SCASC

Southern Conservation Agricultural Systems Conference

8th Annual Conservation Production Systems Training Conference
and
The 30th Southern Conservation Agricultural Systems Conference

July 29-31, 2008
University of Georgia Tifton Campus Conference Center
Tifton, GA

Foreword

The benefits of conservation tillage such as water conservation, reduced runoff, reduced dust in the air, reduced labor needs and fuel savings are widely shared among scientists, researcher and extension personnel. However the information needs to reach and the practice needs adoption by as large number of producer groups as possible. As part of this effort, scientists, researchers and extension personnel in southeastern United States from federal, state and local agencies have been holding an Annual Southern Conservation Agricultural Systems Conference (SCASC) since 1978 to promote the adoption of conservation tillage. Since 2000, the University of Georgia has been holding an Annual Conservation Production Systems Training Conference (CPSTC) for farmers and extension personnel. In 2008, the two groups decided to hold a joint conference on 29-31 July at The University of Georgia Tifton Campus Conference Center in Tifton, Georgia, to increase the impact of the outreach to farmers, extension and research personnel. The theme of the 2008 conference was "Conservation Tillage Systems in a Changing World" promoting hands-on use of precision agriculture technologies to get the most out of conservation tillage systems.

In this proceedings publication, forty three presentation made at the three day joint conference are highlighted and cover topics including precision agricultural tools and economics, water and irrigation issues, cutting edge technology, implementation and monitoring, organic production, pest management and bio-energy shifts. Producers, extension agents, local, state and federal agencies involved in enhancing sustainable agricultural practices through adoption of conservation tillage would find these presentations very useful.

The Conference was cosponsored in part by the GA DNR Pollution Prevention Assistance Division, Fort Valley State University, USDA-Risk Management Agency, Georgia Conservation Tillage Alliance, Georgia Organics, Georgia Soil & Water Conservation Commission, Central Savannah RC&D Council, Coastal Georgia RC&D Council, Seven Rivers RC&D Council, South Georgia Regional Development Center, The University of Georgia College of Agriculture & Environmental Sciences, Georgia Coastal Management Program, USDANatural Resources Conservation Service, USDA Southern Sustainable Agriculture Research and Education, USDA Agricultural Research Service, Southern Conservation Agricultural Systems, Regional Project Number SERA-IEG 20, and many more.

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Precision Agriculture Management Tools

Precision Agriculture Analysis/Economic Impact

Water/Irrigation Issues with Conservation Tillage

Cutting Edge Technology for the Future of Conservation Tillage

Implementing and Monitoring Conservation Programs

Organic Production

Pest Management

Bioenergy Shifts

Effects of Transmission Speed on Equipment Performance and Utilizing Spatial Equipment Performance Data for Management Decisions

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ABSTRACT

With fuel prices reaching all time highs, agricultural producers are searching for ways to minimize operational costs such as fuel usage while also increasing productivity. Adjustment of tractor operational variables including gear selection can optimize fuel usage and improve productivity during field operations. Further, spatial equipment performance data collected using global positioning systems (GPS) can also be utilized to make more informed management decisions regarding equipment and field performance. Therefore, the objectives of this investigation were to 1) investigate the effects of three transmission speeds on equipment performance for two subsoilers (Bigham Brothers Paratill™ and KMC Generation I Rip-Strip) and 2) demonstrate the possibilities of using spatial equipment performance data for management decisions. The data indicated that draft increased from the slow to fast speed by 27% (Paratill™) and 37% (KMC). Fuel consumption showed a 105% increase (slow to fast) for the Paratill™ and a 115% increase (slow to fast) for the KMC. The data from a spatial tillage experiment enabled a fuel cost map to be created to visualize fuel costs and formulate savings through site-specific management. In conclusion, adjustment of operational variables such as transmission speed as well as spatial analysis of equipment data can optimize performance and reduce input costs during tillage operations.

INTRODUCTION

Deep tillage operations are required to alleviate compaction layers often found in the Southeastern United States but this tillage can consume a significant amount of fuel and time for agricultural producers. Subsoilers are common implements used to break the compaction layer found in these soils. Tractor operational variables including transmission speed can be adjusted to increase productivity and decrease fuel usage if managed properly. In addition to machine operation methods, utilizing the GPS and geographic information systems (GIS) technologies to collect spatial data and perform analysis, respectively, can be insightful. Results can be used to develop site-specific management strategies or to modify equipment setup for future operations to improve efficiency and reduce costs.

Grisso et al. (2001) explained the “Gear Up and Throttle Down” concept for saving fuel. Adjusting to a higher gear enables the operator to run at the same travel speed and reduce engine speed 70% to 80% of the rated engine speed. They reported that a larger tractor pulling a light load using the geared up and throttled down concept will use the same or less fuel as a smaller tractor at full load. However, this operating technique is not applicable under increased loads such as those generated by deep tillage.

Ideally for conservation tillage systems, tillage should maintain minimum surface soil disruption while performing adequate subsurface soil disruption to alleviate hardpans. Implement shank design can have an effect on draft and overall equipment performance. Raper (2005) looked at force requirements and soil disruption of eight different subsoiler shanks (5 straight and 3 bentleg subsoiliers) on two different soil types. Results indicated that the straight shanks generated higher draft forces compared to the bentleg design for the Norfolk sandy loam soil (Raper, 2005). The bentleg shanks generated increased side force compared to the straight shank designs. Raper and Bergtold (2007) reported that the use of bentleg or inclined subsoiler shanks can save up to 15% in fuel and 32% in draft.

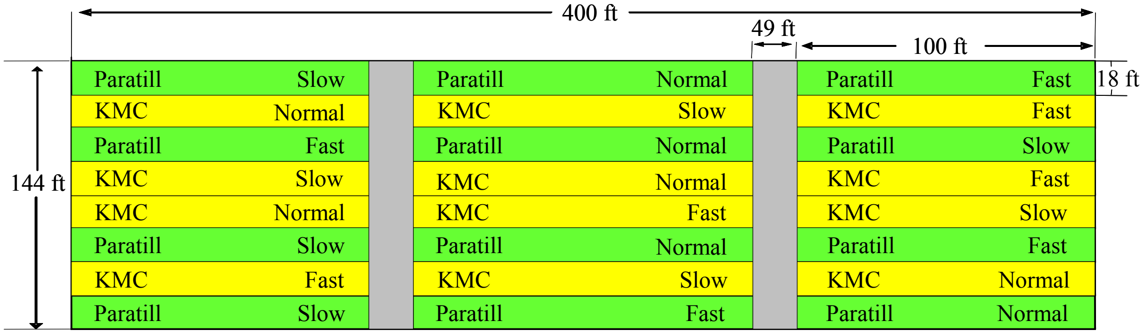
In-field performance monitoring can be important in understanding energy and fuel utilization. Yule et al. (1999) evaluated a real-time GPS data acquisition system on a Zetor agricultural tractor implemented with a tine cultivator outfitted with a consolidation roller. Variables monitored directly included fuel consumption, fuel temperature, engine speed, draft force, pitch and roll angles, GPS position, wheel speed, and ground speed. They created general performance maps of field slope, slip, and operating costs. Operating costs, excluding fuel costs, were calculated according to work rates collected with the tractor performance system. Areas of high slip were identified and field remediation was suggested so that operating costs could be minimized. They concluded that operating costs increased in areas of high slope causing increased wheel slip thereby reducing in-field equipment productivity.

Monitoring equipment performance during tillage operations can be beneficial in improving performance and the management of equipment. Therefore, the objectives of this investigation were to: 1) Investigate the effects of three transmission speeds (approx. 1.9, 3.6 and 5.2 mph) on equipment performance for two subsoilers, and 2) Demonstrate the possibilities of using spatial equipment performance data for management decisions.

METHODS

A 1.2 acre Cahaba sandy loam field located at the E.V. Smith Research and Extension Center in Shorter, AL was selected for this investigation. Three transmission speeds (slow, normal, and fast) with two deep tillage implements were used for a total of six treatments. The experimental design was a randomized block (Figure 1) with 4 replications and blocked based on the tillage implement. The plots measured 100-ft long by 18-ft wide. Each pass of the implement covered 3 plots with a 49.2-ft transition area between each plot. Gear changes occurred within this transition area without stopping or raising the implement out of the ground, allowing the equipment to reach steady-state prior to beginning the next plot. The desired tillage depth range for this experiment was 13 to 14 inches.

Two deep tillage implements were selected: a KMC Generation I Rip-Strip subsoiler and a Bigham Brothers Paratill™, both three-point hitch mounted with a six-row configuration. The KMC implement was a straight shank design while the Paratill™ was a bentleg design. Shank geometry for the Paratill™ and the KMC are presented in Figure 2. A mechanical front wheel drive (MFWD) John Deere 8300 agricultural tractor equipped with a Real-Time Kinematic (RTK) Trimble AutoPilot guidance system was used for this study. The autoguidance system ensured that the tractor maintained a straight path over the center of each pass. A 3-point hitch draft dynamometer fabricated by the USDA-ARS-NSDL in Auburn, AL was used to collect draft forces during tillage. An on-board data acquisition system collected engine speed, fuel consumption, axle torque, wheel speed, ground speed, and exhaust gas temperature (EGT) in real-time.



Paratill	Slow	Paratill	Normal	Paratill	Fast
KMC	Normal	KMC	Slow	KMC	Fast
Paratill	Fast	Paratill	Normal	Paratill	Slow
KMC	Slow	KMC	Normal	KMC	Fast
KMC	Normal	KMC	Fast	KMC	Slow
Paratill	Slow	Paratill	Normal	Paratill	Fast
KMC	Fast	KMC	Slow	KMC	Normal
Paratill	Slow	Paratill	Fast	Paratill	Normal

Figure 1. Experimental layout with treatment assignment and plot dimensions.

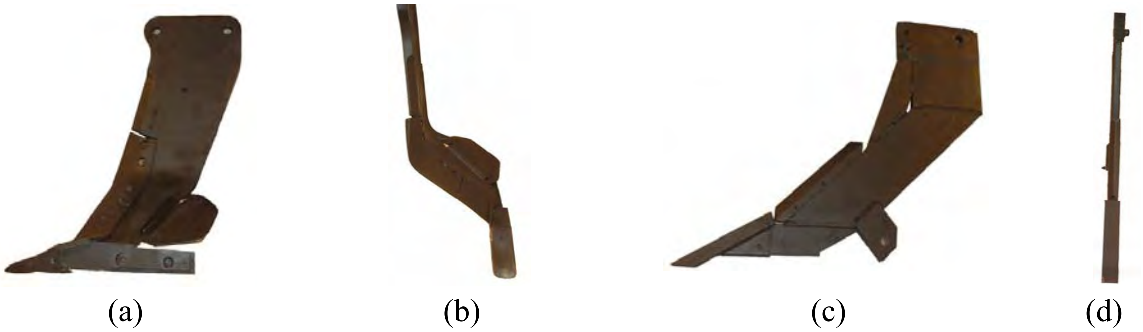

(a) (b) (c) (d)

Figure 2. Tillage shank geometry: (a) Paratill™ side view, (b) Paratill™ front view, (c) KMC side view, and (d) KMC front view (Raper et al., 2005).

Additionally, a spatial tillage experiment was also performed using GPS to link equipment performance data to geographic positions. A John Deere 6420 and a 2-row KMC Generation I Rip-Strip subsoiler was used to till a 3.7 acre field of Marvyn loamy sand located at the E.V. Smith Research and Extension Center, Shorter, AL. Spatial performance data was used to analyze the performance of the equipment throughout the field for the purpose of making site-specific equipment management decisions. The field was divided into 3 zones according to elevation changes to illustrate performance differences in response to field attributes. Figure 3 depicts field elevation map with the test area outlined. Zone 1 experienced a drop in elevation from south to north direction of about 6 ft over 279 ft of length. Zone 2 was relatively level with no more than 3-ft of elevation change over the 820-ft length. Zone 3 did have some slight elevation differences within the zone. Further, each zone was analyzed according to direction of travel (North or South) within each zone and compared.

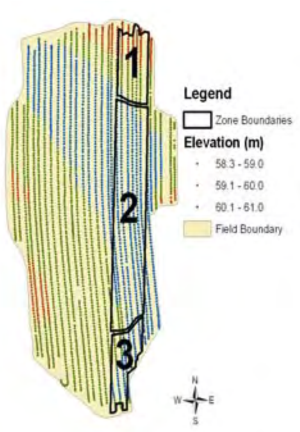


Figure 3. Spatial tillage experiment field elevation with zones outlined.

Results and Discussion

A summary of results for the transmission speed experiment are presented in Table 1. Equipment performance did respond to changes in transmission speed. Fuel consumption showed a 105% increase (slow to fast) for the Paratill™ and a 115% increase (slow to fast) for the KMC. Axle torque showed subtle increases throughout the speed ranges for the KMC. However, the Paratill™ demonstrated a slight decrease in axle torque from the slow to normal speeds by 1% illustrating that the implement pulled with less resistance at the normal speed. Power increased in response to speed with values reaching over 130Hp at the fast speed for both implements. Although not significant, fast speeds for both implements showed considerable increases in draft over the slower speeds shown with a 27% increase (Paratill™) and 37% increase (KMC) from the slow to fast speed. The Paratill™ had an interesting response to speed regarding draft with a 4% decrease from the slow to normal speed indicating an optimum performance range for this implement.

Table 1. Summary of performance data with statistical results for the Paratill™ (slow, normal, and fast) and KMC (slow, normal, and fast).

Implement	GS* (mph)	Slip* (%)	Engine* (rpm)	Fuel* (gal/h)	Torque* (ft-lbs)	Power* (Hp)	Draft* (lbs)	Vert* (lbs)
Paratill™	1.9^{a}	0^{c}	$2,275^{ab}$	5.0^{c}	$10,054^{ab}$	38^{b}	$7,673^{b}$	992^{b}
Paratill™	3.6^{b}	0^{c}	$2,264^{bc}$	7.0^{b}	$9,949^{bc}$	71^{c}	$7,356^{b}$	924^{b}
Paratill™	5.2^{c}	1^{bc}	$2,239^{d}$	10.2^{a}	$10,280^{a}$	135^{a}	$9,809^{a}$	$1,721^{a}$
KMC	1.8^{a}	1^{b}	$2,275^{a}$	4.7^{c}	$9,676^{c}$	36^{b}	$7,295^{b}$	-694^{c}
KMC	3.5^{d}	3^{a}	$2,260^{c}$	7.7^{b}	$10,267^{a}$	88^{d}	$9,123^{a}$	-372^{c}
KMC	5.0^{e}	4^{a}	$2,246^{d}$	10.1^{a}	$10,363^{a}$	138^{a}	$10,017^{a}$	-199^{c}

* Means with similar letters in columns are statistically similar ($\alpha = 0.05$)

The vertical force results showed increases at the fast speed over the slow speed for the Paratill™. The orientation of the draft dynamometer yielded positive forces as pulling the implement into the ground with a negative force pushing the implement out of the ground. The Paratill™ showed that as speed increased so did the vertical force indicating the implement pulled itself into the ground with a higher force as speed increased. This result was most likely due to shank geometry. The KMC tended to push itself out of the ground as indicated by the negative vertical forces. However, the magnitude of vertical force decreased with faster speeds signifying less force or energy was required to sustain the desired depth for the KMC.

The spatial tillage experiment showed that equipment performance was affected by field terrain. The results for comparisons of travel directions within each zone are presented in Table 2. Statistical differences were observed for fuel consumption (Fuel), engine speed (Engine), EGT, axle torque (Torque), wheel speed (Wheel), and ground speed (GS). No statistical differences were evident for slip. For zone 1, when tilling southbound the tractor had to tow uphill and northbound it was traveling downhill. According to the results (Table 2), zone 1 experienced a 23% increase in fuel consumption for the south direction compared to the north direction. A 17% increase in fuel consumption existed for the north direction of zone 3 compared to the south direction. No statistical differences were noticed between the north and south travel directions for zone 2. Zones 1 and 3 were located toward the ends of the test area meaning tillage would have initialized in the south direction of zone 1 and in the north direction of zone 3. Once the tractor begins tillage, it requires some time to get up to steady-state operation. During this time, the engine might notice increased loadings for a short period which would cause increased performance values for these directions. These effects can also be seen in the fuel cost map (Figure 4) illustrating increased fuel cost in orange and located primarily in zones 1 and 3.

Table 2. Summary of results by zone for the spatial tillage experiment.

Zone	Direction**	Fuel* (gal/h)	Engine* (rpm)	EGT* (°F)	Torque* (ft-lbs)	Wheel* (mph)	GS* (mph)	Slip* (%)
1	N	3.5^{c}	2215^{b}	750^{bc}	2581^{c}	3.7^{e}	3.4^{b}	8.7^{a}
	S	4.3^{a}	2399^{a}	732^{c}	3427^{b}	4.0^{ab}	3.5^{a}	10.4^{a}
2	N	3.6^{b}	2190^{bc}	757^{b}	3611^{a}	3.6^{ce}	3.0^{bc}	9.5^{a}
	S	3.6^{bc}	2167^{cd}	766^{ab}	3009^{a}	3.6^{cd}	3.2^{bc}	9.6^{a}
3	N	4.3^{a}	2396^{a}	694^{d}	3081^{a}	4.0^{a}	3.6^{a}	9.8^{a}
	S	3.6^{b}	2142^{d}	779^{a}	3149^{a}	3.5^{d}	3.2^{c}	9.5^{a}

*Means with similar letters in columns were statistically similar ($\alpha = 0.05$).
** N and S represent North and South travel directions respectively.

The fuel cost map is comparative to a yield map, however instead of crop yield this map illustrates how the equipment is performing within the field regarding fuel usage. This enables managers to view areas of low performance and potential problem areas within the field and possibly create solutions to improve performance and reduce costs in these areas. For example, a wet area was present (Figure 4; indicated by arrow) in which the map showed higher fuel costs compared to other areas in the field. Potential uses for these types of maps include using them in conjunction with yield maps to possibly relate equipment performance and fuel cost to yield. This technology could also be used for fine-tuning site-specific tillage or other conservation tillage practices.

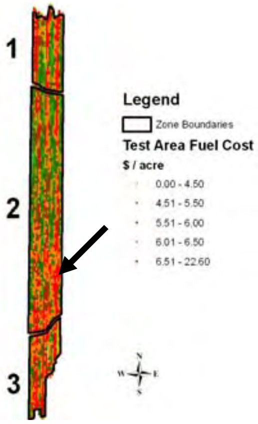


Figure 4. Fuel cost map for test area with zones outlined and arrow indicating wet area.

Conclusions

The results for these two experiments showed that performance was affected by equipment operational variables and field terrain. Increases in fuel consumption occurred as speed increased for both implements. The normal speed showed the lowest draft for the Paratill™. The fast speeds for both implements showed considerable increases in draft over the slower speeds with a 27% increase (Paratill™) and 37% increase (KMC) from the slow to fast speed. Each implement behaved differently in response to speed treatments. The reduced draft loads observed at normal speed for the Paratill™ indicate that an optimum performance range was found. Results also showed that implement and transmission gear selection could play an important role in equipment performance and decreased fuel usage. The ability to monitor and collect equipment performance data can benefit equipment management decisions and lead to fuel savings. Differences in performance were noticed between north and south travel directions which could possibly be improved with different tractor speed/gear configurations to optimize performance. The capability to collect and analyze spatial performance data enables managers to spatially plan tillage routes and perform field remediation in problem areas to improve efficiency in order to save on crop input costs incurred by tillage operation techniques. Combining adjustments including ballast, tire pressure, and gear selection can work together to further improve in-field performance during tillage operations and save costs for producers.

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Cotton yield response to variable rate nematicides according to risk zones

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Abstract

Cotton (*Gossypium hirsutum* L.) lint yield losses by southern root-knot nematode [*Meloidogyne incognita*] (RKN) have increased during the last 20 years. Site-specific management (SSM) of nematicides is a promising method to reduce yield losses, increase profitability and reduce adverse environmental impacts associated with excess allocations of agrochemicals. The impact of two nematicides applied at two rates on RKN population density and lint yield were compared across previously determined RKN risk zones in commercial fields during the 2007 growing season. Root knot nematode risk zones were delineated in 2006 using fuzzy clustering of elevation and slope of the terrain, normalized difference vegetation index (NDVI) calculated from a bare soil spectral reflectance, and apparent soil electrical conductivity [shallow ($EC_{a\text{-shallow}}$) and deep ($EC_{a\text{-deep}}$)]. Four different treatments of nematicides were randomly allocated among blocks that spanned the entire length of the fields. Test bare soil spectral reflectance plots (16 rows by 100 feet long) including the four treatments were also randomly selected within each zone to collect RKN population density, soil water content, and plant height, root galling, and final yield. In general, there were no benefits associated with a high rate of Telone (6 gal ac^{-1}) versus a lower rate of 3 gal ac^{-1}. Similarly, the higher Temik rate of 6 lbs ac^{-1} did not provide additional nematicide control compared to the low rate (3 lbs ac^{-1}). Comparing treatment results across management zones, Telone provided better RKN control compared to Temik in high risk zones, comprised of more coarse-textured, sandy soil. However, in low risk zones, which were comprised of relatively heavier textured soil compared to the high risk areas, the application of Temik would provide sufficient nematicide control. The results from this study clearly showed that RKN control and final yield varied with respect to the nematicide type and rate across management zones (MZ). These results are promising and support the idea of variable rate nematicide applications based on RKN risk zones.

Introduction

Across the U.S. Cotton Belt, southern root-knot nematode [*Meloidogyne incognita*] (RKN) causes considerable yield reduction. In Georgia, this nematode is considered one of the most critical pest problems facing producers today. A University of Georgia survey carried out between 2002 and 2003 by members of the University of Georgia's Cooperative Extension found RKN in all 67 cotton producing counties in Georgia. Seventy percent of the commercial cotton fields they surveyed were infested with some level of these pathogens.

