CONSERVATION TILLAGE FOR BETTER IRRIGATION AND WATER MANAGEMENT IN CORN PRODUCTION

Dinku Endale[1*], James Hook[2], Dana Sullivan[3], Wilson Faircloth[4], Dewey Lee[2], Wayne Reeves[1], Diane Rowland[4]

[1] USDA-ARS, J. Phil Campbell Nat. Res. Cons. Center, Watkinsville, GA
[2] University of Georgia, Crop and Soil Sciences Dept., Tifton GA
[3] USDA-ARS, Southeast Watershed Research Laboratory, Tifton GA
[4] USDA-ARS, National Peanut Research Laboratory, Dawson GA

*Corresponding author's email Dinku. Endale@ars.usda.gov

ABSTRACT

In order to take advantage of the increasing demand for and price of corn related to the unprecedented growth of the corn-based ethanol industry, growers in the Southeast need to alleviate weather and soil limitations that have hindered corn production in the region. We present two years of preliminary results from an ongoing research with objectives to demonstrate the potential of high residue conservation tillage to enhance water conservation and improve irrigation and water use efficiency in corn production. The research is being conducted within two irrigated corn-cotton-peanut rotation studies at University of Georgia research stations at Camilla and Tifton, GA. All crops in the rotation are present each year but this research focuses only on each year's corn crop. At each location treatments are assigned to nine 30 ft x 70 ft plots in four complete blocks in a factorial arrangement consisting of 2 tillage (conventional (CT) without a rye cover crop on 4 plots and strip-tillage (ST) with a rye cover of high residue on 4 and low residue on 1 plot) by 4 irrigations (spanning the zero to full irrigation scale). Strip-tillage enhanced infiltration. While still within statistical margin of error, this led to slightly taller plants with more biomass (stalks and leaves) at tasselling. Corn grain yield differentials arising from tillage treatments have not yet materialized. In non-irrigated plots, grain yield remained 40 to 50 bu ac^{-1} at Camilla and 40 to 100 bu ac^{-1} at Tifton, while fully irrigated plots produced 200 to 250 bu ac^{-1}. Improvement in residue management (raising high residue and being able to plant into it) and developing the irrigation schedule strategies that would capture the advantages of the enhanced infiltration under strip-tillage continue to be areas of research.

INTRODUCTION

Renewable bio-energy production has substantially increased the price and demand for corn (*Zea mays* L.) in the last few years. In response to the enactment of the Renewable Fuels Standard in 2005, mandating the use of 7.5 billion gallons of renewable fuel in the USA by 2012 (from about 4 billion gallons in 2006), the corn-based ethanol industry is expanding at an unprecedented rate (Renewable Fuels Association, 2006). As a result, future corn acreages in the USA are soon expected to be at their highest since 1944 (CTIC, 2007). Corn growers in the US planted over 90 million acres in 2007. Paradoxically, with large production increases corn prices also have been increasing at unprecedented rates. In Georgia corn acreage went up from 275,000 acres in 2006 to 520,000 acres in 2007 (Ethanol Producer Magazine, December 2007 Issue). Unfortunately in Georgia and much of the Southeast, only irrigated corn was able to survive the 2007 season's harsh drought. Corn production in the Southeast has faltered in recent decades due to erratic, at times very low, yields brought about by dry hot weather during the traditional May through July growing season (1.6 million acres in the

1970s to less than 300,000 in 2006, with most decline occurring in the 1980s; CAES, 2007). In early January 2007, a plan for the largest bio-fuel (corn-to-ethanol) plant in the Southeast broke ground. The 36-million-bushel-a-year Mitchell County plant must purchase corn from the mid-west because not enough is grown locally. Although Georgia has long been a corn-deficit state, it now has opportunities to offset massive imports of corn.

In order to compete in the new corn market, producers in the southeastern USA need to overcome the region's soil and water limitations. Many soils in the southeastern USA have low water holding capacity and/or root restrictive layers. Crusting is also a problem because the soils are low in organic matter and this increases runoff from fields. Conventional tillage methods, such as disking and harrowing, promote the development of these soil conditions and increase runoff. High residue conservation tillage systems have been shown to improve soil quality through increased organic matter and infiltration, and reduce runoff and soil loss compared with conventional tillage (Bradley, 1995; Endale et al., 2002; Reeves, 1997; SWCS, 2006; Terra et al., 2005). Recent research in Georgia has estimated that conservation tillage, especially with high residue producing cover crops might be able to reduce statewide irrigation needs (cotton, corn and peanut) by as much as 12% (Reeves et al., 2005). Efficient irrigation is needed not only to conserve water but also to maximize yield

With the anticipated increase in corn production in the southeastern USA, and elsewhere, more research is required quantifying grain and biomass differentials arising from different choices of tillage and water management to help corn producers make informed decisions. Our objective is evaluate how high residue strip-tillage corn compares to one of low residue strip-tillage and conventional tillage corn with respect to irrigation timing and amount and corn growth and yield on two typical Coastal Plain soils. We then want to develop and validate practical irrigation schedules for consistent high yields and quality in corn.

