This implement was used in an experiment to determine the response of grain sorghum *(Sorghum bicolor* [L.] Moench) to the tillage/disposal system. Various C/N ratios were examined by mixing poultry litter or liquid ammonium nitrate with the cellulose.

The objectives of this experiment were to:

1. Determine the effectiveness of an implement designed to apply shredded newspaper in a vertical trench in soil.
2. Determine the effect of shredded newspaper applied in a vertical trench between crop rows on crop response.
3. Determine the effect of shredded newspaper applied in a vertical trench between crop rows on hardpan reconsolidation.

METHODS AND MATERIALS

An experiment to investigate vertical trenching of shredded newspaper was conducted near Shorter, AL, at the Auburn University E.V. Smith Experiment Staton. The shredded newspaper was obtained from CEL-PAK[1] (Decatur, AL) who manufactured it for insulation. This material was passed through a 9.5-mm size screen before being packaged into 11.4-kg bundles. A C/N analysis of the shredded newspaper showed it to contain 48% C and less than 0.5% N.

This experiment used an implement developed at the USDA-ARS National Soil Dynamics Laboratory for digging a trench and applying the shredded newspaper in the trench. This implement consisted of a 15-cm wide shank which was used to subsoil to a depth of 61 cm. A large hopper mounted above the shank held the shredded newspaper that was to be applied into the trench. The shredded newspaper was dispensed directly behind the shank to allow some of the cellulose material to flow to the bottom of the trench. Excavations performed during initial trials showed that a uniform mixture was being obtained along the depth of the trench.

Nitrogen was mixed with the cellulose material to adjust its C/N ratio to an acceptable level for plant growth. The purpose of the added N was to optimize yields and minimize the effects of the large quantities of C being placed into the soil. Two different methods were used for this adjustment. The simplest method consisted of mixing a 32% ammonium nitrate solution with the shredded newspaper prior to applying it in the trench. The C/N ratio was adjusted to 25:l using this technique.

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

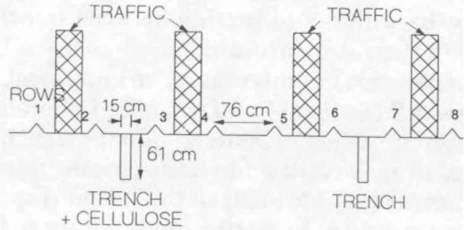

Fig. 12-1. Position of trenches relative to rows.

The second method consisted of mixing poultry litter with the shredded newspaper to achieve this same C/N ratio. A chemical analysis of the poultry litter was performed a few days prior to the experiment and it was found to have 22% C and 3% N. A third C/N ratio was achieved by applying the shredded newspaper directly into the trench without mixing it with any N source. This third ratio was approximately 125:1.

An arrangement of rows and trenches provided a plot area which could be used to determine 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 (Fig. 12-l). 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.

Two different experiments were conducted and each contained four replications. 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 sorghum. A similar experiment was performed in a Norfolk sandy loam soil (fine-loamy, siliceous, thermic Typic Kandindults) with soybean [*Glycine max* (L.) Merr.]. The soybean experiment received no poultry litter treatment.

The trenches were formed and the shredded newspaper applications were made in June 1993. Because very little rain fell for the rest of the summer, a small amount of water was used to irrigate both sets of plots early in the growing season to prevent loss of data. In the grain sorghum experiment, 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.

The soil condition at the end of the 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 forces that roots would 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 experiment across the plot area both inside the trench and in nearby untrenched areas in October 1993, to investigate the effect of trenching on soil condition. A series of 17 measurements were made across the plot in all three different C/N treatments. The soil condition when these measurements were taken was extremely dry which gave large cone index values. Another set of cone index measurements were taken in all treatments in all replications in a saturated soil condition in November 1993. A soil cone penetrometer was inserted both in the trench that contained cellulose and in the trench that did not contain any cellulose at five separate locations within each plot.

Within each plot, two ceramic cup lysimeters with 0.4-µ pore size (Soil Moisture Equipment, Inc., Santa Barbara, CA) were installed midway between the plant row and the trench at depths of 0.3 and 0.6 m. Water samples were taken monthly to determine if any N leaching could be detected, particularly in the plots that received the added amounts of N. No data from these lysimeters was reported in this paper.

Grain yield data were analyzed 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

Grain yield results from the grain sorghum and soybean plots were similar. The most interesting result is the benefit of the rows that were adjacent to the trenches. Grain yields of grain sorghum and soybean 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) (Fig. 12-2 and 12-3). The improved rooting depth afforded by the trench allowed plants adjacent to this area to take advantage of available moisture during a growing season which received little rainfall.

In both the grain sorghum and soybean plots, grain yields were reduced slightly in those plots with shredded newspaper in their trenches. The yield reduction was not statistically significant.

No significant effect of adjusting the C/N ratio of cellulose was found (Fig. 12-4 and 12-5). On the contrary, the crop yield tended to be reduced when these ratios were adjusted, although the differences were not statistically significant.