In Georgia, management strategies such as crop rotation and planting moderately resistant cultivars are currently being implemented to reduce nematode related yield losses. In recent years, the control of nematodes through the application of soil fumigants such as Telone II (1,3 – dichloropropene) before planting and/or the use of a granular nematicide such as Aldicarb (Temik) has become a common practice for cotton growers. However, the high cost of nematicides suggests there may be an advantage to site-specific nematicide applications. Therefore, a management zone approach targeting areas at risk for high nematode populations could reduce the cost of nematicide applications, as well as improve placement and efficacy compared to uniform field application strategies.

Root knot nematodes exhibit an aggregated pattern of spatial variability, influenced primarily by variability in soil texture. This behavior suggests that site-specific management (SSM) of nematicides may be used to improve the efficacy of nematicide control and reduce costs. Studies conducted in Louisiana have shown differences in average nematode population and cotton yield with respect to the application of different nematicides treatments as a function of soil textures (Erwin et al., 2007; Wolcott, 2007). When evaluating the differences in yield between Telone and non-Telone treatments applied across two fields in Louisiana, coarsely textured areas in one of the fields showed a greater response to the application of Telone compared to areas having a relatively heavier soil texture (Erwin et al., 2007).

Although the fields planted with cotton in Georgia do not exhibit abrupt changes in soil texture, differences in soil texture are mainly due to variability in sand particle size. Variability in sand particle size has proven useful in conjunction with topographic information and bare soil reflectance to delineate areas with different levels of risk for high RKN population density (Ortiz et al., 2007b).

The main goal of this study was to compare the impact of rate and type of nematicide on RKN populations and cotton lint yield across management zones having different levels of risk for having a high population of RKN.

Methods

Three fields (20 – 49 ac) located in an intensely row-cropped region of southern Georgia, were selected for this study in 2007. The fields were planted on May 2007 with Delta & Pineland (DPL) 555 Boll-Guard®, Round-Up-Ready® cotton (*Gossypium hirsutum* L.) variety, using a 4 row Monosem vacuum planter. Planting occurred approximately 2 weeks after each field was strip-tilled. Because of space limitations, detailed results from one of the fields, CC field, are presented.

Management zones (MZ) for RKN were delineated based on fuzzy clustering of various surrogate data for soil texture. The methodology for the MZ delineation was developed using data collected in 2005 and 2006 from 11 cotton fields (Ortiz et al., 2007). The surrogate data for soil texture included in the MZ delineation were: terrain elevation and slope, normalized difference vegetation index (NDVI) calculated from bare soil spectral reflectance, and apparent soil electrical conductivity (EC_a). Although the fuzzy clustering of all these variables allowed the identification of three zones with different levels of risk for having high population of RKN at the CC field, the accuracy on the MZ delineation using EC_a alone, measured between 0-3 ft ($EC_{a\text{-deep}}$) with a VERIS® 3100 implement, was reduced only 30% (Figure 1).

The experiment was established in a randomized complete block design to evaluate the differences of two nematicides (Temik and Telone) applied at two different rates. A total of four treatments were randomly allocated in strips of 16 rows, spanning the length of the field. Within each treatment strip, plots (4 rows by 100 feet long) were randomly assigned and replicated six times within each of the three MZ. Treatments included: Temik – 3.0 lbs ac^{-1} (T1), Temik – 6.0 lbs ac^{-1} (T2), Telone – 3.0 gal ac^{-1} plus Temik 3.0 lb ac^{-1} (T3), and Telone – 6.0 gal ac^{-1} plus Temik 3.0 lb ac^{-1} (T4) (Figure 1a, 1b). Between each set of 16 rows of treatments a strip of four rows was left as a buffer which received 3.0 lbs ac^{-1} Temik. This rate was applied in the buffer as the cooperating farmers required, at a minimum, an insecticide rate of Temik in all rows.

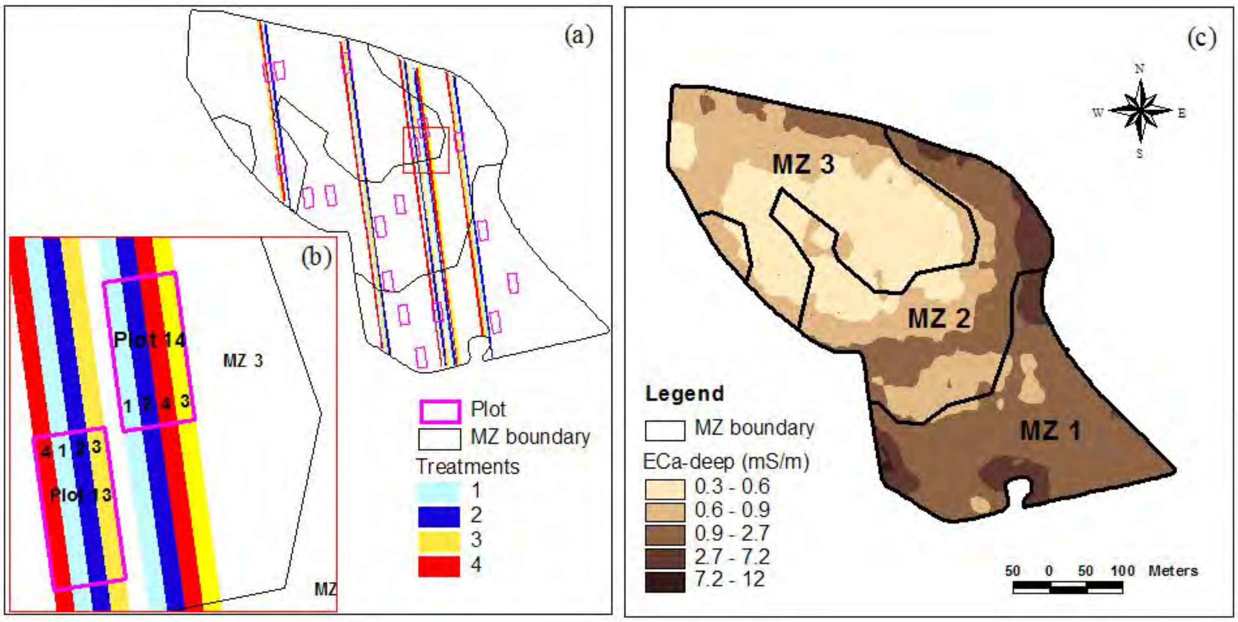

Figure 1. Spatial distribution of plots (a) and nematicide treatments (b) in relation to RKN management zones delineated using 2006 data (c), CC field.

Telone was applied approximately 2 weeks prior to planting using a 4-row KMC strip-till implement fitted with a nitrogen-based Telone application system. All T4 treatments were strip-tilled first, followed by the T3 treatments. Then the non-Telone treatments (T1 and T2) were strip-tilled. Temik was applied at planting from Microsem distributor boxes on the Monosem planter. The T2 treatments were planted first, followed by the T1, T4, and T3 treatments. A Trimble Autopilot auto-steer system made this operation very manageable. Both the Telone and Temik application systems were calibrated prior to field work.

Although each treatment was applied at random in four 16-row strips, sampling was conducted inside each experimental unit (4 rows by 100 feet long). Soil samples for RKN population density determination (second stage juveniles) were composed of soil cores collected at random within each experimental unit three times during the growing season: 76, 108, and 171 days after planting (DAP). Soil probes with a 1.2 in diameter opening and approximately 8 in long were used to extract the soil samples for nematode density analysis. The probes were inserted 6 - 12 in deep into the soil adjacent to the plant tap root. Root knot nematodes were extracted from 100 cm^3 of soil by centrifugal flotation (Jenkins, 1964).

The spatial variability of cotton yield (lint mass) was recorded using an Ag Leader cotton yield monitor system (Ag Leader Technology, Ames, IA) installed on a 9965 four-row John Deere picker. The system used an AgGPS 132 DGPS receiver with differential correction to calculate the position of the harvester at any time in the field.

Spatial analysis of yield monitor and RKN data were processed using the Spatial Analyst extension of ArcVIEW v. 9.0 (ESRI, 2004). Differences in yield due to nematode treatments within and between MZ were performed using PROC MIXED with a restricted maximum likelihood approach accounting for spatially correlated errors using the Statistical Analysis System (SAS Institute, 2000). Nematode treatment effects and the interaction between treatments and zones on RKN population density were computed through PROC MIXED in SAS.

Results

Field characteristics for each of the RKN management zones delineated for the CC field are shown in Table 1. The zone with the highest risk for high population of RKN, has the coarsest soil texture as demonstrated by the lowest values of $EC_{a\text{-deep}}$, slope and NDVI. In contrast, MZ 1 with the lowest risk for high population of RKN exhibited a heavier sand texture compared to MZ 3 (higher values of $EC_{a\text{-deep}}$, slope and NDVI).

Table 1. Characteristics of management zones delineated from fuzzy clustering of elevation, slope, NDVI and $EC_{a\text{-deep}}$. CC field

Zone	Log_{10} (RKN/ 100 cm^3+1)		Elevation (ft)		EC_a-deep (mS/m)		Slope (%)		NDVI		RKN/ 100 cm^3 soil	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1 - Low risk	1.1	73.5	250.0	1.1	1.5	38.8	1.4	19.6	0.09	19.7	41.3	179.8
2	1.6	55.2	256.9	1.7	2.5	87.0	2.1	30.2	0.09	23.4	170.3	191.7
3 - High risk	1.9	35.0	260.5	0.8	0.7	29.3	0.9	56.6	0.06	37.2	174.9	140.3

The RKN management zones delineated using 2006 data were validated prior to analysis of the 2007 data set to ensure differences within or among MZ were attributable to variability in RKN population and not an artifact of poorly delineated zones. The same 0.5 ac grid used in 2006 to collect RKN samples was used in 2007; however, soil samples were only collected from buffer strips. Figure 2 shows the spatial variability of the mid-season RKN population density in 2006 and late-season in 2007. The late-season (129 DAP) RKN population density sampled in 2007 followed the same pattern of RKN spatial variability segregated by the MZ delineated in 2006. The strength of the MZ delineation may be demonstrated by comparing RKN densities between zones, without regard to treatments. Regardless of any nematicide treatment, MZ 3, with the highest RKN risk, exhibited significantly ($P < 0.10$) higher RKN population densities compared to the other two zones.

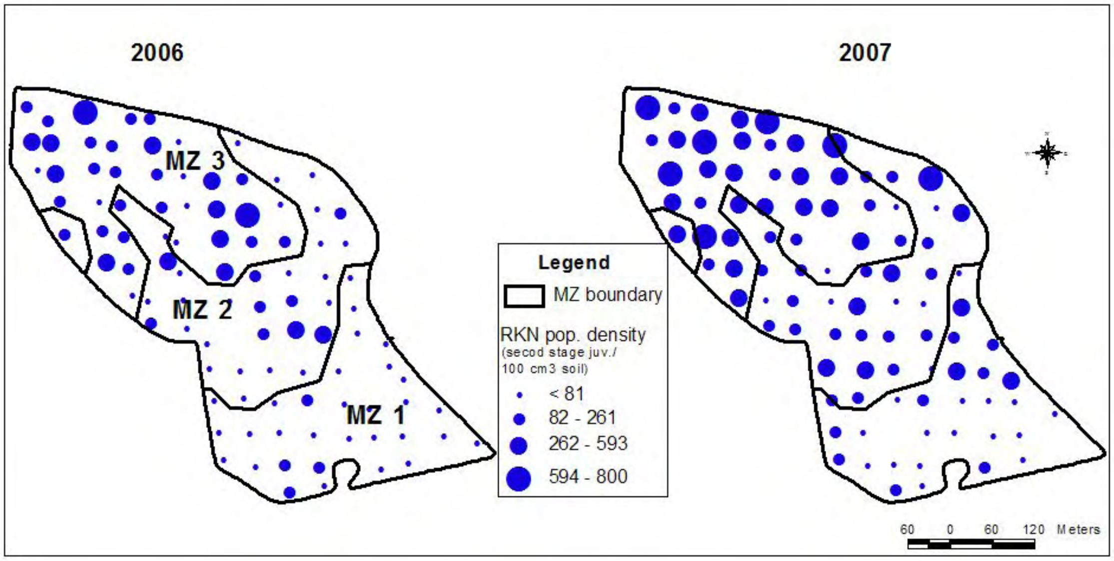

Figure 2. Spatial distribution of RKN population based on grid sampling in mid-season 2006 and late-season 2007 at the CC field.

An analysis of differences in average RKN population densities due to treatment by zone indicated significant treatment differences only in moderate (MZ2) and high (MZ3) RKN risk zones ($P < 0.05$).

In the low-risk zone (MZ1) a numerical difference in RKN population densities was observed between Temik at 6.0 lbs ac^{-1} (T2) and Telone at 6.0 gal ac^{-1} plus Temik at 3.0 lbs ac^{-1} (T4). Although the average reduction in RKN population between T4 and T2 was 57%, this difference was not statistically significant, Table 2, Figure 3. Considering the low risk for high population of RKN within MZ1 along with the lack of significant treatment differences, data suggest that any nematicide applied there had a low impact on RKN population; therefore a low rate of Temik may be sufficient nematicide control within this zone.

Table 2. Average RKN population density differences between nematicide treatments applied across three RKN management zones

Treament	**Zone number**		
	1 - Low risk	**2 - Moderate risk**	**3 - High risk**
	RKN population (second stage juveniles/100 cm^3 of soil)		
Temik 3 lb/ac (T1)	77.94	102.78	173.67
Temik 6 lb/ac (T2)	101.58	152.78	195.44
Telone 3 gal/ac + Temik 3 lb/ac (T3)	63.95	57.33	90.33
Telone 6 gal/ac + Temik 3 lb/ac (T4)	43.27	44.66	57.33

* Significant differences between nematicide treatments within a management zone, P< 0.05.

In MZ 2, there were significant differences between treatments ($P < 0.05$). On average, a reduction in RKN population density was observed between treatments: T4 vs. T1 (56% reduction), T3 vs. T2 (62% reduction), T4 vs. T2 (71% reduction), and between nematicide type - Telone vs. Temik (60 % reduction).

In MZ 3, there were also significant differences between treatments ($P < 0.05$). On average, a reduction in RKN population was observed between treatments: T4 vs. T1 (67% reduction), T3 vs. T2 (54% reduction), T4 vs. T2 (70% reduction), and between nematicide type – Telone vs. Temik (60% reduction).

A significant reduction in RKN population between Telone and Temik treatments (T3T4 vs. T1T2) when we moved across the management zones was observed. In MZ 1, the lowest reduction in average RKN population was observed in Telone treatments over Temik treatments, 36 second stage juveniles/100 cm^3 of soil which corresponded to 40% reduction. In contrast, MZ3 exhibited the highest reduction in average RKN population when using Telone compared to Temik. The reduction was 60% which was equivalent to 111 second stage juveniles/100 cm^3 less on average in the plots receiving any of the Telone treatments.
A consolidated analysis of the RKN population density by zone-treatment showed that not matter the zone there were no differences between Temik rates (T1 and T2 treatments) or Telone rates (T3 and T4 treatments).

When the RKN population density measured at different DAP was analyzed, there were no significant differences between nematicides and rates in MZ 1, however Telone – 6.0 gal ac^{-1} plus Temik 3 lbs ac^{-1} (T4) controlled RKN populations best throughout the growing season, Table 2. The differences between Telone and Temik treatments were statistically significant in MZ 2 and MZ 3. In MZ 2, although the highest rate of Telone (T4) significantly reduced the RKN population, the low rate of Telone (T3) produced similar results. MZ 3 had the highest RKN population throughout the growing season compared to MZ 2 and MZ 1, however Telone treatments (T3 and T4) resulted in the highest reductions in population density, Figure 3 and Table 3. When the RKN population was measured at 108 DAP, the high rate of Telone – 6.0 gallons per acre (T4) controlled RKN population better than the other three nematicide treatments within this zone (MZ3).

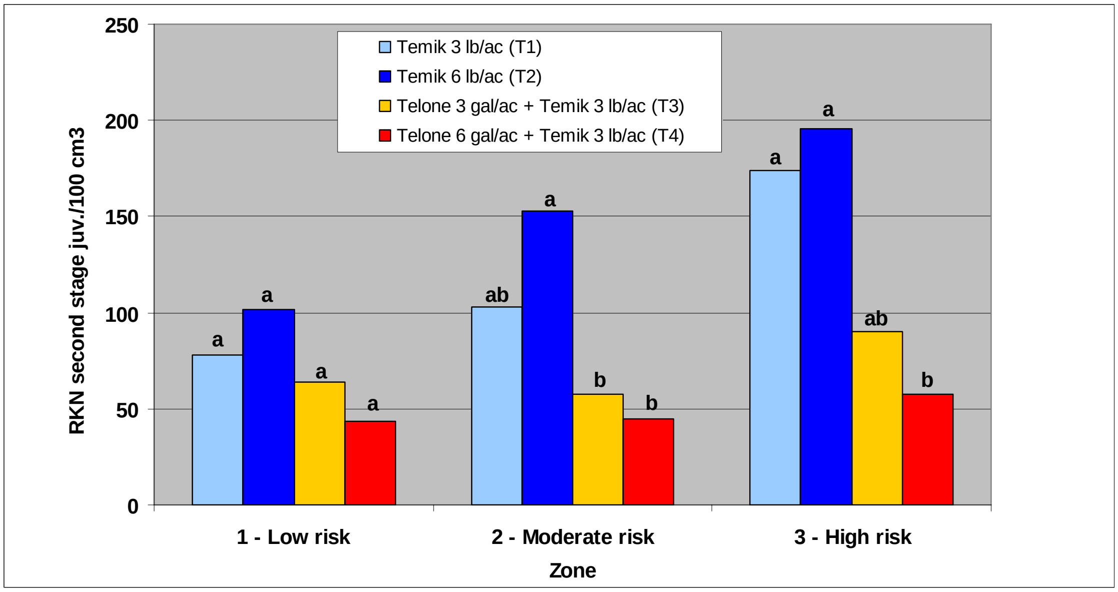

Figure 3. Average RKN population density differences between zones and treatments within zones. CC field.

Table 3. RKN population density differences at different DAP between nematicide treatments applied across three RKN management zones.

Treatment	Zone number 1			Zone number 2*			Zone number 3*		
	DAP 76	108	171	76	108	171	76	108	171
	RKN population density (second stage juveniles / 100 cm^3 of soil)								
1	0.7	154.4	78.3	20.7	218.3	69.3	40.7	323.0	157.3
2	24.0	132.0	148.0	10.7	324.0	123.7	38.0	360.3	188.0
3	4.7	151.2	34.0	9.0	97.0	66.0	24.0	135.3	111.7
4	12.7	61.6	54.7	18.0	85.3	30.7	14.0	68.7	89.3

* Significant differences between nematicide treatments within a management zone, P< 0.05.

The statistical analyses indicated significant yield differences between MZ, treatments and most important an interaction between MZ and treatments (Table 4, Figure 4). In MZ 1, the zone with the lowest risk for high RKN population, there was a significant difference ($P < 0.05$) in yield between treatments. When yield data coming from T4 plots within this zone was compared with yield data from T2 plots, the highest average yield increase was observed on T4 plots, 219 lb lint ac^{-1} (Table 5). However, the average difference in RKN population between these treatments was not significant, peaking at 58 second stage juveniles/100 cm^3 of soil. When the average yield from Temik (T1 and T2) and Telone (T3 and T4) treatments was compared, an increase of 122 lb lint/ac was observed, a 12% yield increase for Telone treatments. Recalling that RKN populations were numerically reduced with applications of Telone within this zone, slight increases in yield associated with T3 and T4 is not unexpected.

In MZ 2, the greatest yields were observed for plots receiving either T3 or T4, increasing yields by 28% (170 lbs ac^{-1}) in plots receiving Telone treatments compared to Temik treatments. The greatest yield increment was observed comparing treatments T4 and T2, 237 lb/ac. This yield response was expected due to the 71% reduction in RKN population caused by the application of high rate of Telone (T4) compared to high rate of Temik (T2).

In MZ 3, the zone with the highest risk for high RKN populations, there were significant yield effects ($P < 0.05$) between Temik and Telone treatments. However, there were no significant differences between Temik rates (T1 and T2 treatments) or Telone rates (T3 and T4 treatments), Table 4. When cotton yields from the two Telone treatments were averaged and compared to the average of the two Temik treatments, cotton yield increased by 71% (228 lbs ac^{-1}) in Telone treated plots. This result could be associated with the 60% reduction in RKN population due to Telone application compared with Temik within this zone.

The similarities in average RKN population between zones 2 and 3 and the contrasting yield between these two zones suggests that RKN population is not the only factor reducing and/or limiting cotton yield. The presence of high RKN population density in zones with low water availability, coarse-textured sandy areas with lowest $EC_{a\text{-deep}}$ values, may exacerbate yield losses. Ortiz et al. (2007a) evaluating the relationship between cotton yield, soil physical and chemical properties, and RKN in two cotton fields found the presence of aggregated high population densities of RKN in coarse textured areas exacerbate yield losses due to the conjunction of low uptake of water and K by RKN infected plants and the low availability of these resources in sandy areas. In this study, a good example of the integrated effects of RKN and landscape attributes is when treatments with similar population densities were compared across management zones (Figure 5). Even though the RKN population density between the three treatments were similar, yield losses increased when RKN were present in coarse-textured sandy areas like MZ3. Therefore, variable or precision application of the appropriate rate and type of nematicide may reduce cost, increase nematicide efficacy and improve economic returns on nematicide inputs.

