Optimizing Conservation Tillage Production: Soil Specific Effects of Management Practices on Cotton, Soybean, and Wheat

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ABSTRACT

Our objective was to determine if crops grown on different soil types differed in their yield response to residue management systems. Two large experiments were conducted near Florence, SC on a field where soil type was mapped on a 100-ft grid. In the first experiment, cotton (*Gossypium hirustum* L.) was grown with conventional and conservation tillage with residue covers of cotton stubble, rye (*Secale cereale* L.) winter cover crop stubble, or corn (*Zea mays* L.) stubble. In the second experiment, a wheat (*Triticum aestivum* L.) and soybean (G*lycine max* L.) double crop system was grown with different surface and deep tillage treatments, and these treatments were compared against a two-year wheat-soybean-corn rotation. Only data from two soil map units (Norfolk loamy sand and Bonneau loamy sand) were used in this analysis. Interactions occurred for yield between soil management factors and soils for cotton and wheat yield, but not for soybeans. Most soil-specific yield responses to these management factors occurred primarily within the conventional tillage regime. For all three crops, both soils had similar yield responses to the soil management factors when conservation tillage was used. Our data indicate that across soil map units, the yield response to residue management inputs is more predictable with conservation tillage than with conventional tillage.

KEYWORDS

Cotton, wheat, soybean, tillage, cover crops

INTRODUCTION

Soil management practices that optimize conservation tillage production are likely to be soil specific (Triplett, 1986), and profit margins will partially dictate the use of a specific management option. Two relatively expensive practices for conservation tillage crop production that are recommended for coastal plain soils are the use of cover crops to increase the amount of surface residues and the use of deep tillage to alleviate compaction. Both practices generally increase plant available water, or at least reduce the effects of water-deficit stress. We hypothesized that plant productivity in response to these management techniques would be soil specific and conducted two experiments to determine the effect of these soil management practices on crop yield. The objective of the first experiment was to determine if Norfolk and Bonneau soils differed in their response to residue management systems for cotton yield. The objective of the second experiment was to determine if these soils differed in their yield response to deep tillage and rotation with corn for double cropped wheat and soybean.

MATERIALS AND METHODS

These two experiments were initiated in the fall of 1996 at Clemson University's Pee Dee Research and Education Center near Florence SC. Both experiments were grown in the same field, and corn was grown in the summer of 1996 prior to the start of these trials. For both experiments, large plots were used (≥400 feet long) and each plot contained several soil map units. Plots were subdivided into 50 ft long subplots. Soil type was determined for each subplot based on a soil map of the field that was generated by USDA-NRCS soil scientists who mapped the field on a 100-ft grid. For this paper, only data from the Norfolk loamy sand (Typic Kandiudult) and Bonneau loamy sand (Arenic Paleudult) are included. These are two common soil types in agricultural fields on the coastal plain of the southeast USA. The Norfolk loamy sand is a very deep, well-drained soil where the loamy sand texture changes to a sandy clay loam texture within 17 inches of the surface. This is a

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productive soil with no major agronomic management concerns. Dissimilar to the Norfolk is the Bonneau soil. The Bonneau soil is also a very deep, well-drained soil, but the loamy sand texture reaches to a depth of 38 inches. Major agronomic considerations for this soil are doughtiness, low nutrient holding capacity, and high wind erosion potential (Anonymous, 1992).

Cotton Experiment

This experiment was designed to provide a range in residue covers, with a large amount of residue with cotton following a corn crop, a medium amount of residue with continuous cotton with a rye winter cover crop, and a low amount of residue with continuous cotton with winter fallow. Treatments were tillage (conservation tillage and disking) and residue type (fallow, rye winter cover crop, and corn stubble). Experimental design was randomized complete block and there were three replicates. Plot size was twelve 38-inch wide cotton rows that ranged in length from 400 to 700 ft long. Treatment assignments to plots remained the same each year.

Rye (approximately 100 lbs seed per acre) was planted in designated plots during the fall of each year. In 1997, 1999, and 2001 corn was planted in early April in designated plot. Corn was grown in 30-inch wide rows in 1997 and in 15-inch wide rows in 1999 and 2001. Seeding rates were 24,000 seeds per acre in 1997 and 30,000 seeds per acre in 1999 and 2001. Cotton was planted in early May each year. Seeding rates were approximately 4 seeds per foot of row in 1997 through 2000. Because of a planting error, seeding rates were approximately 7 plants per foot in 2001.