MATERIALS AND METHODS

This on-going cooperative project is being conducted in two irrigated corn-cotton-peanut rotation studies established in 2002 at University of Georgia research stations at Camilla (Stripling Irrigation Research Park; soil Orangeburg loamy sand, Fine-loamy, silicelous, thermic Typic Kandiudults) and Tifton (Lang Farm; soil Tifton loamy sand, Fine-loamy, kaolinitic, thermic Plinthic Kandiudults), using winter grain cover and conservation (strip) tillage annually. All phases of the rotation are present each year. There are four replicated blocks per crop in a randomized complete block design, each of nine 30 x 70 ft plots. This paper focuses on the corn phase, now in place for three years. Tillage treatments [conventional (4 plots per block) and conservation *strip-till* (5 plots per block); CT and ST] are in a factorial arrangement with four irrigation treatments as described below. The strip-till in each block is further divided into high-residue (4 plots) and low-residue (1 plot) treatments. A linear-move precision application system applies irrigation water to individual plots based on treatments. Soil water content to 3 ft is measured manually two to three times per week in two or more replications (depending on availability of equipment) with capacitance-based soil water sensors. Soil water content at three depths is also measured and logged continuously in one replication using Watermark soil moisture sensors to follow daily cycles of wetting and drying. Telemetry is used to access continuous soil water data to track daily water use and make irrigation decisions.

In 2006 the following four irrigation treatments were imposed: (1) a conservation and a conventional till plot pair was irrigated when the conventional till (bare) soil was dry enough for irrigation (soil water potential above 30 mb); (2) another pair and the low-residue strip-till were irrigated when the conservation till (high residue) soil was dry enough for irrigation; (3) a third pair used *IrrigatorPro-Corn software* for scheduling; and (4) the last pair received no irrigation. In 2007 we modified our irrigation treatments to induce more irrigation treatment effect as the 2006 schedules did not demonstrate clear-cut treatment effects with exception of the dry treatment. The new 2007 schedules were: (1) no-irrigation (except stand establishment) on a pair of CT and ST plots; (2) another CT-ST pair full irrigation to maintain soil water tension above 30 mb on the ST plot (Treatment 9); (3) when treatment 9 reaches V10, irrigate one inch to recharge the soil then every time treatment 9 is irrigated; and (4) when treatment 9 reaches V14, irrigate one inch to recharge the soil then every time treatment 9 is irrigated.

The cropping schedule consisted of growing rye as cover crop in the fall/winter and corn in summer. Approximate dates were: 15 Nov. 2005 to 20 Mar. 2006, 23 Oct. 2006 to 27 Mar. 2007 and 15 Nov. 2007 to 15 Mar. 2008 for cover crop; 22 Mar. 2006 to 10 Aug. 2006, 29 Mar. 2007 to 13 Aug. 2007 and 4 Apr. 2008 to 15 Aug. 2008 for corn. For the high-residue strip-till treatment the cover crop N-fertilizer was applied in early February and the rye was chemically killed two weeks before corn planting. There was no N-fertilization on the low-residue strip-till treatment. The conventional tillage plots have no winter rye cover. Agronomic and cultural practices follow regional and local UGA recommendations. We selectively sampled biomass and made several growth measurement comparisons: 8 Jun. 2006, 21 Jun. 2007 and 12 Jun. 2008 for corn and 22 Mar. 2007 and 19 Mar. 2008 for cover crop. Corn yield was determined by hand harvesting selected rows.

RESULTS AND DISCUSSION

Residue

In 2007 the rye residue varied in a narrow range of 2538 to 2954 lb acre^{-1} at Camilla and 3107 to 3668 lb acre^{-1} at Tifton. In 2008 the low residue plots produced 740 and 1713 lb acre^{-1} of rye at Camilla and Tifton, respectively. The high residue plots averaged only 1072 lb acre^{-1} at Camilla, whereas at Tifton residue ranged from 2700 to 4150 lb acre^{-1}. A late planting was the primary reason for the overall low residue at Camilla in 2008. As corn follows peanut every time, residual N might have influence on the performance of the low residue zero-fertilization treatment after early planting is achieved.