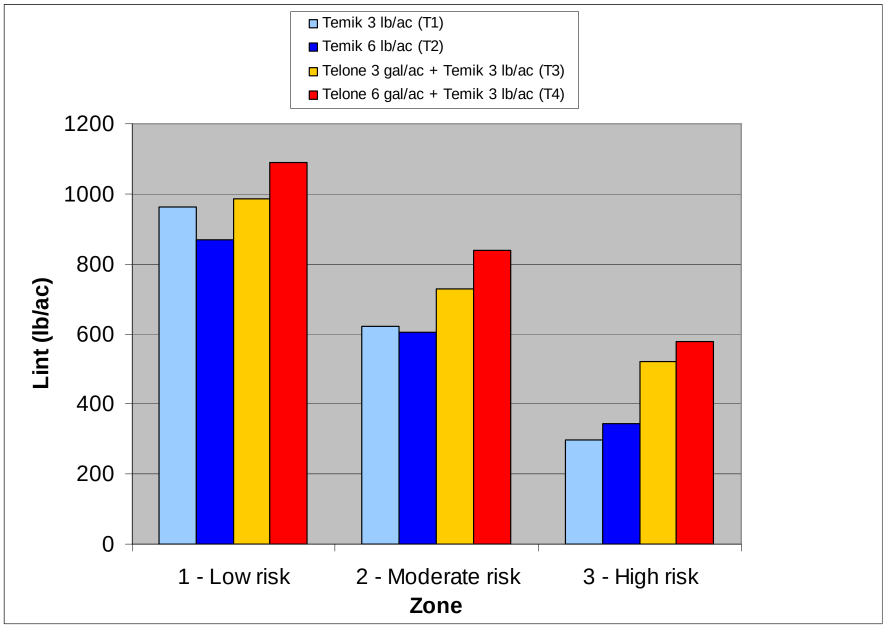

Figure 4. Cotton yield differences between zones and treatments within zones. CC field.

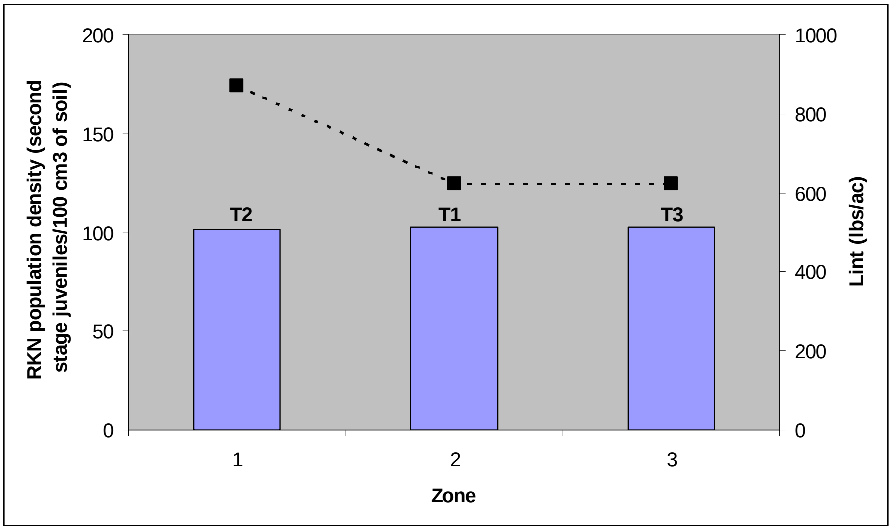

Figure 5. Changes in average RKN population density and cotton yield between zones and treatments within zones. CC field

Table 4. Cotton yield difference to nematicide treatments within a particular management zone, and P values for the CC field in 2007.

Zone								
1*			2*			3*		
Combination	LSD†	Pr > |t|	Combination	LSD†	Pr > |t|	Combination	LSD†	Pr > |t|
T2T1	-92.7	0.0335*	T2T1	-16.7	0.7083	T2T1	46.8	0.0847
T3T1	24.5	0.5689	T3T1	108.0	0.0303*	T3T1	224.2	<.0001*
T4T1	126.4	0.0007*	T4T1	216.9	0.0007*	T4T1	278.6	<.0001*
T3T2	117.2	0.0033*	T3T2	124.6	0.0200*	T3T2	177.3	0.0002*
T4T2	219.1	<.0001*	T4T2	233.6	0.0005*	T4T2	231.8	<.0001*
T4T3	101.9	0.0206*	T4T3	109.0	0.0369*	T4T3	54.4	0.0551
T3T4 vs. T1T2	121.8	<.0001*	T3T4 vs. T1T2	170.8	0.0004*	T3T4 vs. T1T2	228.0	<.0001*

* Significant differences between nematicide treatments within a management zone, $P< 0.05$.
† Least square yield difference between two nematicide treatments.

Studies conducted in the Mississippi Delta river area of Louisiana demostrated that a yield increase of 80-100 lbs lint ac^{-1} was necessary to cover the cost of nematicide treatments such as Telone. In our study, considering differences in RKN population and yield across zones, significant differences in average net return for the nematicide treatments occurred only within higher risk zones. Therefore, the application of Telone (at any rate) was economically prudent in zones MZ2 and MZ3 (Table 5). For example, in MZ 1 with the lowest RKN population, the cost of Telone or higher rate of Temik application would not be offset by yield. In the lower risk zone (MZ 1) the grower would have actually lost money ($553- $541) when using Telone, 3 gal/acre rather than the base Temik, 3 lb/acre, treatment. He would have realized a small gain ($561- $553) by increasing rate to 6 gal/acre.

Table 5. Average net returns by zone and treatment. CC field

Treatment	**Zone**					
	1		**2**		**3**	
	mean	std dev	mean	std dev	mean	std dev
Temik 3 lb/ac (T1)	$553.59	$ 37.44	$361.42	$118.67	$150.82	$ 58.91
Temik 6 lb/ac (T2)	$485.74	$ 59.44	$340.11	$124.07	$173.65	$ 32.05
Telone 3 gal/ac + Temik 3 lb/ac (T3)	$541.43	$ 45.80	$401.80	$114.62	$259.76	$ 31.65
Telone 6 gal/ac + Temik 3 lb/ac (T4)	$561.68	$ 81.18	$413.28	$126.96	$249.63	$ 44.52

Conclusions

The results from this study clearly showed that RKN control and final yield varied with respect to the nematicide type and rate across risk management zones based on fuzzy clustering of terrain elevation and slope, NDVI of bare soil reflectance and apparent soil electrical conductivity. Low RKN population was confirmed in the MZ with the lowest risk level for RKN. In this zone, there were no significant differences in RKN population between the application of Temik or Telone II at any rate. In contrast, the MZ with the highest risk level exhibited the highest RKN population, along with significant differences in nematicidal control between treatments. The highest reduction in average RKN population was observed with the use of Telone. A consolidated analysis of the RKN population density by zone-treatment showed that regardless of the zone there were no differences between Temik rates (T1 and T2 treatments) or Telone rates (T3 and T4 treatments).

Cotton yield increases were observed on plots receiving Telone treatments compared to Temik treatments and these differences increased when we moved from a MZ with a low risk level to high risk level. In general, nematicide control for Telone responded better than Temik on more coarse-textured sandy areas and especially when Telone was applied at a rate of 6 gal ac^{-1}. In contrast, no statistical difference between nematicide types and rates with respect to RKN population and the lowest yield increments was observed in less coarse-textured sandy areas. These results suggest that the application of Temik would be enough to control RKN present in the lower risk zones. Therefore, the application of Telone (at any rate) was economically prudent in moderate and high risk levels (MZ2 and MZ3). In contrast, in the lowest risk zone (MZ1), the cost of Telone or higher rate of Temik application would not be offset by yield.
In conclusion, the results presented here demonstrate the value of variable rate application of nematicide based on management zones depicting different levels of risk for high population of RKN.

Disclaimer

Product names are provided for information only and do not imply endorsement by the University of Georgia or the United States Department of Agriculture Agricultural Research Service

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Evaluating Stocker Cattle in a Southern Piedmont Conservation Tillage Cotton-Cover Crop System to Increase Productivity

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INTRODUCTION

Winter cover crops are often perceived as costly because there are no direct returns from selling the cover crop (Snapp et al., 2005). Additional negative concerns are expressed due to the potential for cover crop induced water stress early in the growth of the main cash crop. Cover crop conservation benefits have been documented for all major crops and growing regions of the US (Dabney, et al., 2001). Beyond the soil conservation benefits, cover crops have been shown to improve water availability by contributing to improvements in soil physical properties that increased water infiltration rate and reduce runoff (Touchton, et al., 1984; Bruce et al., 1995). Payments from government incentive programs, like the Conservation Security Program, can help offset the cost of cover crops (up to \$8 acre^{-1}) (Causarano et al., 2005). Another option for offsetting cover crop costs and increasing farm revenue is grazing of winter cover crops by cattle (*Bos taurus* L.). Grazing stocker cattle in a cotton-peanut rotation in south Alabama produced \$157 gross return and \$75 net return per acre from cattle (Siri-Prieto et al., 2003).

Grazing cover crops may reduce soil productivity due to hoof-induced soil compaction during the grazing period (Miller et al., 1997). Cotton yields were reduced an average of 14% in two out of three years on silt loam soil in North Alabama where cover crops were grazed (Mullins and Burmester, 1997). Soil compaction from grazing is influenced by a number of factors (soil texture, soil water content, grazing intensity, vegetation type and climate regime; Taboada and Lavado, 1988). Siri-Prieto et al. (2003) found that paratill or in-row subsoiling was required to alleviate grazing-induced compaction and maximize cotton and peanut yields in south Alabama.

In the Southern Piedmont, depth to the Bt layer influences rooting volume and water availability (Endale et al., 2006) and in turn can influence the degree of compaction from grazing. Depth to the Bt is spatially distributed with erosion class being a surrogate indicator but at a very rough scale. Other factors influencing soil response to cattle may also be spatially variable but need to be quantified before management strategies can be developed to reduce negative effects. By identifying spatially variable factors with GPS technology management zones can be delineated for prescription deep tillage. Performing deep tillage only on areas with a high probability of compaction would therefore reduce producer costs.

Our objectives were to evaluate the impact of cattle grazing winter annual small grains on (1) cotton production (2) forage available for grazing, and (3) soil compaction. We measured a number of spatially distributed soil and plant properties to identify those that might easily be used to identify management zones for ameliorating any negative effects from cattle.

MATERIALS AND METHODS

This study started in the fall of 2005 and will continue through 2009. Four fields at the USDA-ARS J. Phil Campbell, Sr., Natural Resource Conservation Center in Watkinsville, GA (33° 59' N, 83° 27' W) historically in no-tillage and instrumented to determine management effects on sediment and nutrient losses from typical fields in the Southern Piedmont are used in the study. Three of the fields are 3.3 acres while the fourth is 6.9 acres.

Winter rye (*Secale cereale* L.) is planted with a no-till grain drill in early October as a cover crop on all fields. Poultry litter is applied in the fall to provide sufficient P for both rye and cotton (*Gossypium hirsutum* L.) and supplemental N is added as needed for cotton and rye. On two fields, rye is grazed with heifer cattle for 7 to 10 days starting in late-March. The other two fields are not grazed and the rye is killed with glyphosate the second week of April. Numbers of cattle are adjusted based on forage availability and estimated intake so that pastures are defoliated in less than 10 days. Cover crop biomass is determined prior to and after grazing and just prior to cotton planting. Cover crop residues are analyzed for carbon and N, P, K, Ca, Mg.

Soil type, EC data, depth to Bt, and soil penetrometer data collected in fall of 2006 were combined in a Geographic Information System (GIS) to develop plant sampling zones for the cotton growing season. The cumulative grazing effects on soil compaction will be determined by measuring soil penetration resistance at the same locations in the spring 2006 and 2009 following cotton planting. Geostatistical methods are being used to analyze soil, water, and plant data to determine landscape and grazing effects on cotton productivity.

Cotton is planted the first week of May with a no-till planter. Cotton plants are sampled at first bloom and mid-bloom for biomass, plant height, and nutrient status to determine grazing and landscape effects on growth and nutrient content. Winter grazing effects on plant water stress and soil water availability (0 to 30 cm) are determined from first bloom until cutout by measuring soil water content using TDR probes inserted vertically into the soil. Cotton is harvested in the fall after defoliation using a harvester equipped with a yield monitor and GPS to collect georeferenced yields. Cotton samples from five areas in each field are collected for determination of fiber length, strength, micronair, and uniformity using High Volume Instrument (HVI) classing.

RESULTS AND DISCUSSION

Grazing

In 2006, cereal rye (*Secale cereale* L.) herbage grew from approximately 1000 lbs/acre in late January to 8000 lbs/acre in mid April in the ungrazed plots. On the grazed plots, we began grazing with an herbage mass of approximately 4000 lbs/acre in mid to late March. The grazed plots were defoliated only once and the cattle consumed approximately 2600 lbs of dry matter per acre. In spring of 2007 herbage grew from approximately 1000 lbs/acre in February to 6000 lbs/acre in mid April in the ungrazed plots. On the grazed plots, we began grazing with a herbage mass of approximately 2200 lbs/acre in mid-March during a period of rapid growth. The mid-March grazing period was followed by a mid-April grazing and the animals consumed an estimated 2900 lbs of dry matter per acre during the grazing season. In spring of 2008, herbage grew from approximately 1000 lbs/acre in February to approximately 6000 lbs/acre in early April in the ungrazed plots. Grazing was initiated with only 1500 lbs/acre herbage mass. The watersheds were grazed twice and animals consumed approximately 2200 lbs of dry matter per acre of forage during the grazing season.

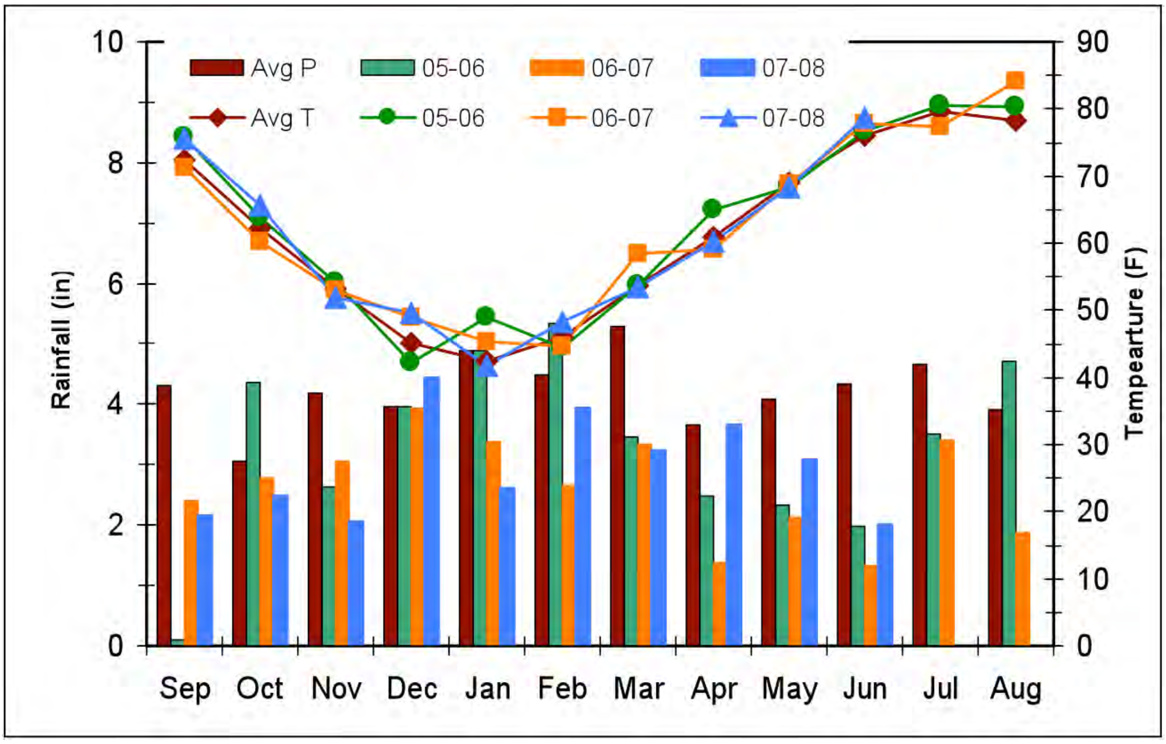
We estimate that 1.5 head/acre can be supported for a 75 day period between February 1st and April 15th if animal management and agronomic management are efficient and climate is adequate. Season to season variation will require careful and flexible management and alter rotational requirements. At $20 to $40 for an 800 lb round bale the 3000 lbs of forage would be worth $70 to $140/acre. The quality of grazed rye is higher than baled forage and should result in improved animal performance. In addition, grazed forage reduces labor, feeding losses and storage costs compared to hay. Adjusted to equivalents of feeding hay, yield/acre is closer to 4000 lbs/acre and the value of grazing the rye cover crop likely ranges from $100 to $200/acre.

Cotton Yields

In 2006, cotton experienced 10 days of cool weather following planting on May 12th and 15th, which delayed germination and growth. Growing season rainfall was below historical averages but timely rains in late July and August were beneficial for cotton yields (Fig 1). Seed cotton yields ranged from 2140 lbs/ac to 2950 lbs/ac. No significant yield differences were detected between grazed and ungrazed fields (both treatments averaged approximately 2500 lbs/ac). After ginning, our yield per acre averaged 1008 lb lint/ac which was greater than the Georgia average of 765 lbs/ac or 1.6 bales/ac.

In 2007, rainfall was very low from planting to harvest. Rainfall in June (1.34 inches) and July (1.72 inches) was well below normal which reduced cotton growth and yield. Using our yield monitor equipped spindle picker, yields ranged from 200 to 300 lbs lint/acre and averaged 250 lbs/acre. About two weeks after using the spindle picker we picked the fields with a stripper unit and harvested another 140 lb lint/acre that was still in the field due to physiological hardlock. With the low yields there was no difference between grazed and ungrazed treatments.

Fig 1. Temperature and Rainfall for the cover crop and cotton growing seasons Fall 2005 to Fall 2006 and the long-term averages at Watkinsville, GA.



CONCLUSIONS

Based on our grazing data, returns from grazing cover crops would be an economic benefit to cotton producers in the Southern Piedmont, especially in periods of poor crop production. In the first three years of the research, cereal rye provided sufficient forage to support approximately 1.5 animals/acre between February 1st and April 15th. Grazing did not influence yield in either year. Return on grazing was similar for both years while cotton returns were more variable. These results indicate grazing cover crops may be an important economic consideration for cotton producers in the Southern Piedmont because of the potential to increase revenues from grazing without reducing cotton yields and to minimize variations in total annual revenues. The research will continue in 2008 and 2009.

ACKNOWLEDGMENTS

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Conservation Tillage, Irrigation and Variety Selection Impacts on Cotton Quality Premiums, Discounts and Profitability: Evidence from the Gin

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Abstract

Fluctuating market prices, increasing production costs, and shifting mill demand, has made cotton markets more uncertain, making cotton quality a more important aspect of the profitability of cotton. The purpose of this research project is to examine the effect conservation tillage systems and variety selections have on cotton quality attributes and cotton profitability. Such information may be useful to agencies promoting conservation tillage systems for cotton producers. In addition, knowledge of these types of effects may help producers and gins maximize profits by providing guidance on variety selection and production decisions that improve cotton lint quality.

Introduction

Fluctuating market prices, increasing production costs, and shifting mill demand, has made cotton markets more uncertain, making cotton quality a more important aspect of the profitability of cotton. A common management strategy for improving profits has been to improve lint yields by adopting more input-intensive varieties or technologies and/or to identify optimal input use rates (to reduce usage) by examining the response relationship between cotton yield and a select number of inputs or factors (Britt et al., 2002). Ethridge and Davis (1982) show that cotton prices can vary with significant changes in quality attributes, which can have significant economic implications for the farmer when cotton prices are low, which has been the case for much of the past decade.

With an increase in demand for quality cotton by textile mills, firms are willing to pay a premium for stronger cotton with less variation in micronaire, improved uniformity in fiber length and lower levels of contamination (Bradow and Davidonis, 2000). Newer varieties of cotton promise to offer higher yield with improved quality, which has historically been seen as a trade off in the past (Kerby et al., 2007). Farmers have traditionally selected high yielding varieties with slightly lower quality characteristics due to their potential to provide higher net returns, but with fiber quality playing a more important role with cotton demand at the mill level, quality is playing a more central role (Bradow and Davidonis, 2000). On the other hand, some farmers have moved away from transgenic varieties to conventional varieties due to an improvement in lint quality and no technology fees, increasing potential returns.

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A number of agronomic factors, such as variety selection, water usage, fertilization methods and temperature regulation influence cotton quality and in turn can be influenced by the choice of tillage system (Bradow and Davidonnis, 2000). A limited amount of research has examined the relationship between cotton quality and tillage system using experimental data (Bauer and Frederick, 2005; Endale et al., 2004; Mert et al., 2006). The results from these studies are not conclusive.

The purpose of this research project is to examine the effect conservation tillage systems and variety selections have on cotton quality attributes and cotton profitability. The quality attributes of interest are those used in the cotton marketing loan program: color or grade, staple length, leaf content, micronaire, uniformity and fiber strength.

Materials and Methods

Economic Methodology

The market price for cotton is determined by the demand and supply for cotton on the world market. This price can be viewed as a collection of implicit prices that are determined by the quantity and quality of cotton in the market. These implicit prices are recognized in the industry as premiums and discounts for different quality attributes (Brown and Ethridge, 1995).

