DEVELOPING CONSERVATION TILLAGE SYSTEMS FOR COTTON IN THE TENNESSEE VALLEY: IN-ROW TILLAGE AND COVER CROP EFFECTS

R.L. Raper, D.W. Reeves
USDA-ARS National Soil Dynamics Laboratory
Auburn, AL
C.H. Burmester
Alabama Agricultural Experiment Station
Auburn University, AL

Abstract

Declining cotton (*Gossypium hirsutum* L.) yields have plagued farmers trying to eliminate tillage from their farms in the Tennessee Valley Region of North Alabama. Many farmers have tried to reduce tillage to meet conservation compliance programs, but have found inadequate rooting systems due to excessive soil compaction severely reduced yields. Experiments were initiated in this region in 1995 to develop conservation tillage systems that incorporated rye (*Secale cereale* L.) cover crops and in-row tillage as a method of maintaining surface cover and disrupting root-impeding layers. This research project also investigated energy requirements of shallow tillage (7") and deep tillage (13") performed in the fall and spring. Seed cotton yields similar to conventional cropping systems were found using the rye cover crop with no-tillage. Decreased yields were found when any form of spring tillage was used. Slightly improved yields occurred when shallow fall tillage was used with a winter cover crop. This conservation tillage practice may offer the best alternative for farmers trying to reduce the negative effects of soil compaction, maintain adequate residue cover, and improve seed cotton yield.

Introduction

Cotton farmers in the Tennessee Valley Region of North Alabama have experienced problems maintaining yields when their highly erodible soils were placed in conservation tillage systems. Many of these soils have been conventionally farmed for more than 100 years. USDA-NRCS (Natural Resource Conservation Service) has mandated that these soils be managed using conservation tillage systems for the farmers to participate in farm programs. Traditional methods of moldboard plowing, chisel plowing, and disking do not leave adequate amounts of crop residue on the surface to meet compliance standards and protect soil from erosion. Because of low amounts of residue produced by cotton, minimum or no-tillage is often required to maintain adequate surface residue coverage.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:621-623 (1998)
National Cotton Council, Memphis TN

Soil compaction problems also plague this region, with soil containing platy structure and exhibiting considerable strength at relatively shallow depths, particularly in no-till fields. Many cotton tap roots have bent at 90-degree angles at depths of less than 6 inches when cotton was directly planted back into the previous year's cotton stubble. Management systems are needed to either loosen the soil profile or increase soil moisture in order to reduce soil strength and increase rooting depth.

This research effort was targeted toward developing minimum tillage systems that would minimally disturb the soil while maintaining adequate surface residue coverage. The timing of the tillage was also investigated to determine whether tillage performed in the fall (when time is readily available) would benefit cotton as much as spring tillage performed immediately before planting. Cover crops were also used to generate additional surface residue and to retain soil moisture.

Materials and Methods

Fall tillage treatments were first applied in the fall of 1994 at the AAES Tennessee Valley Substation in Belle Mina, AL. The soil type in this region is predominantly a Decatur silt loam (clayey, kaolinitic, thermic Rhodic Paleudult). The field had been used for conventional cropped cotton for many years previous to this experiment. The plots are four 40-inch rows wide by 30 ft. long. The experimental design consists of a randomized complete block with 2x2x3 factorial treatments with an additional treatment of conventional tillage. The three factors are: 1) cover crop (none or rye), 2) tillage timing (fall or spring), and 3) tillage depth (none, shallow, or deep). The depth of tillage was established by taking multiple cone-index profiles of the field and determining the depth and thickness of the root-impeding layer. This layer was located at an approximate depth of 6 inches and extend downwarded for about 1 inch. Therefore, the shallow depth of tillage was chosen as 7 inches and the deep depth of tillage was set to be at 13 inches. An experimental Yetter™ implement with in-row subsoilers that could be adjusted to operate at both shallow and deep depths was used for all tillage treatments. Residue managers that consisted of fingered wheels and fluted coulters were used to move residue away from the shanks. Closing disks were also mounted on the rear of the shank to create a small bedded region approximately 12 inches wide and 4 inches high that could be planted into. The conventional tillage treatment consisted of fall disking and chiseling followed by disking and field cultivating in the spring prior to planting.

Soil strength and soil moisture measurements were taken both spring and fall immediately before and after tillage treatments were applied. Soil strength was determined by using a tractor-mounted multiple-cone penetrometer (ASAE, 1997) and then calculating the cone index. Five penetrometer probes were inserted 1) in the row, 2) midway between the row and the untrafficked row middle (10 inches from the row), 3) in the untrafficked row middle (20 inches from the row), 4) midway between the row and the trafficked row middle (10 inches from the row), and 5) in the trafficked row middle (20 inches from the row). Soil moisture was determined gravimetrically (105° C) at shallow (0-6 inches) and deep (6-12 inches) depths.

Tillage energy was measured by using a tractor-mounted three-point hitch dynamometer that was capable of measuring draft, vertical, and side forces. This device was attached to the Yetter™ implement and measured tillage forces for all spring and fall tillage treatments.

Cotton yields were obtained for the growing seasons of 1995, 1996, and 1997. Data were analyzed using SAS and a randomized complete block model. Also, contrasts were used to individually compare the conservation tillage treatments to the conventional tillage treatment. A predetermined significance level of $P \leq 0.05$ was chosen to separate treatment effects.

Results and Discussion

The most recent cone index measurements taken in the row in the fall of 1997 show the benefits afforded to those plots that were tilled the previous fall (Figure 1). The filled symbols that indicate the deep tillage treatment show the loosened soil depth extends down to approximately 13 inches while the shallow tillage treatment loosens a zone down to about 7 inches. These profiles contrast greatly with the soil conditions in plots that received no tillage. The effect of the cover crop seems to slightly increase cone index at most depths for all tillage treatments.