Soil water

Figure 1 shows typical soil water content curves in 2007 corn where plots under strip-till showed greater soil water content at 12- and 16-in depths compared to conventional tillage plots. Where separations were less distinct (other depths), the reason may have had to do with actual transpiration. This is an intricate process controlled by energy input and transfer and the biological make up of the crop related to actual transpiration controlling mechanisms, such as reducing transpiration to different degrees at certain levels of water stress. But overall, soil water content measurements indicate greater infiltration of rainfall and irrigation water in the strip-till treatments. At what level this translates into significant yield advantages continues to be a research area. In 2006 water supply to black layer in inches was 11 to 13 in non-irrigated plots, 21 to 25 in *IrrigatorPro* triggered treatments, and 22 to 24 in those triggered by either the CT or ST soils.

Plant height and biomass

Across treatments, a high correlation was observed between plant height and biomass (stalks & leaves) around tasselling and total water supply to tasseling from rain and irrigation (Table 1). All parameters are significant at $P \leq 0.05$. In 2007 and 2008 by tasselling, water supply in inches was 14 to 16 for fully irrigated plots, 11 to 13 for V10 triggered, 9 to 11 for V14 triggered and 5 to 7 for non-irrigated ones. Irrigated plot corn was on average 1.45 times taller (1.8 to 2 times maximum) than that in non-irrigated plots (<80 in.). Tillage contrasts were within statistical margin of error, with the

Tifton but not Camilla strip-till corn generally showing slightly greater height than that of conventional tillage. Biomass production remained under 4000 lb acre^{-1}in non-irrigated plots whereas it reached to 9000 to 10,000 lb acre^{-1} in fully irrigated plots. While still within statistical margin of error, strip-tillage plots showed slightly enhanced biomass production.

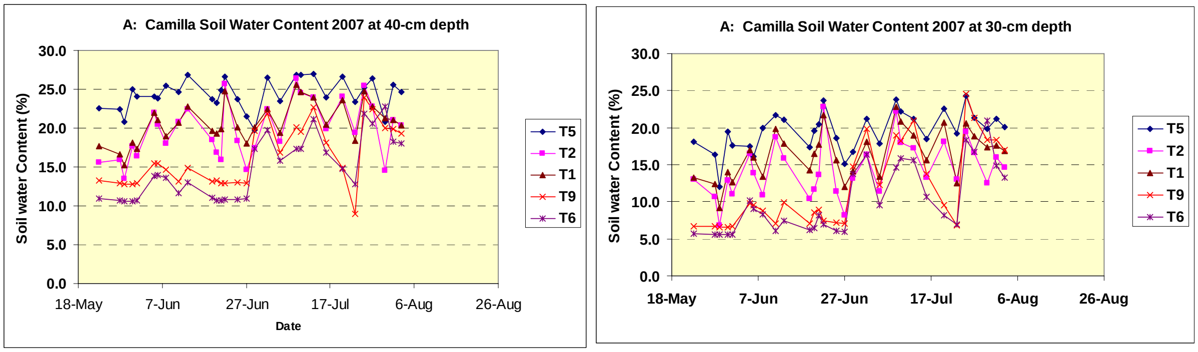

Fig.1. Typical soil water content curves in 2007 corn at Camilla. T5 is strip-till, high residue, full irrigation. T1 is strip-till, low residue, full irrigation. T2 is conventional-till with full irrigation. T9 is strip-till with no irrigation, and T8 is conventional-till with no irrigation.

Table 1: Parameters for linear regression model Y = aX + b with Y as corn plant height (in) or corn biomass (lb acre^{-1}) at tasselling, and Corn grain yield (bu acre^{-1}), and with X as total water supply (in) from planting to tasselling or maturity. Empty cell means no data.