The U.S. Department of Agriculture administers and maintains a system of cotton quality information that is used in and relied upon in the marketing for cotton classification. The common attributes examined, include: color or grade (CG), staple length (SP), leaf content (F), micronaire (M), uniformity (U), fiber strength (ST) and trash (EM). Following Brown and Ethridge (1995) and Ethridge and Davis (1982), it is assumed that cotton price is a function of these quality attributes and follows a hedonic pricing model of the form:

$$P_i^c = f(CG, SP, M, ST, F, EM, U) = \beta_0 \left(\sum_{j=1}^{7} A_{j,i}^{\beta_j} \right) \epsilon_i \quad , \qquad (1)$$

where the $A_{j,i}$'s are the seven quality attributes being examined and ε_i is a stochastic error term. This functional form is appealing because the β_j's are the price flexibilities with respect to the cotton quality attributes, or the percentage change in the price of cotton given a one percent change in one of the cotton quality attributes. It is these price flexibilities which will allow us to examine the impact of conservation tillage and other production practices on cotton profitability, through its affect on the price of cotton.

To incorporate production practices into equation (1) in order to assess their impact on cotton quality attributes and cotton profitability, it is assumed that $\beta_j = \gamma_{j,0} + \gamma_{j,1} N_i + \gamma_{j,2} I_i + \gamma_{j,3} R_i$, where *N* is a binary variable indicating if a farmer uses conservation tillage, I is a binary variable indicating if a farmer irrigates their cotton, and *R* is a binary variable indicating if a farmer plants a round-up ready variety of cotton.

Data

Data was obtained at the gin level to examine the farm level impact of management practices on cotton quality and profitability. Data was secured from a large cotton gin serving northern Alabama, central-southern Tennessee and extreme northwest Mississippi for all cotton bales processed from 1997 to 2004. Data from 2001 was not used due to missing data for that year. The dataset was large covering 21,650 bales from 190 farmers' fields in 1997; 36,665 bales from 222 farmers' fields in 1998; 34,362 bales from 356 farmers' fields in 1999; 42,859 bales from 339 farmers' fields in 2000; 47,693 bales from 396 farmers' fields in 2002; 54,292 bales from 336 farmers' fields in 2003; and 2004 bales from 385 farmers' fields in 2004. The dataset included indicator variables for: farm; field number; use of conservation tillage; use of irrigation; variety planted; yield statistics; ginning statistics; cotton quality attributes using HVI classification; and loan discount amount using the Commodity Credit Corporation (CCC) loan premium and discount schedule for the year the cotton was ginned.

Much of the cotton sold at the gin is sold in mixed lots to mills. These lots may be of varying quality and contain a large number of bales. The buyer purchases the lot at a fixed or negotiated price per pound for the entire lot (Ethridge and Davis, 1982). While these prices would allow us to more directly determine the implicit prices for different quality attributes in the market, they do not allow us to examine how different production choices potentially affect cotton prices and in turn farmer profitability, given the mixed lots usually are made up of cotton from multiple producers and variety types. Thus, in order to examine the impact on cotton profitability, prices are calculated using the CCC national market loan rate for cotton ($0.52) plus the CCC loan premium/discount provided by the gin (see http://www.fsa.usda.gov/ for rates). Given the national loan rate is fixed, changes in cotton prices for this analysis will directly reflect fluctuations in cotton premiums/discounts from changes in cotton quality attributes.

Statistical Analysis

The double log form of equation (1) is estimated as a linear generalized estimating equations model for each year using PROC GENMOD in SAS. This modeling approach allows for correlated data and provides coefficient and standard error estimates that are robust to misspecification of the variance-covariance matrix (Hedeker and Gibbons, 2006). It is likely that quality characteristics of cotton bales from the same field are correlated due to environmental, climatic, agronomic and management factors. Thus, observations from cotton bales from the same cotton field are treated as repeated observations and it is assumed that the correlations between these observations are the same, or exchangeable. Psuedo R^2 are estimated for each regression following Magee (1990).

Results and Discussion

Price flexibilities (β_j's) are reported in Table 1 along with fit statistics for each regression performed. Psuedo R^2 values ranged from 0.64 to 0.80 indicating a relatively good fit to the observed data. Base price flexibilities ($\gamma_{j,0}$) are reported for each quality attribute in Table 1 with the corresponding additive effect from using conservation tillage ($\gamma_{j,1}$), irrigation ($\gamma_{j,2}$) and/or a round-up ready variety ($\gamma_{j,3}$).

Table 1: Estimation Results and Elasticity Estimates for 1997-2000, 2002-2004.

Price Flexibilities	1997	1998	1999	2000	2002	2003	2004
Color/Grade Base	-0.131*	-0.106*	-0.073*	-0.036*	-0.133*	-0.068*	-0.165*
	(0.011)	(0.007)	(0.005)	(0.013)	(0.023)	(0.009)	(0.033)
No-Till Effect	0.016	0.026*	0.013*	-0.000	-0.134*	-0.008	0.051
	(0.022)	(0.011)	(0.007)	(0.014)	(0.028)	(0.010)	(0.033)
Round-Up	0.025	0.014	0.014*	-0.076*	-0.210	0.001	0.000
Ready Effect	(0.030)	(0.010)	(0.007)	(0.008)	(0.183)	(0.007)	(0.000)
Staple Base	0.223*	0.457*	1.090*	1.569*	1.106*	1.089*	0.612*
	(0.039)	(0.029)	(0.054)	(0.078)	(0.109)	(0.072)	(0.130)
No-Till Effect	-0.074	-0.026	0.138*	-0.071	-0.273*	-0.073	0.145
	(0.056)	(0.057)	(0.06)	(0.088)	(0.125)	(0.078)	(0.130)
Round-Up	-0.183*	-0.052	0.001	0.467*	0.255	-0.076	-0.001*
Ready Effect	(0.078)	(0.053)	(0.048)	(0.105)	(0.213)	(0.048)	(0.000)
Micronaire Base	0.181*	0.123*	-0.026	-0.133*	-0.339*	0.154*	-0.104*
	(0.027)	(0.020)	(0.027)	(0.044)	(0.058)	(0.038)	(0.044)
No-Till Effect	0.095*	0.057*	0.041	0.278*	0.107*	0.007	0.108*
	(0.045)	(0.025)	(0.044)	(0.050)	(0.062)	(0.040)	(0.044)
Round-Up	-0.092	-0.130*	-0.115*	0.013	-0.158	0.081*	0.000
Ready Effect	(0.104)	(0.025)	(0.042)	(0.177)	(0.124)	(0.020)	(0.001)
Strength Base	0.132*	0.096*	0.043*	0.129*	0.065*	0.073*	0.185*
	(0.022)	(0.014)	(0.021)	(0.038)	(0.039)	(0.017)	(0.042)
No-Till Effect	-0.029	0.002	0.019	0.000	0.097*	0.052*	-0.021
	(0.031)	(0.022)	(0.024)	(0.040)	(0.040)	(0.019)	(0.042)
Round-Up	0.052	0.001	-0.010	0.183*	-0.033	-0.006	-0.000
Ready Effect	(0.044)	(0.22)	(0.023)	(0.068)	(0.040)	(0.014)	(0.000)
Leaf Content Base	-0.108*	-0.110*	-0.076*	-0.055*	-0.023*	-0.100*	-0.052
	(0.009)	(0.008)	(0.012)	(0.009)	(0.010)	(0.011)	(0.013)
No-Till Effect	-0.008	-0.004	0.013	-0.023*	-0.27*	0.019	-0.016
	(0.012)	(0.014)	(0.013)	(0.011)	(0.010)	(0.012)	(0.013)
Round-Up	-0.024	-0.003	-0.017*	-0.067	0.003	0.016*	-0.001*
Ready Effect	(0.019)	(0.012)	(0.009)	(0.067)	(0.007)	(0.005)	(0.000)
Uniformity Base	0.147*	0.054*	-0.024	0.351*	0.075	0.237*	-0.062
	(0.017)	(0.028)	(0.050)	(0.070)	(0.069)	(0.057)	(0.223)
No-Till Effect	0.103	-0.036	-0.045	-0.158*	0.012	-0.049	0.164
	(0.086)	(0.053)	(0.060)	(0.078)	(0.078)	(0.060)	(0.225)
Round-Up	-0.024	0.137*	0.102*	-0.655*	0.007	0.005	0.001*
Ready Effect	(0.142)	(0.049)	(0.057)	(0.264)	(0.073)	(0.035)	(0.000)
Extraneous Matter	-0.006*	-0.007*	-0.007*	-0.008*	-0.011*	-0.004*	-0.003*
Base	(0.000)	(0.000)	(0.000)	(0.001)	(0.003)	(0.001)	(0.001)
No-Till Effect	-0.000	-0.000	0.001*	0.001	0.005*	-0.002*	-0.003*
	(0.000)	(0.000)	(0.000)	(0.001)	(0.003)	(0.007)	(0.001)
Round-Up	0.000	0.000	-0.000	0.001	-0.004	0.000	-0.000
Ready Effect	(0.001)	(0.000)	(0.000)	(0.001)	(0.004)	(0.001)	(0.000)
			Fit Statistics				
Pseudo R^2	0.64	0.67	0.68	0.74	0.64	0.80	0.73
Number of Observations	21650	35665	34362	42859	47693	54292	57892

* Indicates statistical significance at the P = 0.10 level. Numbers in parentheses below estimates are their standard errors.

As expected, following the CCC loan premium and discount schedule, the base price flexibilities for color grade, leaf content and extraneous matter are negative, meaning as the values of these attributes increase (attribute declines, reducing quality) cotton prices will decline. In contrast, the base price flexibilities for staple, strength and uniformity (when statistically significant) are positive, meaning as the values of these attributes increase (attribute improves, increasing quality) cotton prices will improve. For micronaire, a measure of the cotton fiber fineness and maturity, the sign of the base price flexibility changes based on the year, which likely arises due to the nonlinear relationship between micronaire level and its associated CCC premium/discount. When micronaire is outside the range 3.5 to 4.9 it receives a discount (http://www.fsa.usda.gov/). A note of interest when examining the results is that from 1997 to 2004 an increasingly higher percentage of fields (from 38 to 96 percent) were managed using conservation tillage methods.

The primary estimates of interest are the “effects” parameters in Table 1. These effects are the change in the price flexibilities given different production/management decisions. When an “effect” is the same (different) sign as the base price flexibility for a given quality attribute, the result is an increase (decrease) in the percent change (positive or negative) in the cotton price given a one percent change in the value of the quality attribute. Using conservation tillage methods (no-till effect) had a significant effect on all the quality parameters, but in different years. The only consistent effect was on micronaire over the years. It seems as the use of conservation tillage increased over time, variability in micronaire decreased, reducing the price flexibility and the impact on the price of cotton. Along these same lines, as the number of fields with residue left on the soil surface increased, discounts for extraneous matter increased. Use of conservation tillage increased the absolute values of the price flexibilities for fiber strength and leaf content in two of the seven years examined, as well. The effects for irrigation and round-up ready, while significant for different attributes in different years are not consistent.[2] For irrigation, Enciso et al. (2003) found no significant effects from increasing irrigation on cotton quality attributes. The results concerning the use of round-up ready varieties could be due to the ever changing availability of new technologies available on the market and the wide number of varieties utilized. Further intense study of specific varieties is needed.

Conclusions

Cotton prices guide the production and marketing decisions made by farmers directly impacting cotton profitability. Cotton quality attributes play an important part in determining cotton lint demand by textile mills, which in turn affects cotton prices and the implicit price for cotton quality attributes (Ethridge and Hudson, 1998). The impact of management factors, such as conservation tillage, can directly affect these implicit prices, potentially impacting cotton production decisions. While the impact of using conservation tillage, irrigation and/or round-up ready varieties is variable from year to year, it may be important to know the impact of these management practices on cotton quality attributes and prices in past years to help predict the impact on future cotton cropping decisions.

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[2] The effects for irrigation are not shown in Table 1 due to space limitations, but are available from the authors upon request.

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Economic Feasibility Analysis of Transitioning to Organically Grown Peanuts

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Summary: Several hurdles still exist in transitioning to an organic peanut production process in the Southeast. In particular, there is little research or information to help peanut growers economically manage the required 3-year transition period from the last application of a non-approved substance to the first organically certified crop. Two different growers are currently transitioning to organic peanut production. An economic analysis based on the first year of data, 2007, is performed to determine the returns on investment. Production costs and yields are collected from grower records and economic returns are analyzed for 2007.

Creating Management Zones for Nutrient Application Decisions in a Bermuda Grass Hay Field

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ABSTRACT

Precision agriculture or ‘precision ag’ dictates an investment in technologies, adding additional costs to the producer. This is why most precision ag has focused on larger farms with traditional row crops. To date, precision ag has not been used as much on smaller farms commonly found in the Piedmont region of the Southeast or enterprises with less profit margin than row crops, i.e., forages. This can be seen in the growth of precision or variable-rate application services in the Coastal Plain vs. the Piedmont.

The land and herd management (LHM) team at the USDA-ARS J. Phil Campbell Sr., Research Center, Watkinsville GA, was motivated by increasing fertilizer prices and a flat research budget to improve efficiencies of fertilizer applications supporting the Center’s research herd of 200 Angus cows. The objective was to develop a practical means for site-specific nutrient applications for hay production, using low cost precision ag tools and equipment/services readily available to forage producers in the Piedmont.

The Center has 1183 acres consisting of woods, ponds, administrative areas, crops, and pastures that support a cow/calf herd. The South Unit has 77 acres that has been harvested for hay three or four times a year since 1993. In summer, the field is a mixture of warm season grasses: 60% bermudagrass [*Cynodon dactylon* (L.) Pers.], 30% Johnson grass [*Sorghum halepense* (L.) Pers.], and 10% large crabgrass [*Digitaria sanquinalis* (L.) Scop]. In spring the field is predominantly ryegrass [*Lolium multiflorum* (Lam.)]. The principal soil type is a Cecil sandy loam with a Pacolet stony sandy loam on slopes.

Since 1993, cultural practices treated the field uniformly; sampling annually for pH, P, and K. Six composite samples were taken across the field; each composite consisting of 20 random sub-samples taken with a hand-held probe (6-in depth). Samples were analyzed at the University of Georgia (UGA), College of Agricultural & Environmental Sciences’ (CAES) Agricultural & Environmental Services Laboratory (AESL). Soil test results, averaged for the six composite samples, were used for determining/applying lime and fertilizer requirements. From 2001-2007, mean fertilizer rates were 180 lbs N/ac/yr, 30 lbs P/ac/yr, and 120 lbs K/ac/yr. During this time, funding constraints prevented applying total nutrient needs called for in soil tests. Weeds and pests were controlled according to UGA Extension recommendations.

In spring 2007, bulk soil electrical conductivity (EC) data was collected at 0-1ft (0-30 cm) and 0-3ft (0-90cm) using a Veris® model 3100 Soil EC Mapping System. This data was used with aerial photographs, first-order soil surveys, and historical field information to determine preliminary Management Zones for soil sampling. Areas of the field were evaluated for soil type

and texture as indicated by the soil survey and EC maps. This combined with the field manager's knowledge of previous yields identified sampling sites reflecting the spatial variability of the field while minimizing the number of samples needed. Twenty-seven sites were established and five subsamples were taken with a hand-held probe to a depth of 6-in within a 15ft circle at each site and composited. Samples were analyzed at the UGA CAES AESL.

Using soil test results, separate site-specific maps were created for P and K requirements. Because of little variation in pH within the field, a uniform application of lime (1 ton/ac) was applied in January 2007. Three zones were developed for P and K needs in order to minimize applicator trips based on custom fertilizer blends. Each sampling site was linked with the prescribed blend for that zone (22-0-20, 17-17-17, or 21-7-15), resulting in a fertilizer prescription map (fig. 1). Using a handheld GPS receiver, application areas were outlined with marking flags for the applicator.

There was greater spatial variability for soil test K compared to P and lime requirements. Due to funding constraints in 2007 we were unable to apply the total required amounts of P and K. Even so, making a single fertilizer application based on field-average soil test values vs. our prescription-blend variable rate application would have resulted in P being over-applied by 12%. At a cost of $1.74/lb P, this inefficient over-application would have cost $307.46. Thus, we believe our practical method for applying fertilizer using non-variable rate equipment will allow us to more efficiently manage fertilizer applications in the future. We also speculate that the use of soils and manager-knowledge data to determine geo-referenced sites for soil samples will improve the precision of nutrient need determinations over time.

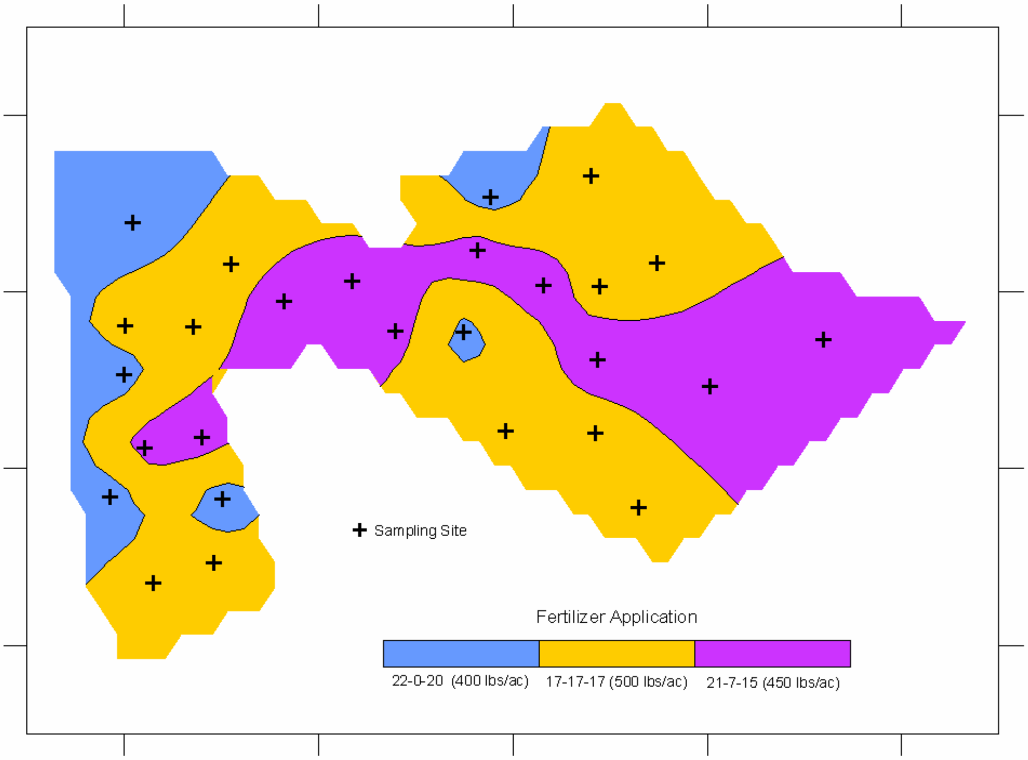

Figure 1. Map of hay field showing areas for applying different fertilizer blends.

Conservation and Conventional Tillage Peanut Production Functions: Estimation, Elasticities, and Efficiency

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Summary: Peanut trial data was analyzed across six farms to estimate a production function for plot yield based on plot length. Other inputs for each farm were assumed constant. A quadratic production function was estimated for three models: all tillage types, conservation tillage, and conventional tillage. Elasticities of scale for each model were determined. A Chow test shows that there is a significant difference between conservation and conventional production functions. Further analysis was performed using a stochastic frontier specifying stochastic noise (attributable to the farm), and inefficiency (based on tillage type). Preliminary analysis shows significant inefficiency due to tillage type practice.

Deficit Irrigation and Conservation Tillage Effects on Water Use and Yield of Cotton

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ABSTRACT

Many producers in the Texas High Plains supplement growing season rainfall with irrigation using water supplied from the Ogallala aquifer. Increasing pumping costs and declining well capacities in the Southern High Plains compel producers to grow alternative drought tolerant crops and improve precipitation capture using residue retaining conservation tillage practices. Sorghum [*Sorghum bicolor* (L.) Moench] grown in rotation with wheat (*Triticum aestivum* L.) is a cropping sequence that efficiently captures and uses rain. This Wheat–Sorghum–Fallow, WSF, cropping sequence (Fig. 1) could be modified to use cotton (*Gossypium hirsutum* L.) in place of sorghum, but residue levels will be decreased. Crop residue increases infiltration of rain and reduces evaporation that, consequently, increases storage of precipitation for subsequent crop use. Reducing evaporation of irrigation water with residue cover may increase water use efficiency by increasing the portion transpired by the plant. Our objectives were to adapt cotton and wheat to a limited irrigation cropping sequence with fallow periods, and to quantify the effect of residue management practices on i) fallow precipitation storage, and ii) yield of deficit irrigated cotton.

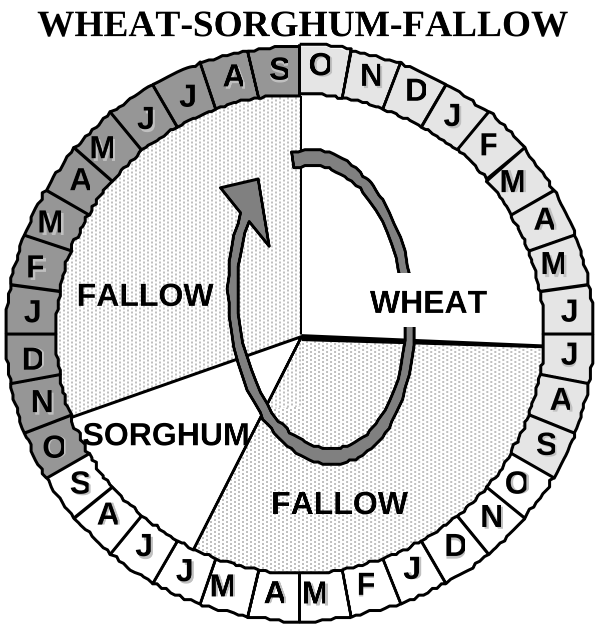

Figure 1. The three-year wheat-sorghum-fallow (WSF) rotation begins with wheat establishment in October. Wheat is harvested 10-months later in July and the soil is fallowed until June of the second year (11-months) when grain sorghum is grown using stored soil water to augment summer rain. After sorghum harvest in November of the third year the soil is again fallowed for 10-months when the sequence is repeated. The modified sequence substitutes cotton for sorghum.