The cotton yield of 1995 is not reported in this paper because of a severe boll worm infestation that severely decreased seed cotton, particularly in those plots with larger and healthier plants. Statistical analysis of the 1996 yield (which was aided by ample rainfall; Table 1) only shows a cover crop effect. When the conventional tillage treatment was contrasted with the other factors, only the effect of the rye cover crop was close to being significant ($P \leq 0.0583$). Statistical analysis of the 1997 yield (which was drought stressed; Table 1) showed many significant effects: tillage timing, tillage depth, and cover crop. The conventional tillage treatment was found to be superior to spring tillage treatments, deep tillage treatments, and no cover crop treatments.

As expected, similar energy requirements were found for each of the three sets of yearly energy data (Table 2). The previous fall and spring's energy data were included together for statistical analysis because of their combined respective influence on the crop. In the first two years' analysis, the effect of timing of tillage (either spring or fall) was significant. Fall tillage usually required lesser horsepower requirements, with the exception of the first year's data at the deeper tillage depth. Also, in each of the three years, the effect of tillage depth was significant. Shallow tillage (approximately 7") usually required 50% of the horsepower requirements of deep tillage (approximately 13"). In the second and third year's analysis, a trend existed that indicated that a cover crop caused an increase in tillage forces. The large amounts of residue that had to be sheared or moved by the residue managers may have contributed to these increased draft forces.

The cotton yield data indicates that the presence of a cover crop provides the greatest potential for improving yields with conservation tillage systems. Comparable yields with conventional farming systems can be achieved through the use of a cover crop. Fall tillage also seems to offer slight benefits over no-tillage and substantial benefits over spring tillage. Tilling deeper than necessary to disrupt the hardpan was also found to not increase yields, but actually caused yield decreases. The 25 hp energy requirements of the shallow tillage treatment make it possible for farmers to till 8 rows at a time with their large tractors to ameliorate the effects of severe surface soil compaction. Most farmers are reluctant to till less than this width because of the time and energy costs involved. Farmers adopting conservation tillage systems that include cover crops and shallow fall in-row tillage should receive excellent soil protection from erosion, reduced soil compaction effects, and superior crop yields.

Summary

Competitive crop yields with conventional tillage systems were obtained by conservation tillage systems that incorporated cover crops. Slightly increased, seed cotton yields were obtained by using shallow fall tillage that only went deep enough to disrupt the root-impeding layer. Energy measurements indicate that farmers wishing to utilize this conservation tillage practice can till 8-rows at a time with their large tractors and minimize the negative effects of soil compaction and root-impeding layers.

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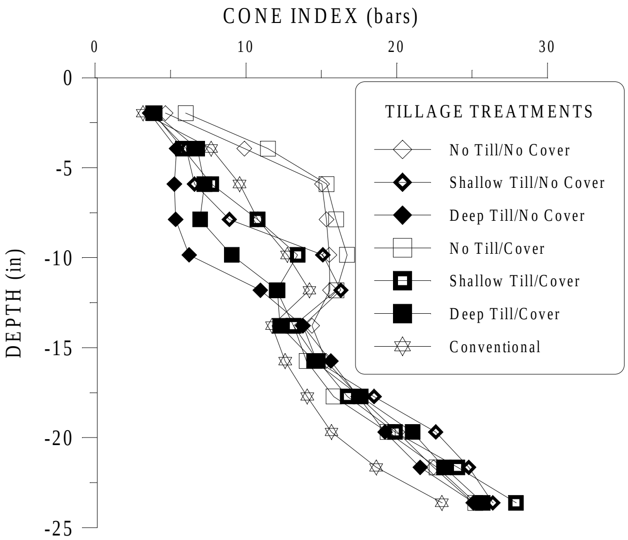

Figure 1. Cone index profiles of tillage treatments performed in fall taken immediately beneath the row.

Table 1. Seed Cotton Yields

Tillage Treatment	Cover Crop	1996 Seed Cotton Yield (lbs./ac)	1997 Seed Cotton Yield (lbs/ac)	Average (lbs/ac)
No-Till	Yes	3534	2838 ab*	3186
Fall-shallow	Yes	3689	3000 a	3345
Fall-deep	Yes	3651	2690 abcd	3170
Spring-shallow	Yes	3709	2491 bcde	3100
Spring-deep	Yes	3575	2456 cde	3015
Conventional	No	3338	2823 abc	3081
No-Till	No	3332	2567 bcd	2951
Fall-shallow	No	3242	2420 de	2831
Fall-deep	No	3414	2393 de	2904
Spring-shallow	No	3512	2380 de	2946
Spring-deep	No	3479	2162 e	2821

*Within each year, means with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).

Table 2. Tillage Draft Energy

Tillage Treatment	Cover Crop	1995 Crop Year Draft Energy (hp)	1996 Crop Year Draft Energy (hp)	1997 Crop Year Draft Energy (hp)	Average (hp)
Fall-shallow	Yes	27.2 bc*	15.6 e	30.6 c	24.5
Fall-deep	Yes	56.3 a	35.7 b	58.7 a	50.2
Spring-shallow	Yes	19.4 c	26.1 cd	48.3 ab	31.3
Spring-deep	Yes	27.1 bc	60.7 a	47.1 ab	45.0
Fall-shallow	No	24.9 bc	14.8 e	27.6 c	22.4
Fall-deep	No	55.3 a	31.7 bc	52.2 a	46.4
Spring-shallow	No	21.2 bc	21.9 de	36.8 bc	26.6
Spring-deep	No	30.1 b	56.8 a	48.0 ab	45.0

*Within each year, means with the same letter are not significantly different at $\alpha = 0.05$ (LSD test).