		Height			Biomass			Yield		
Year	Site	a	b	r^2	a	b	r^2	a	b	r^2
2006	Camilla	7.15	14.73	0.96	702.27	-566.68	0.94	13.69	-100.42	0.98
	Tifton	-	-	-	-	-	-	13.37	-113.58	0.91
2007	Camilla	2.69	8.57	0.93	547.94	1577.04	0.92	8.56	-34.34	0.79
	Tifton	2.11	13.20	0.91	414.26	2661.28	0.84	7.71	0.90	0.93
2008	Camilla	4.09	43.07	0.97	451.75	412.29	0.88	-	-	-
	Tifton	4.18	39.81	0.94	510.34	685.90	0.95	-	-	-

Grain yield

As with height and biomass, across treatments a high correlation was observed between yield and water supply to black layer (Table 1). At Camilla, yield of non-irrigated plots remained below 55 bu acre^{-1}, whereas in irrigated plots it varied in the narrow range of 225 to 250 bu acre^{-1} in 2006, and 130 to 200 bu acre^{-1} in 2007. At Tifton non-irrigated plot yield varied from 40 to 70 in 2006, and 80 to 100 bu acre^{-1} in 2007. Fully irrigated plots produced from 200 to 215 bu acre^{-1}, whereas those with less irrigation produced yields in the range of 140 and 200 bu acre^{-1}. Strip-till did not show significant yield advantage over conventional tillage.

CONCLUSIONS

Two years of research has shown the advantages of strip-till in increasing infiltration in the two coastal plain soils under corn. While still within statistical margin of error, this would have led to the slightly improved response observed with respect to plant height and biomass production under strip- than conventional till. Because of the complex corn physiology governing and controlling transipiration rate, which directly influences grain production, we have not yet seen a direct tillage-grain yield correlation. Improvement in residue management (raising high residue and being able to plant into it) and developing the irrigation schedule strategies that would capture the advantages of the enhanced infiltration under strip-till continue to be areas of research.

ACKNOWLEDGMENTS

We appreciate the partial funding for the research from the Georgia Agricultural Commodity Commission for Corn. We are grateful to Sidney Cromer for competently spearheading all soil water monitoring, field and irrigation scheduling activities and documentations at Camilla and Tifton, Rad Yager and Ivey Griner for research activities at Camilla, and Stephen Norris for sample collection processing and maintaining records. As superintendent of the Camilla research facility, Calvin Perry fully supported the research activities. Several workers and students including John Gardner, Robert Pippin, Ricky Fletcher, Gene Fowler, Joseph Powel, Corrin Breeding Burt Calhoun, Rebecca Hickey, TJ Booone, Shaun Jones, TJ Tucker, and Andrew Stargel participated in different research activities. We thank them all.

REFERENCES

Bradley, J.F. 1995. Success with no-till cotton. p. 31-38. *In* M.R. McClelland, T.D. Valco, and F.E. Frans (ed.) Conservation-tillage systems for cotton: A review of research and demonstration results from across the cotton belt. Arkansas Agric. Exp. Stn., Fayetteville, AR.

CAES. 2007. A guide to corn production in Georgia 2007. Lee D. (ed). The University of Georgia, College of Agriculture and Environmental Sciences, Cooperative Extension Service, Athens, GA.

CTIC. 2007. More Corn: Is conservation tillage at risk. Partners 25(2). Conservation Tillage Information Center, Lafayette, IN.

Endale, D.M., D.E. Radcliffe, J.L. Steiner, and M.L. Cabrera. 2002. Drainage characteristics of a Southern Piedmont soil following six years of conventionally tilled or no-till cropping systems. Transactions of the ASAE: 45(5): 1423-1432.

Reeves, D.W. 1997. The role of soil organic matter in maintaining soil quality in continuous cropping system. Soil and Tillage Res. 43:131-167.

Reeves, D.W., M.L. Norflet, D.A. Abrahmson, H.H. Schomberg, H. Causarano, and G.L. Hawkins. 2005. Conservation tillage in Georgia: Economics and water resources. Pp 665-668. In K.J. Hatcher (ed.) Proceedings of the 2005 Georgia Water Resources Conference, April 25-27, 2005, Athens, GA. Institute of Ecology, UGA, Athens, GA.

Renewable Fuels Association. 2006. From Niche to Nation. Ethanol industry outlook 2006. Available http://www.ethanolrfa.org/objects/pdf/outlook/outlook_2006.pdf Accessed 07-06-08

SWCS. 2006. Environmental benefits of conservation on cropland. The status of our knowledge. Max Schnepf and Craig Cox (ed). Soil and Water Conservation Society, Ankeny, Iowa.

Terra, J.A., D.W. Reeves, J.N. Shaw and R.L. Raper. 2005. Impacts of landscape attributes on carbon sequestration during the transition from conventional to conservation management practices on a Coastal Plain filed. J. Soil & Water Conser. 60(6):437-446.