All phases of a Wheat-Cotton-Fallow (WCF) cropping system were installed in 2004 on a Pullman soil (fine, mixed, superactive, thermic Torrertic Paleustoll) that was irrigated by a 300 ft long linear move mid-elevation spray irrigation system. Grain was harvested from uniformly cropped wheat that was sown at 60 lbs/ac in 10 in. rows during October. Wheat was not fertilized because ~ 50 lbs (N)/ac is typically mineralized during fallow and is usually sufficient for dryland wheat crops. Wheat residues were fallowed for ~11 months using disk, stubblemulch (sweep plow), or no –tillage residue management. Weed control in no-till fallow used a one time application of 2.5 lbs/ac a.i. atrazine [6-chloro-N-ethyl-N’-(1-methylethyl)-1,3,5-triazine-2,4-

diamine] and 1.0 lb/ac a.i. applications of glyphosate [N-(phosphonomethyl) glycine] as needed for weed escapes. After wheat fallow, 100 lbs. (N)/ac was applied through the irrigation system and cotton was planted during mid-May with unit planters in rows 30 in. apart at a population of 60,000 seed/ac. Growing season weeds were controled after tilled fallow with 1 lb/ac a.i. trifluralin [2,6-dinitro-N, N-dipropyl-4-(triflouromethyl) benzenamine] and for no-till with 1.5 lbs/ac a.i. diuron [3-(3,4-dichlorophenyl) 1,1-dimethylurea] plus 0.75 lbs/ac a.i. metolachlor [2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide] with glyphosate applied to control weed escapes. Cotton was irrigated in treatment strips receiving 1 or 2 in. applications every 10 days to duplicate irrigation using 2 or 4 gpm/ac pumping capacities common for weak and good wells in this region.

Treatment combinations of irrigation levels (2) and tillage residue management practices (3) were replicated 3 times resulting in 18 plots for each rotation phase. Measurements included precipitation and gravimetric soil water content to 7.5 ft at planting and harvest for each phase of the rotation and cotton growth and yield. We compared treatment effects on cotton yield and measured soil water storage and use according to a randomized complete block split-strip plot arrangement of an analysis of variance (ANOVA).

Fallow period storage of precipitation as soil water increased as the amount of surface residue increased, but this water storage varied with precipitation amount during fallow. Following the dry 2005-2006 fallow period that received <3.5 in. precipitation, available soil water was 5 in. for no-till, 4 in. for sweep till, and 2.5 in. with disk tillage. In contrast, 11.9 in. of precipitation occurred during the 2006-2007 fallow period, resulting in soil profile storage of 8.0 in. available soil water regardless of tillage treatment. Our study shows that residue increases soil water storage during fallow for subsequent cotton use.

Cotton yields generally increased with residue retaining conservation tillage practices or increased irrigation (Table 1.). Residues decreased evaporation of irrigation water and growing season rainfall. This benefit plus differences in soil water at planting increased cotton water use and resulted in higher yields with no or sweep tillage (LSD ~ 68 lb/ac). Increasing irrigation from 1 to 2 in. every 10 d increased lint yield from 15% with disking to 30% with no-till. High initial soil water and good early season rainfall during 2007 diminished the tillage and irrigation effects on yields (LSD ~ 105 lbs/ac). That is, tillage did not affect yields when irrigated with 2 in. every 10 d and was not different from no-till cotton irrigated with 1 in. every 10 d.

Table 1. Cotton lint yield (lbs/ac) in 2006 and 2007 as affected by tillage and irrigation depth.

	2006 Irrigation / 10 d		2007 Irrigation / 10 d	
Tillage	1 in.	2 in.	1 in.	2 in.
No-till	754	1095	706	644
Sweep	654	876	521	683
Disk	487	556	519	657
Rainfall, in.	10.7		6.6	
Irrigation, in.	5.0	10.0	4.0	8.0

We conclude that residue retaining conservation tillage practices increased crop water use and yield when growing season precipitation was limited through increased fallow season soil water storage and reduced evaporation of irrigation water and rainfall.

Tillage Effects on the Soil Moisture Regime

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Before the development of herbicides capable of providing full-season weed control without pre-plant tillage or post-emergence cultivation, both were necessary for crop production on all soils and for all crops. By eliminating weed control as a reason for tillage, conservation tillage practices, including no-tillage (NT), are increasingly being adopted by producers. But large differences in soils and their response, which includes available moisture, to tillage and other components of management systems, have become apparent. On some soils, but not on others, no tillage can lead to improvement in the amount of water available for the growing crop, which may translate into greater crop productivity during growing seasons with limited rainfall. A major factor in moisture supply, crop response and soil management for NT crop production is the potential of the soil to shrink and crack as it dries. Soils that crack upon drying include individual members of entisols, inceptisols, mollisols, alfisols, and ultisols, as well as vertisols. Cracks provide convenient avenues for rapid rainfall infiltration into dry soil, although some cracking soils with high clay content may have hydraulic conductivity rates in the range of millimeters/day when saturated. In the Southeastern US, moisture regimes with respect to tillage should be given as much attention as other aspects of cropping systems.

When tilled, soils that do not contain adequate amounts of 2:1 clay to crack upon drying and have a sandy loam or finer texture exhibit a positive yield response to postemergence cultivation even in the absence of weeds. Raindrop impact on bare, tilled soil orients soil particles to form a crust that seals the soil surface and reduces the rainfall infiltration rate. Cultivation following rainfall breaks the crust, increasing the amount of water infiltrating with the next rainfall event. However, in many cases, after the crop canopy is formed and as the crop matures, cultivation is not practical. In tilled production systems, fall or spring tillage loosens the soil and buries part of or all crop residue. Tillage is a drying operation and loosened soil dries on the surface. Although macropores are disrupted, if the layer loosened by primary tillage is not pulverized with additional tillage and remains rough with voids between clods, water intake from the first rainfall event following tillage is rapid with little runoff. But, without additional cultivation the soil surface crusts with successive rainfall events, reducing infiltration and greatly increasing runoff. In turn, crop productivity response to NT and non-cultivated management, without cover, can be precipitous. Crop yield can be as much as 20% lower than that of tilled and cultivated during years with moisture deficits during the growing season (Triplett et al., 1968). Conversely, with optimum management, crop yields can be 20 to 30% greater for NT than the best tilled production systems on these same soils.

Various mechanisms are involved in improved moisture supplies with NT and mulch cover on non cracking soils. These include: increased rainfall infiltration, less runoff, changes in water movement patterns, reduced evaporation from the soil surface, improvement in the availability of moisture in the soil profile, and better utilization of small rainfall events. Although these effects may be additive, the relative importance of each likely varies with site, soil, crop, growing season and rainfall patterns. However, improved infiltration so that less water runs off, making more available for the crop, is a dominant mechanism. A brief review of each follows:

No-tillage yields on non cracking soils increases with the amount of **mulch cover** present. Mulch cover of 70 to 80% of the soil surface at planting time decreases to ~60% as the crop matures but is adequate to protect the soil surface and provide yields equal to, or better than, tilled plus cultivated systems. The mulch can be from crop residue, cover crops, killed weeds, or animal waste applied to the field. Crops vary in the amount of mulch remaining after crop harvest and its persistence, and this must be considered in management systems employed. For example, corn provides greater and more persistent residue than soybeans. Mulch intercepts energy from raindrop impact, decreasing the amount of crusting that occurs in bare soil. Mulch on the soil surface feeds earthworms. These, in turn, burrow to create macropores.

Recent interest in removing crop residue as a source of biomass for energy production or for animal feed could impact crop management systems. On non cracking soils, a cover crop grown to provide mulch for NT production would be needed. On cracking soils that do not respond to mulch cover when under NT management, removing residue would have less effect on moisture availability for the crop, although the potential for soil loss would be increased.

Triplett et al (1968) determined the **infiltration rate** on a non cracking soil with a sprinkling infiltrometer on tilled and NT treatments after three yrs corn production (Table 1). Treatments included tilled and cultivated, NT bare, and NT with either a normal or a double application of mulch for the study period. Infiltration runs included NT both with mulch present and removed. The infiltration rate for NT bare tended to be less than for the tilled treatment. Infiltration increased with the amount of mulch and was significantly greater with the double-mulch treatment than for the tilled treatment, even when the mulch was removed. Apparently the soil surface was stabilized and macropores formed under the mulch were maintained and functional, even with the mulch removed.

Edwards et al. (1988) characterized macropores on a 0.5 ha watershed with a 9% slope and a silt loam soil managed with NT. With annual rainfall of greater than one meter, **runoff** averaged less than one centimeter on an annual basis. Thus, practically all of the rain falling on this site moved into the soil. However, macropores must be continuous to the soil surface in order to function. Tillage destroys their continuity and there is some evidence that, following tillage, three years of NT crop production with mulch cover is required to reestablish a fully functional macropore system (Triplett et. al 1996). These large pores are important for rainfall infiltration and **water movement patterns**. Doubling the diameter of the pore increases water conduction by 4X. Ehlers (1975) demonstrated that rainfall on the soil surface flows into macropores then moves into the surrounding soil from the pores rather than moving from the soil surface as a wetting front as occurs in tilled soil.

Evaporation from the soil surface is reduced by mulch cover, although moisture use is similar for tilled and NT with mulch, once the crop canopy is formed (Blevins et al 1971). Van Doren and Triplett (1969) compared early corn growth with several treatments which included soil covered with crop residue and soil fitted with a medal grid which prevented runoff. They reported improved vegetative growth under the mulch. In turn, these larger plants produced greater grain yield. The mechanism of the crop response is not known but could reflect differences in infiltration pattern with macropores under the mulch, and/or greater evaporation from the soil surface without mulch, or modification of soil temperature variation during early crop growth, or rooting pattern as suggested in the next paragraph, or a combination of factors.

Moisture availability for crops is influenced by rooting patterns and root development. The mobility of water in unsaturated soil is limited at best, and roots must be present to explore the soil and extract soil moisture. Tilled production systems with postemergence cultivation destroy roots to the depth of cultivation and rainfall must infiltrate and percolate through the cultivated zone to be available for the crop. Triplett and Van Doren (1969) demonstrated that corn roots developed at the mulch-soil surface interface in a NT system. Although the focus in their study was toward availability of non-mobile, surface applied nutrients, the presence of roots in this zone indicates conditions were favorable for their development, and that moisture from small rainfall events passes through the mulch to the soil surface and would be available for the crop. In a later study, Paltineanu and Starr (2000) noted that small rainfall events were utilized more effectively with NT. They also observed that rain falling on the corn canopy ran down plant stems and infiltrated closer to the crop row than in tilled systems.

The tillage response and moisture patterns are different in soils that crack when dry. Shrinkage cracks open to the depth of drying. These cracks form convenient avenues for rainfall infiltration and as rainfall moves into the cracks, it wets the soil deeper in the profile, much as described for precipitation moving into macropores for non-cracking soils. There has been no positive crop yield response to cultivation in the absence of weeds reported on cracking soils. In fact, there can be a negative response because of root pruning. There is little or no yield response to mulch cover, even in years with rainfall deficit. Crop productivity on cracking soils has not been improved with NT and can be reduced under some circumstances. Since crop yields comprise a dominant factor in profitability, yields must be maintained at or near the potential for tilled systems for reduced or NT to be readily adopted. Morrison et al (1990) described a system for successful NT on vertisols. In this system, wide beds were formed and multiple crop rows were planted on the beds. Crops were rotated, which reduced disease potential described earlier as a problem for corn grown in monoculture on a cracking soil (Tiarks, 1977).

If yields can be maintained at an acceptable level, factors in addition to moisture conservation that might favor adoption of reduced tillage systems include:

1. Increased worker productivity. NT eliminates trips over the field and workers can increase the area managed (Triplett and Dick. 2008).
2. Land considered marginal because of erosion hazard can be used for cropping. In recent studies (unpublished), we have been planting NT corn in permanent pastures on sloping sites and harvesting the crop by grazing with steers. Grain sampling on these sites for crop yield indicated productivity in the 7 to 9 Mt/ha range. Soil compaction and reduced infiltration was not an obvious problem on the soils and sites used for these studies.

Table 1. Mulch and tillage effect on infiltration, bulk density and air filled porosity. Mean of 3 replications (after Triplett et al., 1968)

Treatment	Initial Run			Wet Run		
	Antecedent Bulk density 1. 3-8.9 cm	Instantaneous infiltration rate after 1 hr.	Total infiltration after 1 hr.	Antecedent Bulk density 1.3-8.9 cm	Instantaneous infiltration rate after 1 hr.	Total infiltration after 1 hr.
	gm cm^{-3}	cm hr^{-1}	cm	gm cm^{-3}	cm hr^{-1}	cm
A. Plowed bare	1.33a*	0.66b	1.80b	1.33a	0.43bc	1.04c
B. NT bare	1.43b	0.28b	1.22b	1.42ab	0.25c	0.64c
C. NT 40% residue	1.50b	1.17b	2.34b	1.48b	0.46bc	1.35bc
D. NT 80% residue	1.46b	2.64a	4.39a	1.46b	1.41a	3.48a
E. NT 40% residue, residue removed	1.50b	0.48b	1.63b	1.49b	0.30bc	1.04c
F. NT 80% residue, residue removed	1.46b	2.41a	4.17a	1.51b	1.09b	2.49ab
LSD at 5%	0.10	1.07	1.73	0.10	0.76	1.17

*Values within each column followed by the same letter are not significantly different at the 5% level of probability. Duncan's multiple range test.

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Hydrologic Impacts of Strip Tillage for a Coastal Plain Soil

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ABSTRACT

Strip till, planting into a narrowly tilled strip, is a growing practice among many Coastal Plain farmers. Strip tillage increases crop residue at the surface, leading to reduced evaporation and reduced raindrop impact. This research examines nine years of rainfall-runoff data from a paired conventional till / strip till research site. The study site is a 1.9 ha parcel on the University of Georgia Gibbs Farm located in Tift County, GA, U.S.A. The study began in late 1998. The site was divided into six 0.2 ha plots. Three plots were placed in conventional tillage while three were strip tilled. Cotton was planted in 1999, 2000, 2001, 2003, 2005, and 2007. Peanuts were planted in 2002, 2004, and 2006. Precipitation, surface runoff, and subsurface flow data were collected and summarized for the nine year period.

The total water loss, the sum of the surface and lateral subsurface flow runoff, as a fraction of rainfall received was calculated for both tillage treatments. On an annual basis, the total water lost as a % of rainfall from the conventional till system averaged 34% while it averaged 33% for the strip till systems. Total water loss varied from 12% (2007) to 51% (2003) for the conventional tillage treatment and from 9% (2007) to 53% (2005) for the strip tillage treatment. On the average, the conventional till system lost 23% through surface runoff and 11% through the subsurface. For the strip till system the annual losses were 14% through surface runoff and 19% through subsurface losses.

An 84% increase in lateral subsurface flow was observed from the strip till plots. The greatest increase in lateral subsurface flow occurred primarily during the month of March when antecedent moisture conditions are typically the greatest and evapotranspiration the least. Lateral subsurface flow losses during the summer growing season were typically small, although larger losses were observed during periods when summer tropical depressions produced larger rainfall totals. During the months from June through August a net average gain of 30 mm of infiltrated water was observed for the strip till plots (Fig. 1). During dryer years, when no subsurface losses were observed during the summer months the gains were larger.

The results indicate strip till systems experience enhanced infiltration. This increase is most prevalent during the crop growing season from June through August (Fig. 1). During the growing season, June, July, and August, evapotranspiration reduces soil water leading to less subsurface losses in the strip till system. Aside from the periods of very high summer rainfall caused by tropical storms, there is a net gain in soil water in the profile for the strip till system during the growing season, presumably benefiting crop growth.

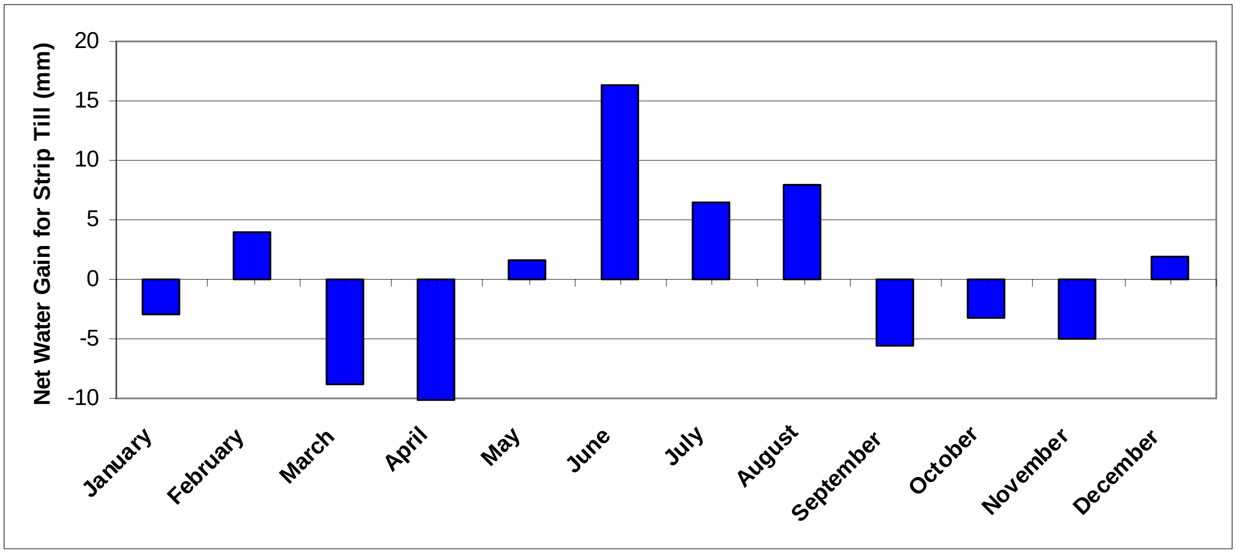

Figure 1. Average monthly net water gain for the strip till system.

Annual water gains in the strip till system obtained through enhanced infiltration and reduced surface runoff were offset by increased subsurface losses. Strip till had the greatest benefit in terms of increased water gains during years with the least annual precipitation. These results indicate that strip till systems can potentially increase plant available water through enhanced infiltration. This increase is most prevalent during the crop growing season from June through August. Water losses through subsurface flow tend to cancel out any gains obtained through increased infiltration occurring throughout the remainder of the year.

Economics of Zero-Grade Rice Management from the Perspectives of the Landlord and the Tenant

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ABSTRACT

Water is becoming increasingly limiting in parts of Arkansas where rice has historically been produced. The majority of rice acres in Arkansas are flood irrigated using contour levee systems. Contour levee rice fields require large amounts of applied water to maintain a flood during the production season. Fields precision leveled to a zero-grade require significantly less applied water and provide significant savings in production costs relative to contour levee fields. However, zero-grade is a land improvement and requires a large initial capital investment, and much time may pass before economic benefits are received. Also, with the majority of rice acres in Arkansas owned or partially owned by someone other than the producer, it is beneficial to determine how the monetary benefits are distributed to landowner and tenant when a field is precision leveled. This study uses net present value (NPV) approach to evaluate the monetary benefits for both parties under alternative yield situations.

Precision leveling expenses were gathered by phone conversations with farmers and land leveling professionals during 2008. Monetary benefits to zero-grade were defined as the difference in per acre tenant and landlord net returns between zero-grade and contour levee management. Present values of monetary benefits to zero-grade were calculated for alternative planning horizons (years) assuming a typical rice-soybean rotation for contour levee management and a continuous rice rotation for zero-grade management and a discount rate of 6.5%. The NPV for each planning horizon was calculated as the sum of present values to zero-grade management less the initial per acre cost of precision leveling to a zero grade. Five different tenure arrangements were evaluated: 1) 75-25 straight share (**75-25ss**, landlord receives 25% of crop); 2) 75-25 cost share (**75-25cs**, landlord receives 25% of crop and pays 25% of fertilizer costs); 3) 70-30 straight share (**70-30ss**, landlord receives 30% of crop; 4) 70-30 cost share (**70-30cs**, landlords pays 30% of fertilizer expenses and receives 30% of crop; and 5) 50-50 cost share (**50-50cs**, landlord pays 50% of seed, fertilizer, and pesticide expenses, 100% of irrigation expenses, and receives 50% of crop).

The results in Table 1 indicate that under the 75-25ss the tenant would prefer the same arrangement after improvements if a 10% yield gain occurs. Renegotiating to a 50-50cs would be preferred if no yield gain occurred or a 20% yield loss occurred in the first year. Positive NPV would be captured renegotiating to a 70-30 unless a 20% yield loss occurred. It would take until year five for the tenant to achieve a positive NPV under this scenario. The 75-25cs arrangement renegotiated to both a 70-30ss and a 50-50cs would have a positive NPV under a 10% yield gain and no yield gain. The yield loss of 20% would give the tenant a positive NPV under the 50-50cs but a negative NPV under the 70-30ss.

Under a 75-25 straight share the landowner would benefit from greatest to least by increasing share rent by 5%, staying at the 75-25ss, and changing to a 50-50cs arrangement,

respectively. With a 10% yield gain and 5% increase in straight share, a landowner would have a positive NPV in year 10 but it would be negative in year 10 if yield loss was 20%. The worst scenario for the landowner would be to change from the 75-25ss to the 50-50cs arrangement. Under the new 50-50cs a 10% yield gain, 0% yield gain or a 20% yield loss would have a negative NPV for more than 20 years. A landowner with a 75-25cs arrangement would have a positive NPV in year 10 if a 10% yield gain occurs. Changing to a 50-50cs would have a positive NPV for a 10% yield gain but would be negative for a 0% yield gain and a 20% yield loss.

Table 1. Cumulative NPV for tenant and landowner under alternative land tenure and productivity.