An effort was made to excavate and visually inspect the trenches for rooting activity near the end of the growing season. Only a small amount

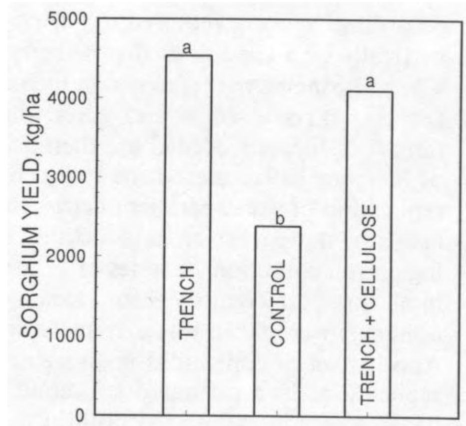

Fig. 12-2. Grain sorghum yield in rows adjacent to trenches (Rows 2 and 3 for cellulose plus trench and Rows 6 and 7 for trench alone) and in control rows (Rows 4 and 5). Means with the same letter are not significantly different at $\alpha = 0.05$.

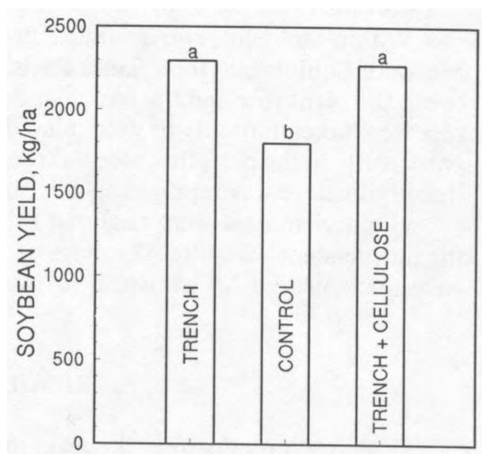

Fig. 12-3. Soybean yields in rows adjacent to trenches (Rows 2 and 3 for cellulose plus trench and Rows 6 and 7 for trench alone) and in control rows (Rows 4 and 5). Means with the same letter are not significantly different at $\alpha = 0.05$.

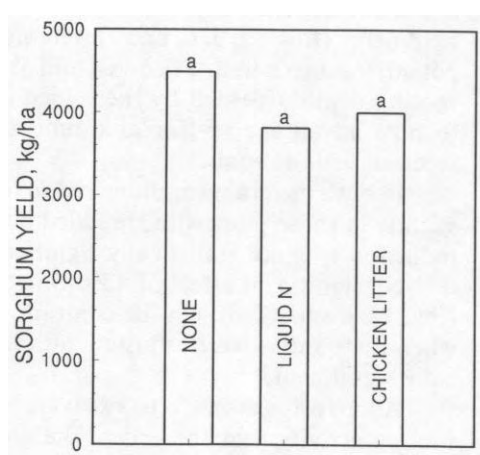

Fig. 12-4. Grain sorghum yields in Rows 2 and 3 adjacent to trenches filled with cellulose material that had C/N ratios balanced to 25:1. Means with the same letter are not significantly different at $\alpha = 0.05$.

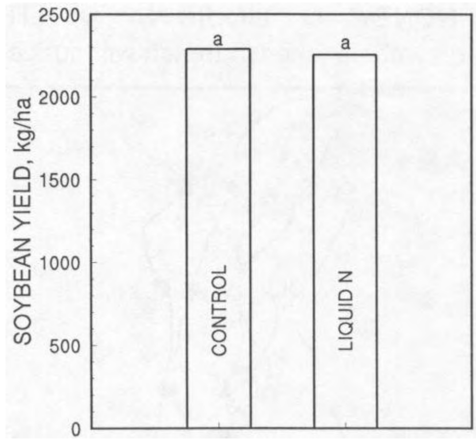

Fig. 12-5. Soybean yields in Rows 2 and 3 adjacent to trenches filled with cellulose material that had C/N ratios balanced to 25: I Means with the same letter are not significantly different at $\alpha = 0.05$.

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. The results show that the effect of the trench is much broader than the 15-cm width of the tillage tool (Fig. 12-6). This is evident in both trenches, with and without cellulose.

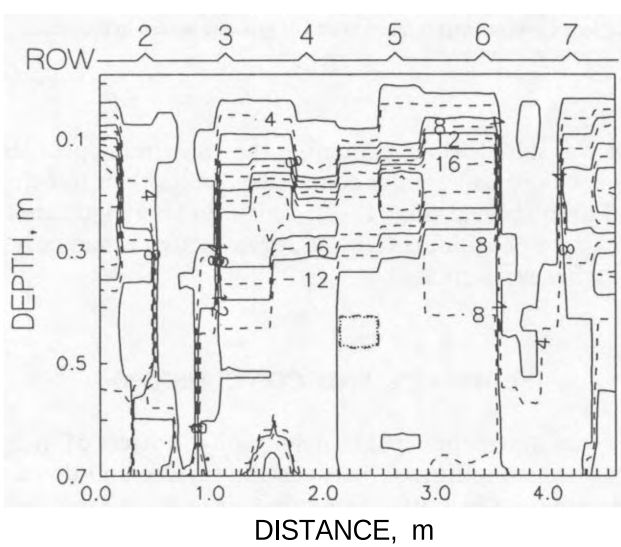

Fig. 12-6. Cone index (MPa) profile taken at end of growing season across the grain sorghum experiment with the cellulose trench between Rows 2 and 3 and the non-cellulose trench between ROWS 6 and 7. The C/N treatment for this plot was ammonium nitrate.