The conservation tillage management consisted of killing existing vegetation with herbicides at least two weeks before planting cotton each year. Herbicides used were glyphosate only in 1997, 1998, and 1999 and glyphosate and 2, 4-D in 2000 and 2001. The conventional tillage plots were disked twice and smoothed with an S-tined harrow equipped with rolling baskets about two weeks before planting cotton. Just prior to cotton planting, plots were deep-tilled to approximately 14 inches with a six-legged paratill. Shanks on the paratill were spaced 26 inches apart to allow for nearly complete loosening of the surface layer. This same tillage and weed management procedure was used prior to planting the corn plots in 1997, 1999, and 2001.

Lime and fertilizer applications were made as recommended for rainfed cotton by Clemson University Extension. Plots were scouted regularly and insecticide applications were made as needed to control insect pests. Two interior rows of each plot were harvested with a spindle picker. Samples of seedcotton were collected from the harvest bags from each subplot. These samples were ginned and lint percent was calculated from the ginout data.

Wheat-Soybean Experiment

This experiment was designed to evaluate surface and deep tillage in a continuous wheat-soybean double crop rotation and to compare those treatment combinations to deep-tilled wheat and soybean grown in a two-year rotation with corn. Treatments for the continuous wheat-soybean rotation were surface tillage (disking and conservation tillage) and deep tillage (paratill and no deep tillage). Surface tillage (disking and conservation tillage) was the only variable investigated for the wheat and soybeans grown in rotation with corn. Because deep tillage was not evaluated in the corn rotation treatment, we did not have a true factorial experiment in regard to tillage and rotation. Therefore, the four combinations of surface and deep tillage and the two treatments that included rotation with corn were treated as six soil management levels in the analysis of variance. Experimental design was randomized complete block and there were three replicates. Plots were 30 feet

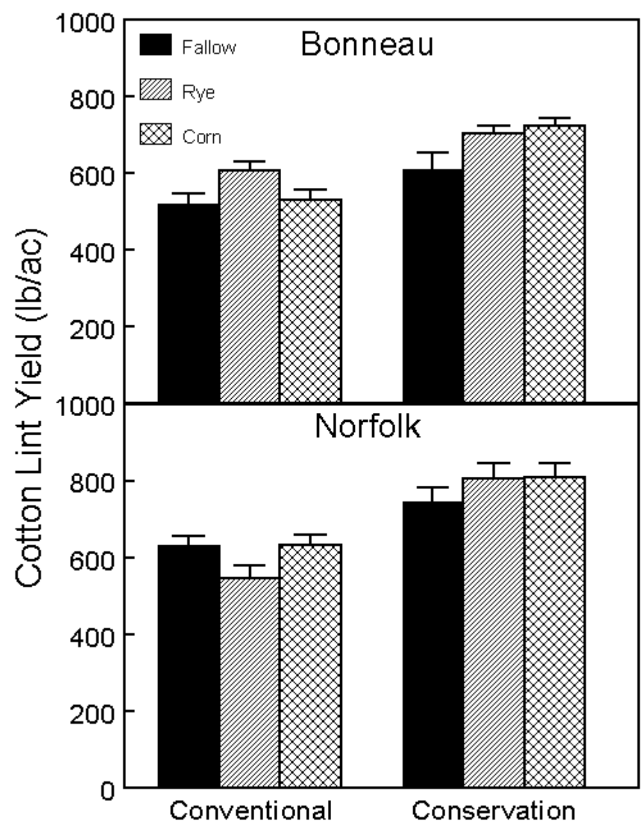

Fig. 1. Effect of residue cover and tillage on lint yield of cotton grown on two soil types near Florence, SC. Bars indicate continuous cotton (Fallow), continuous cotton grown with a rye winter cover crop (Rye), and cotton rotated with corn (Corn). Error bars are standard errors of means.

wide and 500 feet long, and treatment assignments to plots remained the same each year.

The soybeans and wheat were grown in 7.5-inch wide rows at recommended seeding rates (4 seeds per foot of row for soybean and 8 seeds per foot of row for wheat). Wheat was planted in November each year; soybeans were planted in June. In the plots rotated with corn, the corn was planted in April of 1998 and 2000. Row spacing for the corn was 30-inches wide in 1998 and 15-inches wide in 2000.