	Tenant					Landowner				
Planning horizon (years)	**75-25ss to 75-25ss**	**75-25ss to 70-30ss**	**75-25ss to 50-50cs**	**75-25cs to 70-30ss**	**75-25cs to 50-50cs**	**75-25ss to 75-25ss**	**75-25ss to 70-30ss**	**75-25ss to 50-50cs**	**75-25cs to 70-30ss**	**75-25cs to 50-50cs**
10% yield gain										
1	174.74	130.25	172.37	78.61	120.73	-727.23	-682.74	-724.86	-630.47	-672.59
5	714.74	516.06	704.14	347.57	535.64	-492.38	-293.70	-481.78	-123.53	-311.61
10	1,224.16	877.01	1,205.62	606.00	934.61	-311.52	35.62	-292.99	309.14	-19.47
15	1,623.27	1,165.18	1,598.81	800.08	1,233.70	-169.85	288.24	-145.39	656.78	223.15
20	1,907.72	1,366.73	1,878.84	944.38	1,456.49	-68.85	472.13	-39.97	898.38	386.27
0% yield gain										
1	120.48	79.76	136.97	28.12	85.33	-746.10	-705.38	-762.59	-653.11	-710.33
5	472.45	290.62	546.08	122.12	377.59	-576.62	-394.79	-650.25	-224.62	-480.08
10	800.81	483.11	929.47	212.09	658.45	-458.71	-141.00	-587.36	132.51	-313.85
15	1,064.63	645.39	1,234.40	280.28	869.29	-364.07	55.17	-533.84	423.71	-165.30
20	1,247.98	752.87	1,448.48	330.52	1,026.12	-298.23	196.88	-498.72	623.13	-72.48
20% yield loss										
1	11.95	-21.22	66.18	-72.86	14.54	-783.83	-750.93	-838.05	-698.39	-788.17
5	170.42	9.60	349.06	-158.90	180.57	-681.63	-507.28	-860.27	-350.63	-686.74
10	498.78	202.08	732.45	-68.94	461.43	-563.72	-238.27	-797.38	6.50	-523.08
15	762.60	364.36	1,037.38	-0.74	672.27	-469.08	-30.33	-743.86	297.70	-377.71
20	945.95	471.84	1,251.46	49.49	829.10	-403.24	119.89	-708.74	497.12	-288.35

Cover Cropping and Strip Tillage Improve Soil Moisture Retention for Peanut in the Semi-Arid Climate of West Texas

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Summary: Strip tillage into a cover crop has not been utilized for peanut in semi-arid regions due to concerns that the cover crop removes water from the soil needed for maximum peanut performance. A long-term field study has been initiated and preliminary data indicated that water investment into establishment of a cover crop had a positive return in retention of water in the soil profile, improved peanut quality, and had no detrimental effect on peanut yield versus traditional, high-intensity tillage practices.

Rooting Dynamics Associated with Minimal Tillage in the Semi-Arid Peanut Production Region of West Texas

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ABSTRACT

Conservation tillage systems have the potential to significantly affect the rooting architecture of many crops. These effects can include increases in overall root mass, changes in fine vs. large root partitioning, changes in effective rooting depth, and concentration of root mass at deeper soil depths. Determining changes in crop root systems in response to tillage are important to quantify because they can have far reaching implications on a host of biotic and abiotic processes including: crop water-use, organic carbon cycling, soil aeration and compaction, and microbial population dynamics. Recently, research has demonstrated the positive effects on crop root systems in conservation tillage systems in the southeastern U.S. In particular, benefits to soil water holding capacity and concomitant decreases in crop water uptake have been quantified and used as evidence for the ability of conservation tillage to increase the water-use efficiency of a reduced cropping system as a whole. One particular environment that could dramatically benefit from a more water efficient production environment is the peanut and cotton production area of west Texas, U.S. In order to investigate the practicality and utility of conservation tillage systems in west Texas peanut and cotton production, the following objectives were addressed in both conventional and conservation tillage treatment plots: **1) to document and quantify variation in root production and architecture between the two tillage systems,** and **2) determine if irrigation deficit could be ameliorated through the use of conservation tillage in this semi-arid region.**

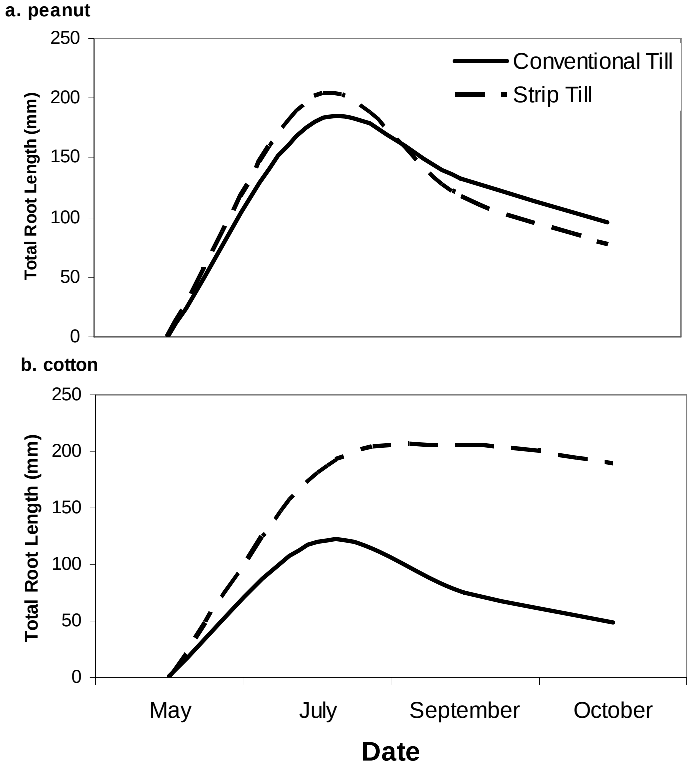

Figure 1: Sum of total root length produced (from 0 to 0.9 m depth) in a west Texas peanut and cotton production system over the growing season as measured by minirhizotrons.

Root system establishment, development, and architecture were examined throughout the growing season in a peanut and cotton production system in Lubbock, Texas through the use of mini-rhizotrons. Peanuts were

grown in a factorial combination of two irrigation regimes (50% and 100% ET replacement) and two tillage systems (conventional, and strip tillage). The strip tillage system utilized a full bed cover crop in the previous fall and winter seasons which was terminated just prior to planting the primary crop. Rhizotron tubes were installed within the row and images were taken four times during the season.

In 2007, rainfall was much higher than average and the field site experienced water-logging and probably hypoxic soil conditions during the early and mid-season. Therefore, irrigation treatments were not able to be established and all measurements were taken under a "100%" or fully irrigated condition. With water-logged soils, root establishment was likely to be significantly reduced for the year. Despite the overall high moisture status of the soils within these experimental plots, measurements of soil moisture in the mid- to late-season revealed improved water retention in the strip tillage plots. Therefore, root system dynamics had the potential to respond differentially between conventional and conservation tillage systems due to differences in water availability at the height of the growing season. This was certainly the case for root production in the cotton crop but the effects of tillage were negligible in the peanut crop (Figure 1). For peanut, total root production was slightly higher in the strip tillage system during mid-season but fell off to lower levels than in the conventional tillage treatments later in the season. In contrast, significant differences between the tillage systems in the cotton crop were evident beginning with the first set of images and continuing into the late season. Cotton root production was much greater in the strip tillage system than in the conventional.

The potential for strip tillage systems to increase crop root growth in the semi-arid region of west Texas could have important impacts for increasing the water-use efficiency of peanut and/or cotton production. For the cotton crop, greater overall root production and deeper rooting depths (data not shown) have the potential to increase water uptake, decrease effects of soil moisture deficit, and increase overall crop water-use efficiency. This could still be the case for peanut because the unusual hypoxic soil conditions may have contributed to the lack of variation between conservation and conventional tillage in 2007. Although the unusually high precipitation in 2007 precluded the ability to assign causality, ongoing tests within these same plots are currently being conducted to further quantify effects of tillage in full and deficit irrigation systems on crop rooting patterns in this semi-arid region in 2008.

Yield and Water Use Efficiency of Cotton and Peanut in Conventional and Sod-Based Cropping Systems

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Abstract

An experiment was conducted at the North Florida Research and Education Center, Quincy, FL to determine cotton and peanut plant water status, yield and water use efficiency of conventional (peanut-cotton-cotton) and sod-based (bahiagrass-bahiagrass-peanut-cotton) cropping systems under irrigated and non-irrigated conditions. The experiment was a split-plot design with three replicates. Irrigation regime was the main plot and cropping system was subplot. Under irrigated conditions, peanut in sod-based system had significant higher yield than the conventional peanut, but cotton yield response to cropping system depended on years. Under non-irrigated conditions, both cotton and peanut in the sod-based cropping system had higher leaf water potential and higher yields compared with conventional cropping system. Therefore, especially under non-irrigated condition, sod-based cropping system mitigated water deficit stress effect on crops and improved crop yield and water use efficiency compared to the conventional cropping system.

Introduction

Studies have shown that sod-based rotation of peanut and cotton in the southeast US can significantly reduce disease pressure (Dickson and Hewlett, 1989; Johnson et al., 1999; Marois and Wright, 2003), improve crop growth, and increase crop yield and profits (Brenneman et al., 1995; Katsvairo et al., 2006) compared with conventional cropping systems. In this report, we determined yields and water use efficiencies of irrigated and non-irrigated peanut and cotton in sod-based and conventional systems.

Materials and Methods

A crop rotation study was initiated in 2000 at the University of Florida's North Florida Research and Education Center in Quincy, FL. The soil type at the experimental location is Dothan sandy loam. Treatments included two cropping systems (sod-based and conventional peanut/cotton rotations) and two irrigation regimes (irrigated and non-irrigated). The sod-based system was a 4-yr rotation with bahiagrass-bahiagrass-peanut-cotton and the conventional system was a 3-yr rotation with peanut-cotton-cotton. Both systems used conservation tillage (strip-till for summer crops) with winter oat cover crop following the summer crops. The non-irrigated plots never received any irrigation during the experiment. The irrigated plots were irrigated using a lateral move irrigation system if needed. In 2000–2006, irrigation was applied based on Florida cotton production guidelines. In 2007, irrigation was applied when lowest leaf water potential was approximately -15 bars during squaring and fruiting (Zhao and Oosterhuis, 1997).

The second year bahiagrass in the sod-based rotation was killed in late Oct. of each year with 3 qts. of Roundup Weather Max per acre for the coming year peanut. In late March of each year, about 3 weeks prior to cotton planting, oat cover crop was killed with Roundup and plot rows were strip-tilled using a Brown Ro-till implement. Cotton cultivar ‘DP 458 BG’ (2002-2004) or

'DP 555 BG/RR' (2005-2007) was used for this long-term rotation study. All plantings were made from late April to early May using a Monosem pneumatic planter with a row spacing of 3 feet and about 4.5 seeds per foot row. Nitrogen (25 lbs. N acre^{-1}), P (50 lbs. P acre^{-1}), and K (75 lbs. K acre^{-1}) from a combination fertilizer (5-10-15) were band applied adjacent to each row at planting. Cotton was sidedressed with additional N of 60 lbs. acre^{-1} (ammonia nitrate) at first square stage. Peanut (cv. 'Georgia Green' or 'AP-3') was planted at 8 seeds per foot row in mid to late May. Peanuts were dug in mid-Sept. to early Oct. Details of bahiagrass and peanut management and other cotton crop management practices were done according to standard University of Florida crop production recommendations.

During the 2007 growing season, lowest leaf water potential (LWP) of uppermost fully expanded leaves was measured with a plant water status console (Soil Moisture Inc., CA). Seedcotton was mechanically harvested from four middle rows in each plot two weeks after defoliation for determination of seedcotton yield. Two seedcotton subsamples (2 lbs each) in each plot were ginned to determine turnout (lint %). Lint yield was estimated based on seedcotton yield and lint %. When peanut reached maturity stage, the four middle rows in each plot were mechanically dug and inverted prior to harvest. Pod samples were placed in a forced-air dryer at 113°F for 72 hours and weighed. Pod yield were determined based on the sample dry weight. Crop water used efficiency (WUE) was estimated using crop yield dividing by the sum of precipitation and amount of irrigation during the growing season from April to Sept.

The experiment was a split-block design with 3 replications. Irrigation was the main plot and crop rotation was the sub-plot. The sub-plot size was 80 × 60 feet with 20 rows in each plot. All data were analyzed for variances using the GLM procedures and Fisher LSD tests were employed to separate mean differences between irrigation treatments or cropping systems (SAS Inc., 2002).

Results and Discussion

Precipitation and irrigation during the experimental years

Cumulative precipitation and amount of irrigation for irrigated treatments during growing seasons in this study are presented in Table 1. Overall, the 2002 and 2003 growing seasons were close to normal with precipitation of 25.2 and 28.7 inches, respectively; the 2004 and 2005 growing seasons were wet with 6.4 to 6.7 inches more precipitation compared to long-term average (30.0 inches); and the 2006 and 2007 growing seasons were dry. Especially the 2007 was extremely dry with only 51% of normal precipitation from Apr. to Sept. (Table 1). The wide range of precipitation during the experiment allows us to analyze crop WUE and yield responses to irrigation. Amount of irrigation in the 2002 to 2007 growing seasons for the study ranged from 4.4 to 7.6 inches (Table 1).

Table 1. Accumulated precipitation and amount of irrigation in the 2002 to 2007 growing seasons from April to September at Quincy, FL.

Year	2002	2003	2004	2005	2006	2007	Long-term
	------------------------------------- (inch) -------------------------------------						
Precipitation	25.2	28.7	36.3	36.7	17.2	15.4	30.0
Irrigation	7.4	4.4	5.0	7.5	7.6	5.1	---
Year type	Normal	Normal	Wet	Wet	Dry	Dry	---

Leaf water potential

In general, both peanut and cotton grown in the sod-based cropping system had greater LWP than plants grown in the conventional system, especially under non-irrigated conditions (Data not shown). During the 2007 growing season, the mean LWP values of sod-based and conventional peanuts were -4.9 and -8.3 bars, respectively, under irrigated conditions and -8.3 and -16.2 bars, respectively, under non-irrigated conditions. Similarly, LWP of sod-based and conventional cotton were -14.1 and -14.6 bars, respectively, under irrigated conditions and -15.9 and -17.5 bars, respectively, under non-irrigated conditions.

Yields

Pod yields did not differ between irrigated and non-irrigated peanuts, except for conventional peanut in 2007 which was an extremely dry year with a significantly lower yield for non-irrigated peanut in the conventional system (Table 2). Averaged across years and the cropping systems, yields of the irrigated and non-irrigated peanuts were 3228 and 3125 lbs. acre^{-1}, respectively. Peanut yield varied among years and ranged from 2146 to 4342 lbs. acre^{-1}. In most years, sod-based peanut had significantly higher yield than conventional peanut, except for 2002 in which yield did not differ between the two cropping systems. Averaged across years and irrigation regimes, the sod-based peanut (3464 lbs acre^{-1}) had a 20% ($P < 0.01$) higher yield than the conventional peanut (2889 lbs acre^{-1}, Table 2).

Table 2. Peanut pod yield response to the sod-based and conventional cropping systems under irrigated (Irr.) and non-irrigated (Non-irr.) conditions in Quincy, FL.

Year	Sod-based			Conventional		
	Irr.	Non-irr.	Mean	Irr.	Non-irr.	Mean
	---------------------------- (lbs. acre^{-1}) ----------------------------					
2002	3245	3360	3302	3300	3014	3157
2003	2829	2737	2783	2197	1719	1958
2004	3282	3287	3284	2245	2584	2414
2005	3041	2780	2911	2142	2150	2146
2006	4154	4165	4159	3492	3590	3541
2007	4423	4261	4342	4382*	3854	4118
Mean by Irr.	3496	3432		2960	2818	
Mean by system	3464**			2889		

* and ** indicate that differences between Irr. And Non-irr. Within a year or between the two systems are significant at $P \leq 0.05$ and $P \leq 0.01$, respectively.

Lint yields of the sod-based cotton in 2002 (both irrigated and non-irrigated) and 2007 (irrigated) were significantly higher than that of the conventional cotton. There was no statistical difference between the two cropping systems in cotton yields in other years. Averaged across years and irrigation regimes, lint yields of the sod-based and conventional cotton were 1109 and 1026 lbs. acre^{-1} (Table 3). Year and irrigation significantly affected lint yield with $P < 0.0001$ and 0.01, respectively and their interaction effect on lint yield was also significant ($P < 0.01$). Among the six experimental years, lint yield ranged from 751 to 1530 lbs. acre^{-1} for irrigated cotton and from 641 to 1501 lbs. acre^{-1} for non-irrigated cotton (Table 3). Lint yields in 2002, 2003 and 2004 were significantly lower than those in other years for both irrigated and non-irrigated cotton

($P < 0.05 – 0.01$). Irrigation only improved lint yield in dry years of 2006 and 2007 (Table 3). These results indicate that irrigation may not always be necessary for cotton production in the southeast USA.

Table 3. Cotton lint yield response to the sod-based and conventional cropping systems under irrigated (Irr.) and non-irrigated (Non-irr.) conditions in Quincy, FL.

Year	Sod-based			Conventional		
	Irr.	Non-irr.	Mean	Irr.	Non-irr.	Mean
	------------------------------ (lbs. acre^{-1}) ---------------------------------					
2002	929	946	938	666	641	653
2003	751	769	760	784	847	816
2004	774	828	801	735	767	751
2005	1530	1505	1518	1373	1436	1404
2006	1462*	1285	1373	1448*	1286	1367
2007	1513*	1021	1267	1303*	1024	1164
Mean by Irr.	1160	1059		1052	1000	
Mean by system	1109			1026		

Although irrigation is necessary for high yield in dry years, it is possible to use less irrigation water to reach yield goals and thus reduce production cost in the southeast. For instance, in 2007, an extremely dry year, irrigation was scheduled based on LWP. When lowest LWP of cotton dropped to -15 bars, irrigation was provided in the irrigated plots. Compared to 2006 (also a dry year), 2007 had 1.8 inches less precipitation and 2.5 inches less irrigation (Table 1) during the growing season, but lint yield of irrigated cotton was equivalent (Table 3). Therefore, there is a great potential to reduce the amount of irrigation and to improve crop production profits even in dry years.

Water use efficiency

Peanut WUE varied greatly among years, depending on precipitation, irrigation, and crop yield (Data not shown). Averaged across years, non-irrigated peanut in sod-based system had the greatest, while irrigated peanut in conventional system had the least WUE. The sod-based peanut had significantly greater WUE compared to conventional peanut under both irrigated (increased 15%) and non-irrigated (increased 19%) conditions ($P < 0.01$, Fig. 1 left). The WUE of sod-based cotton was slightly (5 to 11%) higher than that of conventional cotton, but the differences were not statistically significant within an irrigated treatment (Fig. 1 right). Overall, the non-irrigated crops had higher WUE than irrigated crops (Fig. 1).

Conclusions

Results of six-year irrigation and non-irrigation study in sod-based and conventional cropping systems with winter oat cover crop and a wide range of precipitation and amount of irrigation indicated that irrigation in normal years in the southeast USA did not improve either peanut or cotton yield because the long-term precipitation during the growing season is almost equivalent to potential evapotranspiration in the region. Even in dry years, there is great potential to reduce irrigation water, conserve regional water resource, and improve crop WUE and production profits. Compared to conventional system, sod-based peanut/cotton rotation can improve soil quality and other growth environment, resulting in high crop yields and WUE.

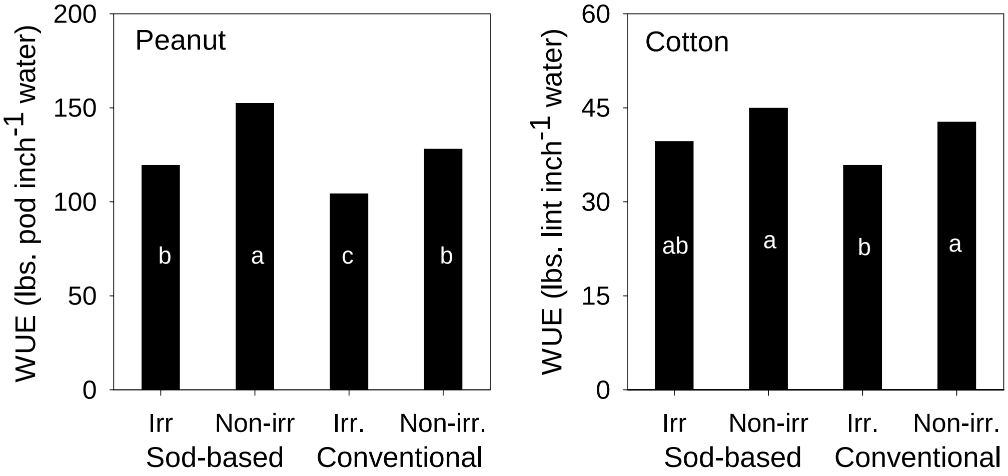

Fig. 1. Water use efficiency (WUE) of sod-based and conventional peanuts and cotton under irrigated and non-irrigated conditions. Data are 6-yr means from 2002 to 2007 in Quincy, FL.