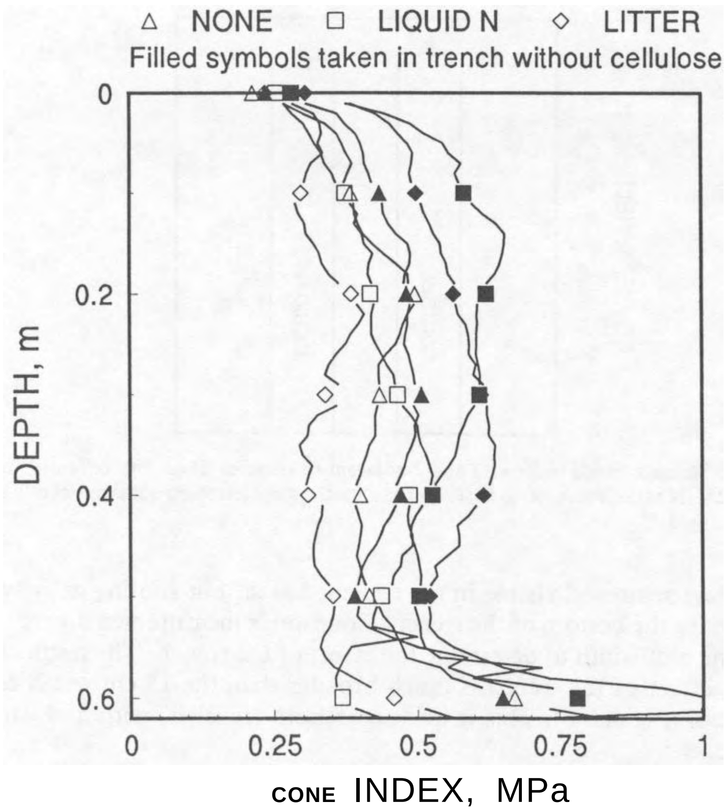

Fig. 12-7. Cone index measurements taken at end of growing season in the center of the trenches of the grain sorghum experiment.

A trend was noted while examining the cone index profiles: trenches without any cellulose had greater cone index values than trenches in which cellulose had been applied (Fig. 12-7). This trend may indicate that reconsolidation is already beginning to occur, even though it had only been 5 mo since the trenches were created.

SUMMARY AND CONCLUSIONS

Experiments were conducted to determine the effect of inserting cellulose waste in a trench uniformly between the surface and down to a depth of 61 cm between rows in a grain sorghum and soybean experiment. An implement was designed and built to disrupt the hardpan and incorporate these cellulose materials into the trench in one pass. The cellulose application implement performed well and enabled shredded newspaper to be applied uniformly in a vertical trench.

The vertical trench provided a dramatic positive rooting environment improvement over soil that was not subsoiled and this benefit was reflected in grain sorghum and soybean yields. At the end of the growing season, a trend was found toward reduced reconsolidation in trenches formed with shredded newspaper applied in the trenches as compared to trenches formed without shredded newspaper applied in the trenches. Decreasing the C/N ratio of the shredded newspaper to 25:l also was found to have no effect on grain sorghum or soybean yields.

ACKNOWLEDGMENTS

The authors would like to thank B.H. Washington, Design Engineer at the USDA-ARS National Soil Dynamics Laboratory in Auburn, Alabama, for his contribution in designing the combination trenching and cellulose disposal implement. This manuscript is designated Journal Series no. 2-933676 by the Alabama Agricultural Experiment Station.

REFERENCES

American Society of Agricultural Engineers. 1993. Soil cone penetrometer. ASAE, St. Joseph, MI.

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.

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

Curley, R.G., B.A. Krantz, J.A. Vomicil. and W.J. Chancellor. 1958. Vertical mulching; one possible solution to soil compaction problems. Univ. California Agric. Ext. Stn. Bull.

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. p. 1143-1146. *In* Proc. of the Beltwide Cotton Conf., Vol. 3, Nashville, TN. 6-10 January. Natl. 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. Utiliz. 1:79-92. 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. p. 225-249. *In* D.L. Karlen et al. (ed.) Agricultural utilization of urban and industrial by-products. ASA Spec. Publ. 58. ASA, CSSA, and SSSA, Madison, WI.

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

Hyde, G.M., J.E. George, K.E. Saxon, and J.B. Simpson. 1989. Slotmulch insertion machine: Design and performance. ASAE Paper no. 891502. ASAE, St. Joseph, Ml.

Rathie., W.L. 1991. Once and future landfills. National Geographic, May, p. 116-134.

Saxton, K.E. 1980. Slot mulch tillage for water management and reduced erosion. p. 42-49. *In* Proc. Conf. on Crop Production with Conservation in the 80's. Vol. 3, Chicago, IL. 1-2 December. ASAE, St. Joseph, MI.

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