The conservation tillage management consisted of killing existing vegetation with herbicides and planting the crop. The conventional tillage plots were disked twice and smoothed with an S-tined harrow equipped with rolling baskets prior to planting. Just before planting, plots that received deep tillage were deep-tilled to approximately 14 inches with the same six-legged paratill that was used in the cotton experiment.

Lime and fertilizer applications were made as recommended for these crops by Clemson University Extension. Yields were determined by harvesting the plots with a combine equipped with an eight-foot wide cutting bar. Samples were collected from each harvest bag for seed moisture determinations.

RESULTS

Cotton Experiment

All treatments (including the cotton grown into corn stubble) were evaluated only in 1998 and 2000. Therefore, only data from those two years were included for this analysis.

Significant sources of variation for lint yield from the analysis of variance included soil, tillage, the tillage x year interaction (all $P \leq 0.01$), and the cover x tillage x soil interaction ($P = 0.1$). As expected, the Norfolk soil produced higher cotton lint yield than the Bonneau soil. Average yield of the cotton grown on the Norfolk soil was 700 lb/ac while lint yield of the cotton grown on the Bonneau soil averaged 629 lb/ac. Conservation tillage resulted in higher lint yield than conventional tillage both years, but the difference between the two tillage systems was 225 lb/ac in 1998 and only 83 lb/ac in 2000.

The nature of the cover x tillage x soil interaction indicates that residue management practices for the two tillage systems are soil specific. For cotton grown with conventional tillage, lint yield of the crop following a winter rye cover crop had higher yield than continuous cotton with winter fallow or cotton rotated with corn on the Bonneau soil (Fig. 1). On the Norfolk soil, however; cotton grown following the rye winter cover crop had lower yield than the other two residue types. There was no difference between continuous cotton grown with winter fallow and cotton grown in rotation with corn on either soil (Fig. 1). With conservation tillage, the yield response to the residue types was the same on both soils. Lint yield was lowest when the only residue cover was cotton stubble, and there was no difference between continuous cotton grown with a rye winter cover crop and cotton grown in rotation with corn.

Wheat-Soybean Experiment

Since all treatments, including the wheat and soybeans grown in rotation with corn, were only grown in 1999 and 2001, only data from those two years were included for this analysis. Both 1999 and 2001 had lower than average rainfall for both wheat and soybean growing seasons, and this resulted in low yields for this experiment (Figs. 2 and 3).

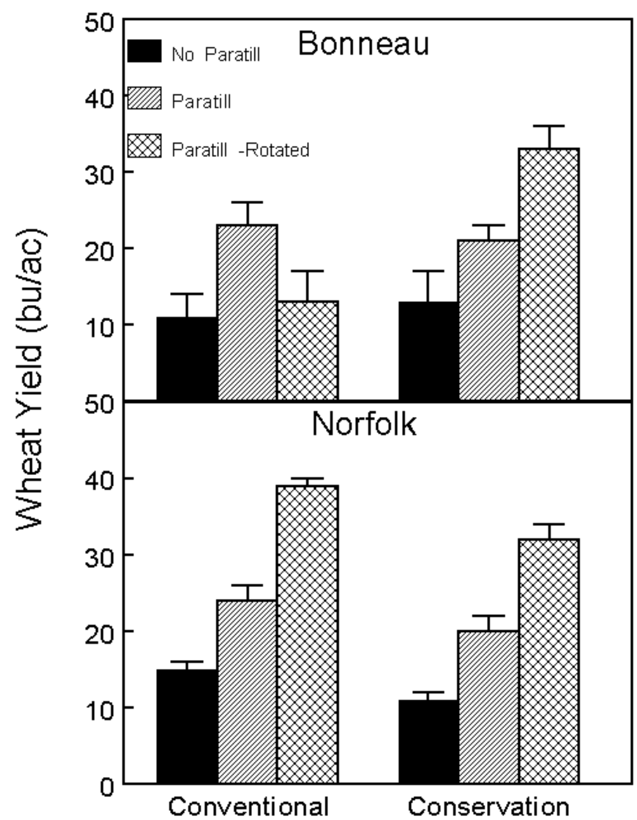

Fig. 2. Effect of surface and deep tillage and rotation with corn on yield of wheat grown in a wheat-soybean double crop system on two soil types near Florence, SC. Bars indicate continuous wheat-soybean with no deep tillage (No Paratill), continuous wheat-soybean with deep tillage (Paratill), and wheat-soybean rotated with corn with deep tillage (Paratill-Rotated). Error bars are standard errors of means.