Acknowledgement

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Aggregate stability, carbon and nitrogen storage in soils after eight years of swine effluent application and crop rotation

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SUMMARY

In a long term (9 years) trial under center pivot irrigation in Oklahma's Panhandle, forms of organic and inorganic N input, crop rotation, and tillage systems were evaluated. After a 9 yr period, aggregate stability, total C and total N were determined in the following treatments: 1) NT/0 (C/W) – No tillage, no N input under corn/wheat rotation; 2) NT/75/S (C/W) – No tillage, 75 kg N ha^{-1} from swine effluent under corn/wheat rotation; 3) NT/150/S (C/W) – No tillage, 150 kg N ha^{-1} from swine effluent under corn/wheat rotation; 4) NT/300/S (C/W) – No tillage, 300 kg N ha^{-1} from swine effluent under corn/wheat rotation; 5) NT/150/AA (C/W) – No tillage, 150 kg N ha^{-1} from Anhydrous Ammonia under corn/wheat rotation; 6) CT/0 (C/W) – Conventional tillage, no N input under corn/wheat rotation; 7) NT/0 (S/W) – No tillage, no N input under sorghum/wheat rotation; 8) NT/75/S (S/W) – No tillage, 75 kg N ha^{-1} from swine effluent under sorghum/wheat rotation; 9) NT/150/S (S/W) – No tillage, 150 kg N ha^{-1} from swine effluent under sorghum/wheat rotation; 10) NT/300/S (S/W) – No tillage, 300 kg N ha^{-1} from swine effluent under sorghum/wheat rotation; 11) NT/150/AA (S/W) - No tillage, 150 kg N ha^{-1} from Anhydrous Ammonia under sorghum/wheat rotation; 12) CT/0 (S/W) – Conventional tillage, no N input under sorghum/wheat rotation. Samples were collected from 0 – 10 cm, air dried and sieved to pass a 2mm sieve for total C and N analysis, while water aggregate stability samples were sieved to pass a 8mm sieve and air dried. Initial and air dried moisture content were determined (data not shown). Total N and C was determined using a Carlo Erba Analyzer and water aggregate stability was determined with a mechanical shaker at 30 rotations per minute using 5 sieves set (4, 2, 1, 0.5, and 0.25 mm mesh).

The use of manure did not necessarily result in an increase of total C and N in the surface 10 cm of soil . The treatment that showed the greatestamount of Total C received anhydrous ammonia as the N source and had a corn/wheat rotation. When crop rotations where compared, sorghum/wheat rotation generally had greater amounts of total C and N when compared to the corn/wheat rotation. Even the treatment that did not receive N input and was conventionally tilled, but was under sorghum/wheat rotation had significant increase in total C and N. The corn/wheat rotation increased total C and N when going from 75 to 150 kg N ha^{-1} using swine effluent , but increasing from 150 to 300 kg N ha^{-1} did not result in a response in total C and N. The corn/wheat rotation responded to N application from both sources, but did not increased soil total C and N without N fertilization, while the sorghum/wheat rotation did not necessarily had to have N input to increase its total C and N levels. Total N showed positive correlation with total C, since total N level stayed around 10% of the total C level. Aggregate stability did not have positive correlation with swine effluent input. However it did respond to crop

rotation. The use of corn/wheat rotation resulted in higher aggregate stability (GMD and sum of 3 classes) then sorghum/wheat rotation.

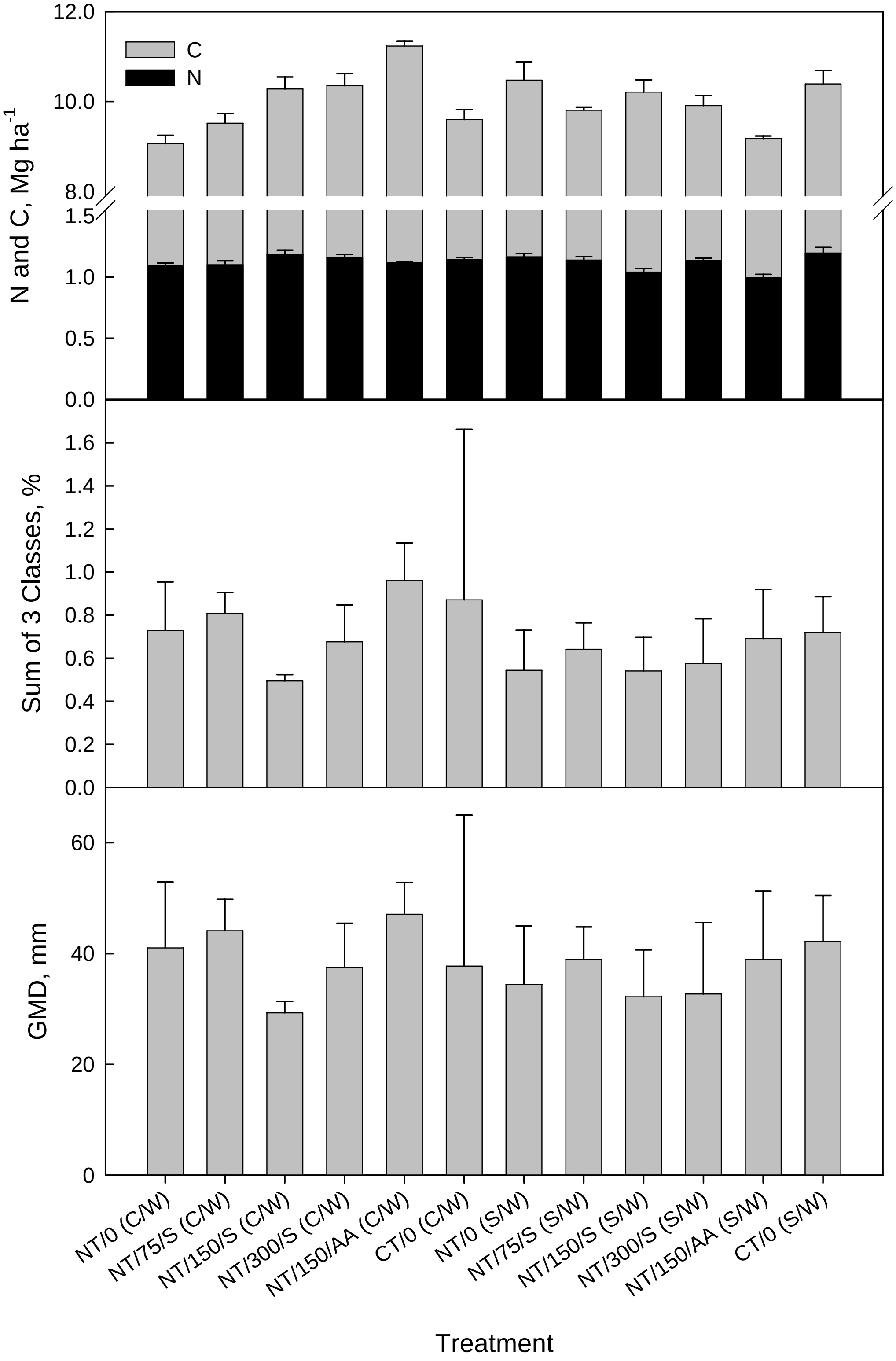

Figure 1. Total N and C, Aggregate stability (Sum of 3 classes and GMD – geometric mean diameter) of soil under different N source, crop rotation and tillage practices in Oklahoma’s panhandle.

Evaluating the Use of Pearl Millet to Reduce Nutrient Run-off in the Southeast Piedmont Region of Georgia

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ABSTRACT

The Southeastern Piedmont (SEP) region of Georgia is a high nutrient status area for phosphorous and nitrogen. With the objective of reducing nutrient runoff, 6 farm fields modified their pasture methods and implemented a new practice, with two of the fields being switched to pearl millet. Recently, there has been much interest in the Southeast, especially in Georgia, for growing pearl millet for grain due to its increased drought tolerance, lower production costs, and higher protein composition. Pearl millet has also been shown to be a viable alternative for poultry feed, which could have a positive impact on Georgia's valuable broiler industry. The objective of the study was to evaluate the profitability of raising pearl millet and determine if it was economically viable as a nutrient management practice.

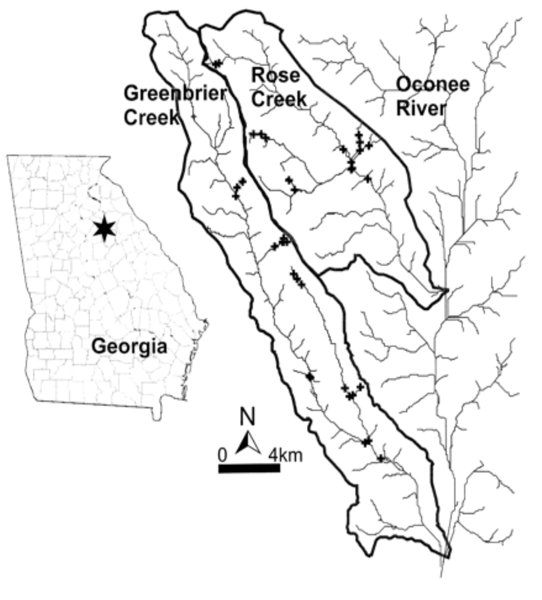

Figure 1. Southeastern Piedmont Region

Table 1. Enterprise Budget Analysis Results

	Farm A			Farm B			Overall Means
	2005	2006	Mean	2005	2006	Mean	
Yield* (bu/ac)	63.5	55.0	59.3	26.1	27.1	26.6	42.9
Revenue($/ac)	$115	$126	$121	$47	$62	$55	$88
Total Cost ($/ac)	$276	$316	$296	$292	$249	$270	$283
Avg Net Revenue ($/ac)	($161)	($189)	($175)	($245)	($187)	($216)	($195)
Breakeven Price ($/bu)	$4.34	$5.74	$4.99	$11.19	$9.20	$10.17	$6.60
Breakeven Yield (bu)	152.7	174.8	163.8	161.5	138.1	149.8	156.8

*One bushel is 57.5 pounds.

Two farms in cooperation with USDA/ARS planted pearl millet as part of a larger demonstration project during 2005 and 2006. The producers were interviewed and their production records were documented. Costs were standardized across producers and results were determined using farm enterprise budget analysis. The results indicate that in order for the production of pearl millet for grain to be profitable in the Southeastern Piedmont region, a producer must receive a price higher than $0.11/lb, which was nearly three times the price in 2006. From a nutrient management standpoint, early water quality analysis suggested that there were improvements in the levels of nitrogen and phosphorus. It may be necessary to provide government assistance to entice producers to plant pearl millet for nutrient reduction in the future if market prices do not improve.

CONSERVATION TILLAGE FOR BETTER IRRIGATION AND WATER MANAGEMENT IN CORN PRODUCTION

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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.

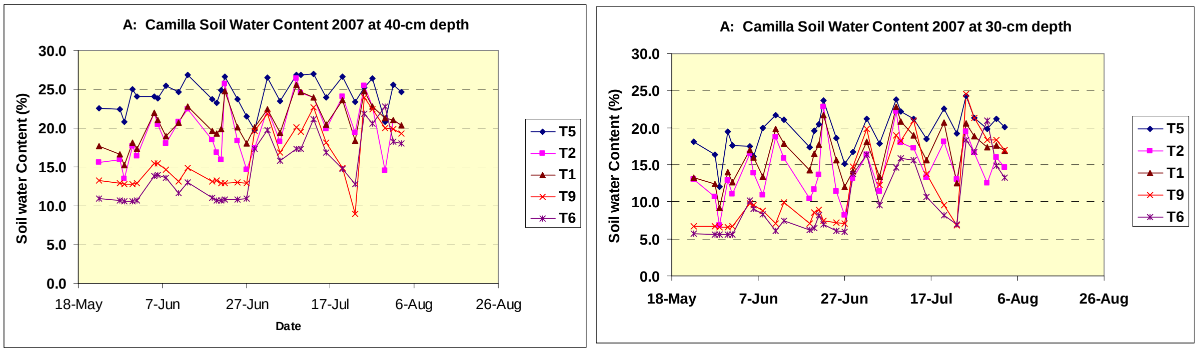

Fig.1. Typical soil water content curves in 2007 corn at Camilla. T5 is strip-till, high residue, full irrigation. T1 is strip-till, low residue, full irrigation. T2 is conventional-till with full irrigation. T9 is strip-till with no irrigation, and T8 is conventional-till with no irrigation.

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.

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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.

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Furrow Diking and Conservation Tillage to Conserve Soil and Water

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Summary: Crop production in Georgia is limited. Increased water capture would improve natural water use and reduce supplemental irrigation amounts. We quantified water capturing and erosional characteristics of furrow dike tillage (DT) by comparing infiltration, runoff, and soil loss from a Tifton loamy sand cropped to DT and non-DT conventional- (CT) and conservation- (ST) tillage systems. We will present infiltration, runoff, and soil loss rates and amounts from DT and non-DT CT and ST field plots (2-m wide by 3-m long; n=3) under simulated rainfall (target constant intensity=50 mm/h).

IMPACT OF CONSERVATION PRODUCTION PRACTICES ON SOIL MOISTURE AVAILABILITY IN ALLUVIAL SOILS

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Introduction

Conservation production practices have been shown to improve soil quality, and may increase cotton crop yield and quality. Reductions in tillage and incorporation of cover crops have the potential to improve soil nutrients and water availability, reducing the need for supplemental irrigation on sandy soils. Traditional high-intensity tillage methods are still the norm in the Mississippi Delta. While the region enjoys high levels of rainfall, increasing use of ground water for crop irrigation has begun to deplete the alluvial aquifer. We are interested in exploring the potential of conservation production practices to increase economic returns, in part by reducing fuel costs, and conserve ground water resources by reducing the need for supplemental irrigation. Two critical issues that we face are timely residue management and good germination of the cash crop.

The soils of the Lower Mississippi River Alluvial Flood Plain are nutrient rich, geographically young soils deposited during cyclical flooding and drying episodes, with an average thickness between 125 and 150 feet in depth. The soils within a given field may range from excessively drained silt loams and loamy sands of natural levees to the poorly drained silty clay loams and clays found chiefly in slack water areas. Minor differences in elevation can accentuate differences in soil drainage characteristics (Cox *et al.*, 2006), and result in distinct differences in soil properties. The clay soils hold moisture early in the year, decreasing soil temperature and impeding germination, and resulting in drastic variations in plant stand establishment. Alternatively, during particularly dry years added moisture in the wetter portions of fields can be beneficial to the crop. These differences in soil texture and topography, and the resultant variations in hydrologic properties, are primary determinants of crop yield (Iqbal *et al.*, 2005). The inherent within-field variability also creates management challenges to insure timely tillage, field preparation and planting, and contributes to spatial variability of crop growth and yield. Introducing conservation practices to these highly variable fields is a challenge, as the different soil types respond differently to tillage and cover crops. Conservation methods are compromised by early season rains that limit access to fields, increase soil water-logging, and decrease soil temperatures.

Farmers are under increasing pressure to reduce the impact of management practices on the environment. Although dryland agriculture has historically been profitable in the area, producers are becoming increasingly reliant on supplemental irrigation to ensure adequate yields and reduce risks of production. Increasing pressure on the alluvial aquifer and concerns for aquifer depletion have led to interest in alternative methods of improving profitability while minimizing environmental impact. However, no clear roadmap is available as to how to best implement cultural practices for optimal environmental benefit while maintaining profitability. The consequences of production practices on conservation of soil and water resources are also unknown for the alluvial soils. NRCS conservation program payments are based on the Soil Conditioning Index (SCI), which determines improvements in soil quality through three subfactors: organic matter (OM), field operations (FO), and erosion (ER) (NRCS, 1999). Changes in management practices do not result in a consistent change in SCI subfactors for all soils and environments (Zobeck *et al.*, 2007).

This research was undertaken to examine the impact of conservation production practices on cotton yield and quality. Differences in soil nutrients and water availability following different tillage practices and with incorporation of winter wheat cover crops into cotton production were measured to determine the impact of production practices on soil quality.

Materials and Methods

Cotton (*Gossypium hirsutum* cv. DPL 444BR) was planted in 32 rows x 30 m plots in the spring, with eight replications of each treatment. Conventional production practices included in-row subsoiling in the fall. Conservation plots were not subsoiled, and were planted with winter wheat cover crop in the fall. Cover crops were terminated with herbicide three weeks prior to planting the cash crop and rolled. Standard agricultural practices of fertilizer, insect and weed control were followed. Soil moisture was measured with Watermark soil moisture sensors[1] placed at 15 cm (6”) intervals in the rooting zone to a depth of 0.9 m (36”). Irrigation was supplied with an overhead sprinkler irrigation system, begun when the readily available soil moisture at 30 cm (12”) was depleted to -50 - -70 mbars, and continued at 5 day increments thereafter until the end of the season unless significant rainfall was received. Plots were harvested with a commercial cotton picker equipped with a sampling system for large plot harvests. Seed cotton was ginned on a 10-saw research gin. Standard cotton classing was performed at the USDA-Agricultural Marketing Service Classing Office in Dumas, AR.

Results and Discussion

Increased organic matter through use of cover crops has been shown to improve yields of the subsequent cash crop and reduce erosion from the soil surface (Raper *et al.*, 2000; Rhoton, 2000). However, soil organic matter is rapidly depleted under the typical environmental conditions in the Mississippi Delta. Even after three years under conservation management, soil organic matter changed very little (Figure 1). Conservation practices that included a winter wheat cover had only a very slight impact on SCI (Table 1). While the conservation production system showed a positive SCI, the slight improvement would only result in a $2.32 per acre per year payment (P. Rodrigue, NRCS, personal communication). While positive environmental benefits may occur in the long-term, a yield increase from implementation of conservation practices was not observed until the third year (Figure 2).

Conservation systems with high levels of cover crop residue are beneficial for sandy soils in part due to increased percolation of water into the soil profile (Raper *et al.*, 2000). After the cover crop is terminated, the crop residue acts as a mulch to reduce evaporation from the soil surface.

Research from our fields indicates that increases in soil moisture with cover crops may be more of a detriment in the Delta, especially early in the season. During the winter, the entire soil profile saturates with water due to the heavy winter rains, as measured by soil moisture sensors (data not shown). Prior to planting, the soil surface dries out more quickly in conventional plots due to increased evaporation than in conservation plots with cover crops. The reduced soil moisture in the conventional tilled plots results in a better seed bed, improved seed placement and soil contact, and better plant stand. The reduced soil moisture also helps increase seed bed temperatures, further enhancing germination. DeFelice *et al.* (2006) found that conservation systems resulted in a negative yield advantage for corn and soybeans on poorly drained soils. The need to increase surface drainage in the early spring may limit the use of cover crops in the Delta, further exacerbating efforts to increase the use of conservation tillage practices and limiting potential conservation incentive payments to farmers.

During the growing season, treatments with winter wheat cover crops were found to require more water than conventional plots (Figure 2). Yield in conservation plots responded to irrigation in two of the three years of the study. This is contrary to what was seen in other studies using rye as a cover crop (Balkcom et al., 2006). This may result from the lower biomass produced with winter wheat compared to rye, or the slow improvement in soil quality with implementation of conservation practices.

Conclusion

Adapting conservation practices for alluvial soils requires ingenuity in addressing early-season soil moisture levels that limit seed bed preparation, planting, and germination. Failure to establish a good plant stand reduces yield of the cash crop. Incentive payments made to farmers to encourage implementation of conservation production practices need to be examined for applicability to Delta soils and environment.

[1]Disclaimer

Mention of a trade name or proprietary product does not constitute an endorsement by the U.S. Department of Agriculture. Details of specific products are provided for information only, and do not imply approval of a product to the exclusion of others that may be available.

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Subfactor	**Conventional tillage**	**Conservation Tillage, with cover crop**
OM	**-0.52**	**-0.29**
FO	**0.3**	**0.84**
ER	**-0.26**	**0.61**
SCI	**-0.14**	**0.34**

Table 1. Calculated Soil Conditioning Index for two production systems on Dundee silty clay loam in Stoneville, MS after three years of treatment.

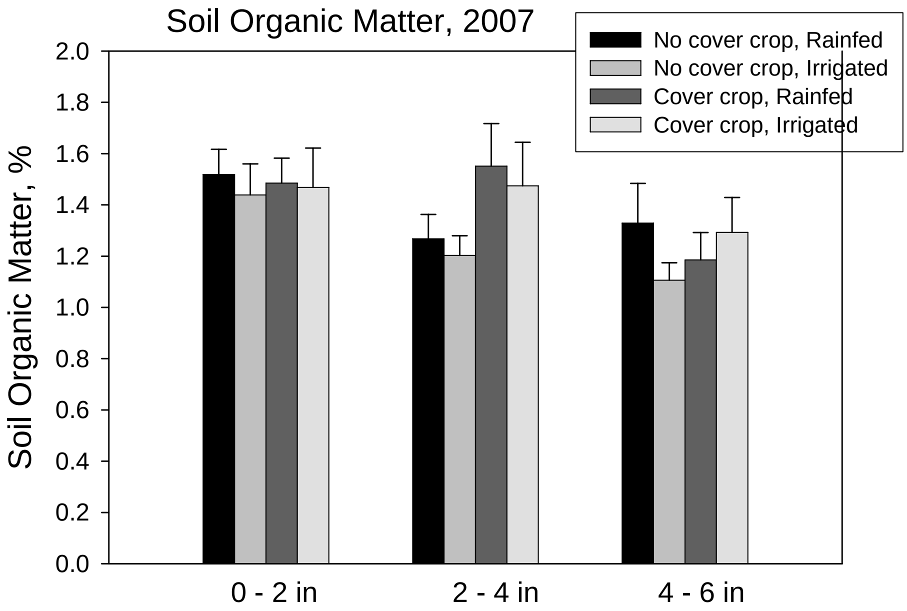

Figure 1. Changes in soil organic matter after three years under different production systems.