For wheat yield, significant sources of variation from the analysis of variance were year, soil, soil management, and the soil x soil management interaction (all $P \leq 0.01$). Average wheat yields were 31 bu/ac in 1999 and 19 bu/ac in 2001. Similar to the results from the cotton experiment, average wheat yield was greater on the Norfolk soil (26 bu/ac) than on the Bonneau soil (23 bu/ac). Deep tillage with a paratill increased yield on both soils in both conventional and conservation tillage (Figure 2). The soil X soil management interaction was primarily the result of the wheat yield response to rotation with corn. For conventional tillage on the Norfolk soil and for conservation tillage systems on both soils, rotating with corn resulted in substantially higher yield than continuous wheat-soybean. On the Bonneau soil with conventional tillage, however, yield for the wheat rotated with corn was lower than wheat yield from the continuous wheat-soybean treatment that was paratilled (Fig. 2).

For soybean yield, significant sources of variation from the analysis of variance were year, soil, soil management, and the soil management X year interaction. Average soybean yields were 29 bu/ac in 1999 and 15 bu/ac in 2001. Soybean yield on the Norfolk soil average 23 bu/ac and yield on the Bonneau soil averaged 20 bu/ac. The soil management X year interaction was primarily due to magnitude differences between treatment combinations between years and not ranking. Lower yields in 2001 than in 1999 resulted in smaller differences between treatments in that year.

The Norfolk and the Bonneau soils had similar soybean yield response to the treatment combinations; the soil X soil management interaction was not significant ($P = 0.16$). For both conventional and conservation tillage on both soils, lowest yield was generally for soybean grown without deep tillage, and greatest yield was for soybeans rotated with corn (which was deep tilled) (Fig. 3).

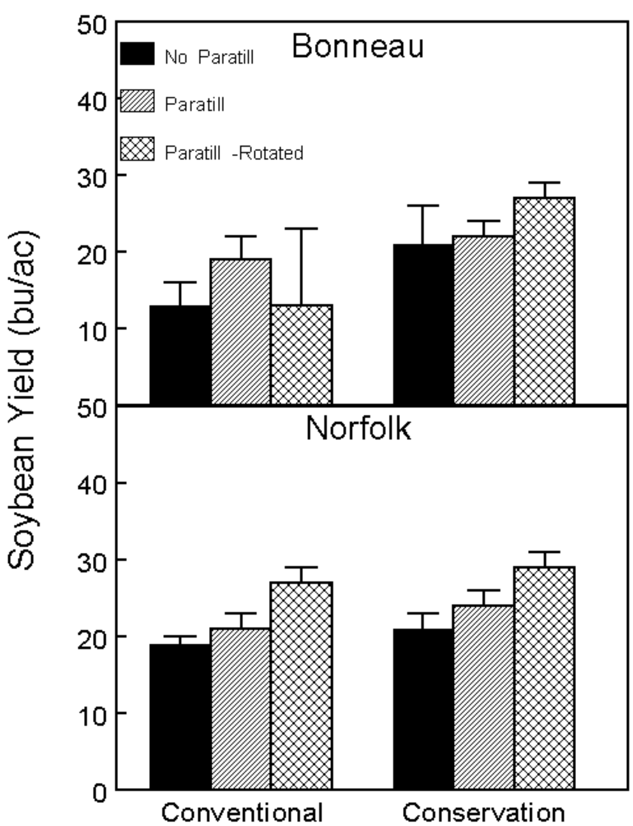

Fig. 3. Effect of surface and deep tillage and rotation with corn on yield of soybean grown in a wheat-soybean double crop system on two soil types near Florence, SC. Bars indicate continuous wheat-soybean with no deep tillage (No Paratill), continuous wheat-soybean with deep tillage (Paratill), and wheat-soybean rotated with corn with deep tillage (Paratill-Rotated). Error bars are standard errors of means.

SUMMARY

Some results of this experiment support and some results are contrary to our hypothesis that soil management systems are specific to these two soils. Interactions occurred between the management factors and the soils for cotton and wheat yield, but did not occur for soybeans. However, inspection of Figures 1, 2, and 3 indicate that the soil-specific yield responses to these management factors occurred primarily within the conventional tillage management regime. For all three crops, both soils had similar yield responses to the treatments we evaluated when conservation tillage was used. Although further research is needed to support these findings, they suggest that grower returns to management practices may be more predictable throughout and across fields when conservation tillage is used.

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