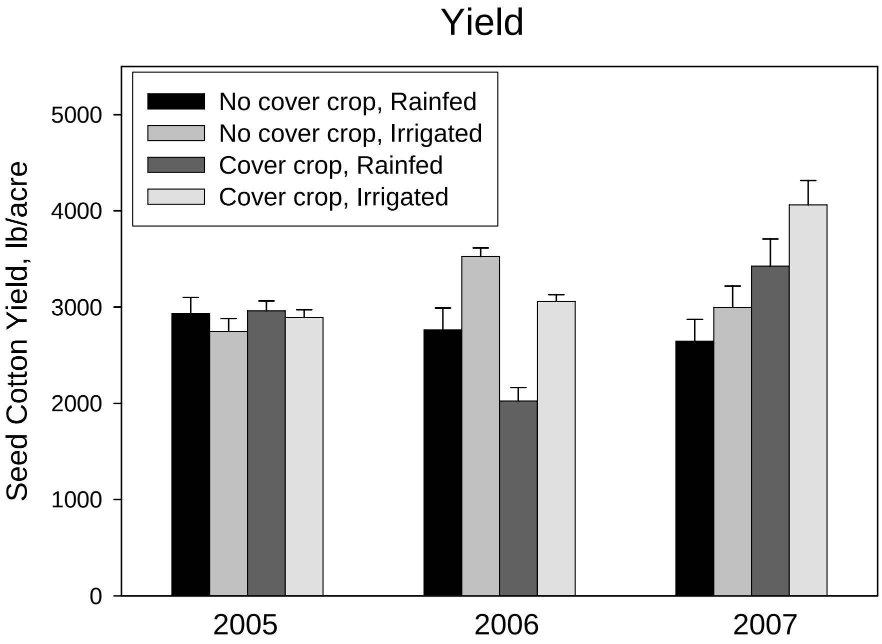

Figure 2. Impact of management practices and irrigation on cotton yield.

Soil and Water Conservation via Reduced Tillage in the Georgia Piedmont

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INTRODUCTION

Piedmont soils have historically been managed under conventional tillage practices and are susceptible to runoff and sediment losses. The Cecil series is the most extensive soil in the Piedmont region, occurring from Alabama to Virginia. Because of its row-crop production history, the Cecil series has experienced accelerated erosion and subsequent degradation of its intrinsic soil properties, productivity, and overall environmental quality.

Most of Georgia receives 48-52 inches of rainfall annually. Rainfall patterns tend to generate runoff producing storms with extended periods of drought during the crop growing season. As a result, supplemental irrigation is often needed to prevent yield-limiting water stress. In Georgia, a major effort has been undertaken to conserve soil resources and reduce water and energy requirements for row crop production through conservation tillage. Conservation tillage systems offer an effective, viable management tool for row crop production and soil and water conservation. Piedmont soils benefit from conservation tillage via reduced runoff and sediment transport and enhanced infiltration and soil resistance to detachment by accumulating surface residue, increasing near surface soil organic carbon with time, and dissipating raindrop impact energy.

Current agricultural water issues and the need to reduce input costs in farming operations add importance to making sound irrigation and management decisions to ensure efficient water use, natural resource conservation, and on-farm profitability. We quantified infiltration, runoff, and sediment losses from a Cecil sandy loam managed under CT and NT systems with commercial fertilizer and poultry litter fertilizer sources.

MATERIALS AND METHODS

The study was conducted near Watkinsville, GA (N 33^o 54', W 83^o 24'). The site consisted of twelve (12) 39x100 ft plots located on a Cecil sandy loam (Typic Kanhapludult). Since 1991, study plots have been managed under CT and NT systems in a randomized complete block (split plot) design (n=3). Main plots were divided into CT and NT, and subplots were divided into 2 fertilizer treatments: mineral commercial fertilizer (CF) and poultry litter (PL). The 4 tillage-fertilizer treatments were CT-PL, CT-CF, NT-PL, and NT-CF. The study area was planted to corn (*Zea Mays*). Immediately after planting corn, 12 rainfall simulation plots were established on the tillage-fertilizer treatment plots.

Rainfall simulation plots (60-ft^2, 6-ft wide by 10-ft long) were established on each treatment (n=3). Each simulation plot had a slope of 2%. Before simulating rainfall, antecedent water content was determined gravimetrically (Gardner, 1986) at 5 depths (top 12 inches) from 5 locations surrounding each 60 ft^2 plot. The oscillating-nozzled rainfall simulator (Frauenfeld and Truman, 2004) with 80150 veejet nozzles was placed 10 ft above each 60 ft^2 plot. Rainfall was simulated at a constant (2 in h^{-1}) intensity (60 min) (water source=groundwater). All runoff (R) and soil loss (E) were collected from each 60-ft^2 plot (5-min intervals) throughout each simulation, and determined gravimetrically. Infiltration (INF) was calculated (rainfall-runoff).

Four treatments (CT-PL, CT-CF, NT-PL, NT-CF) were replicated 3 times (2 tillage systems x 2 fertilizer sources x 3 reps) for a total of 12 rainfall simulations. Means, coefficient of variations (CV, %), and standard error bars are given for measured data. We perfomred unpaired t-tests to determine significance among treatment means. All test statistics were evaluated at P=0.05.

RESULTS AND DISCUSSION

Hydrology and erosion parameters for fertilzer source (PL, CF) sub-treatments of each tillage treatment were not significanly different at the 0.05 level from each other, thus were combined into overall CT and NT treatments (n=6). Also, the 12-run average rainfall intensity (measured) was 2.21 in/h (CV=4%, NS).

Runoff (R) and infiltration (INF) for combined CT and NT treatments are given in Table 1. CT plots had 2.2 X less infiltration and 6.0 X more runoff than NT plots, eventhough NT plots had 2.5 X higher gravimetric water contents (w) in the 0-1 in soil layer (all at P=0.0001). This translates into 90% of the simulated rainfall infiltrating NT plots (CT plots=45%) and only 10% of the simulated rainfall running off NT plots (CT plots=55%), a 2 and 5.5 X difference among tillage treatments.

Differences occurred for infiltration and runoff amounts (Table 1) and rates (Fig. 1) within each event (infiltration rate curves not shown). For CT plots, runoff rates steadily increased throughout the first 40-45 min of simulated rainfall before reaching quasi-steady-state conditions (1.8-1.9 in/h). Conversely, runoff rates for NT plots increased at a much slower rate than that for CT plots never exceeding a runoff rate of 0.5 in/h. Maximum runoff rate (R_{max}) for CT plots (1.9 in/h) was 3.8 X greater than corresponding values for NT plots (0.5 in/h).

Soil loss (E) for combined CT and NT treatments are given in Table 1. CT plots had 11.1 X more soil loss than NT plots (P=0.0005), again despite differences in antecedent water content of the 0-1 in soil layer. Soil loss values given translate into 1367 lbs/A soil loss for the CT treatment and 120 lbs/A soil loss for the NT treatment.

Differences occurred for overall sediment yields (Table 1) and soil loss rates (Fig. 2) within each event. For CT plots, soil loss rates steadily increased throughout the first 35-40 min of simulated rainfall before reaching quasi-steady-state conditions (1.9-2.0 lb/A/h). Conversely, soil loss rates for NT plots increased ever so slightly never exceeding a soil loss rate of 0.22 lb/A/h. Maximum soil loss rate for CT plots (2.08 lb/A/h) was 9.4 X greater than corresponding values for NT plots (0.22 lb/A/h).

Differences in infiltration, runoff, and soil loss between CT and NT treatments can be explained, in part, by differences in the rate of surface seal development and/or soil surface protection from raindrop impact by residue. For example, difference between INF_{max} and INF_{min} (d INF) was 4.5 X greater for CT plots (1.8) than for NT plots (0.4). Values for d INF relate to degree of surface seal formation with larger values of d INF being proportional to or indicative of greater alterations or changes in each soil's surface due to surface sealing. Furthermore, surface residue accumulation in NT systems generally limits soil detachment by raindrop impact, expressed as splash sediment. CT plots had 4.5 X more splash sediment (S_s) during the first 10 min of each simulated rainfall event than NT plots (P=0.0001) (Table 1). Results support the concept that NT with surface residue management is effective in reducing raindrop impact, descreasing surface sealing and its negative impact, and soil detachment. Note that r values for runoff (R) vs. soil loss (E) from CT, NT, and both CT and NT combined were 0.96, 0.94, and 0.97, respectively.

From a practical standpoint, producers want to know how a particular tillage system will affect how much rainfall and/or irrigation will infiltrate into the soil surface, thus potentially becoming available for plant uptake. Crop production in Georgia and the Southeast is water limited; thus, supplemental irrigation is needed to sustain profitable crop production. Reduced tillage systems that retain more irrigation and/or rainfall, lose less water as runoff, use water more efficiently, and conserve soil and water resources will reduce supplemental irrigation amounts and other input costs and improve producer's proft margin. Over the 60 min of simulated rainfall, significant infiltration differences (2 X) occurred between NT and CT plots (Table 1). Therefore, given the rainfall intensity (2.2 in/h), and assuming that evapotranspiration (ET) was 0.2 in/day and all infiltration was available to plants, the 0.9 inches of infiltration during the 60 min simulated rainfall event for CT plots would result in 4.9 days of water for crop use; whereas the 2.0 inches of infiltration during the 60 min simulated rainfall event for NT plots would result in 10.2 days of water for crop use. This difference (5.3 days of water for crop use or 2.1 X) is extremely important for low water holding capacity Ultisols that experience extended periods of drought annually. For example, a producer utilizing a CT system would get 4.9 days of water for crop use for the 2 inch rainfall event before needing to consider supplemental irrigation, while the producer utilizing a NT system would get 10.2 days of water for crop use for the same rainfall event before needing to irrigate. To further illustrate water savings with NT, if we assume that 16 irrigations (1 in/irrigation/A) is needed to produce a given crop under CT conditions as described herein, then ~8 irrigations would be needed to produce the same crop under NT conditions. If the cost to apply each irrigation was $20/A-inch of water, then the 8 irrigations saved would also save ~$160/A in irrigation cost.

Table 1. Hydrology and erosion parameters for treatments studied.

Tillage	w	INF	INF	R	R	R_{max}	E	S_s	PAW
	%	in/h	%	in/h	%	in/h	oz	oz	days
CT	6 (29)	0.9 (37)	45 (38)	1.2 (31)	55 (31)	1.9 (15)	32.3 (40)	0.9	4.9
NT	16 (38)	2.0 (07)	90 (04)	0.2 (40)	10 (40)	0.5 (57)	2.9 (53)	0.2	10.2
Diff	2.5 X	2.2 X	2.0 X	6.0 X	5.5 X	3.8 X	11.1 X	4.5 X	2.1 X
P(T</=t)	0.0074	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005	0.0001	0.0001

x (CV), n=6; w=antecedent (gravimetric) water content in the 0-1 in soil layer; INF=infiltration; R=runoff; Rmax=maximum 5 min runoff rate; E=total soil loss; Ss=soil splash during 0-10 min time period; PAW=estimated plant available water (assumed ET=0.2 in/d).

CONCLUSIONS

We quantified infiltration, runoff, and sediment yields from a Cecil sandy loam (slope=2%) managed under CT and NT systems. Treatments included tillage (CT, NT) and fertilizer source (commercial, CF; poultry litter, PL), each replicated three times (CT-PL, CT-CF, NT-PL, NT-CF), for a total of 12 field plots or simulations. Each 60-ft^2 field plot received simulated rainfall at a constant rate (target rate=2 in/h; 12-run ave.=2.2 in/h; CV=4%) for 60 min.

1. Fertilizer source sub-treatment did not significantly affect hydrology and erosion parameters at the 0.05 level. Data from these sub-treatments were combined into overall CT and NT main treatments (n=6).

2. CT plots had 2.2 X less infiltration and 6.0 X more runoff than NT plots, eventhough NT plots had 2.5 X higher soil water contents in the 0-1 inch soil layer. NT and CT plots had 90% and 45% (2 X difference) of the simulated rainfall infiltrated; whereas NT and CT plots had 10% and 55% (5.5 X difference) of the simulated rainfall runoff. CT plots (1367 lbs/A) had 11.1 X more soil loss than NT plots (120 lbs/A). Maximum runoff rate for CT plots (1.9 in/h) was 3.8 X greater than that for NT plots (0.5 in/h); maximum soil loss rate for CT plots (2.08 lb/A/h) was 9.4 X greater than that for NT plots (0.22 lb/A/h).

3. Compared to NT plots, CT plots had 4.5 X more splash sediment and were 4.5 X more susceptible to surface sealing. NT with surface residue is effective in reducing raindrop impact, descreasing surface sealing and its negative impact, and soil detachment.

4. Assuming that evapotranspiration was 0.2 in/day and all infiltration was available to plants, CT plots had 4.9 days of water for crop use; whereas NT plots had 10.2 days of water for crop use. This difference (5.3 days of water for crop use) would result in a producer utilizing a NT system to irrigate ~ 2.1 X less than a producer utilizing a CT system to produce the same crop, a 50% water and energy savings in irrigation cost.

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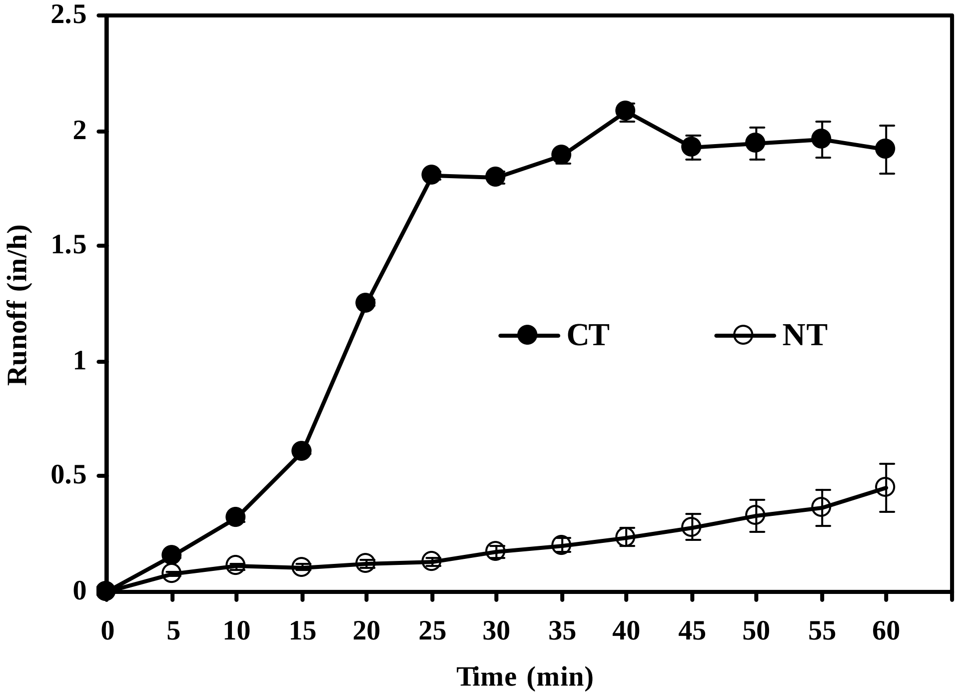

Fig. 1. Runoff rates for the combined CT and NT treatments from the Cecil sandy loam (bars=standard error).

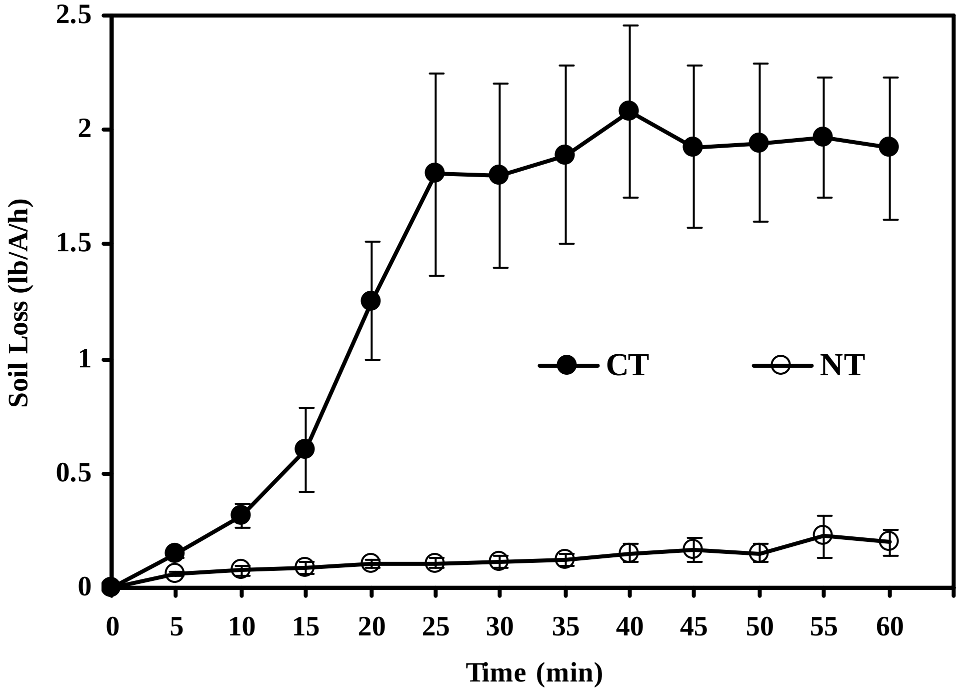

Fig. 2. Soil loss rates for the combined CT and NT treatments from the Cecil sandy loam (bars=standard error).

Overview of the Sod Based Rotation Using Conservation Techniques

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Abstract

Perennial grasses are the backbone of the U.S. livestock industry and are widely recognized as a key in conserving soil. Certain government programs require perennial grasses such as the Conservation Reserve Program (CRP) as a way to enhance and protect soil quality while setting aside land from production. Perennial grasses are used along roadsides all across the country to provide stable slopes for water runoff and to keep erosion to a minimum while providing a firm foundation for auto traffic with their immense root systems. Most perennial grasses have a wide tolerance to soil fertility, moisture, pH and other environmental conditions making them a good choice for various uses. Research has shown the benefits of perennial grasses to following crops; however, it is seldom reintroduced into the rotation once fields are taken out for row crop production. Our research has focused on a short term system that keeps perennial grasses in the rotation with row crops and has been found to be economically and environmentally advantageous. Several of our publications highlight the increasing organic matter content and water infiltration along with improved plant growth and yields of following crops that economically take 2-3 years in the conventional rotation to make the profit that is made the first year after perennial grasses. In both conventional and the perennial grass rotations, conservation tillage techniques have been adhered to in order to provide information for growers on implementing then in a farming system. As a general rule perennial grasses have been turned under when going to a row crop or have had intense tillage prior to planting a row crop. The sod based rotation has been shown to conserve natural resources, increase crop yields, and improve long-term agricultural sustainability and profitability.

Introduction

In the southeast USA, peanut, cotton and corn are major summer agronomic crops requiring a long growing season. However, regional farmers face great challenges in maintaining production sustainability and profitability using the traditional crop rotation system of peanut-cotton-cotton. For instance, Florida ranks 15th in cotton yield and total production among 17 states where cotton is planted (USDA, 2005). In 10 U.S. peanut production states, mean peanut yield of Florida ranks 8th in 2007. The major challenges include multiple pests, infertile soils, low soil organic matter (OM), and low soil water holding capacity. Integration of perennial grasses, such as bahiagrass, into the current rotation system of peanut and cotton has been proposed and proved by several studies (Katsvairo et al., 2007; Wright et al., 2007). For example, including bahiagrass in the rotation adds significantly to the soil organic and nitrogen pools as well as helps diminish nematodes and other pests normally found with annual row crops (Boman et al., 1996; Elkins et al., 1977; Marois, 2002; Marois and Wright, 2002).

Our current sod based rotation research is a multi-states project (Florida, Alabama and Georgia). In Florida (Marianna) and Alabama (Headland) sites, cattle are used to graze the grass produced as cow-calf operation. At another Florida site and a Georgia site, the grass is harvested as hay. Winter annual forages planted after cotton and peanut are also used for grazing or harvested as hay. In this paper, we summarized our sod based rotation studies at University of Florida’s North Florida Research and Education Center (NFREC).

Sod Based Rotation Studies in Florida

Four major field trials of the sod based rotation research at the University of Florida's NFREC include:

(1) "Comparison of the sod based peanut-cotton rotation system (Bahiagrass-Bahiagrass-Peanut-Cotton) and a conventional peanut-cotton rotation system (Peanut-Cotton-Cotton)". This study consists of the two cropping systems, two levels (low N and high N) of N applications and two irrigation regimes (irrigated and non-irrigated) with three replications to determine long-term sustainability, profitability, and N and water use efficiencies of the sod based rotation. Bahiagrass in this study is used for hay;

(2) "Bahiagrass kill date and tillage method effects on peanut growth, yield and grades in the sod based rotation". This study was conducted at two locations (Marianna and Quincy of the NFREC) and has two bahiagrass kill dates (fall vs. spring) and six tillage methods (strip-till, disk+turned, disk+chisel, paratill+strip-till, disk+strip-till, and strip-till+45 kg N ha^{-1}) with four replications;

(3) "Corn growth and yield responses to crop sequences in sod based peanut-cotton-corn rotations". The study includes three crop sequences, (i) bahiagrass-bahiagrass-corn-corn, (ii) bahiagrass-bahiagrass-cotton-corn, and (iii) bahiagrass-bahiagrass-peanut-corn with four replications;

(4) "Integration of cattle into the sod based peanut-cotton rotation system". In the system, bahiagrass and winter cover crops are grazed by cattle. This is a center pivot irrigation system at Marianna with a total of 160 acres. Four quadrants are four phases of the system (bahia-bahia-peanut-cotton). To investigate short-term and long-term impacts of cattle on soil properties, crop growth and yield as well as economic returns, three 50 x 50 ft exclusion cages have been established in each quadrant.

In these studies, we investigated soil physical, chemical and biological properties, including soil bulk density, soil penetration resistance, soil water infiltration, soil water content and water holding capacity, soil conductivity, soil organic matter and mineral nutrient concentration and availability, soil earthworm population and soil respiration; plant disease, insects and weeds pressure; crop growth, physiology, yields and quality; system inputs and net returns.

Highlights

When rotating summer crops with bahiagrass, both nutrients and water in the deep soil profile are utilized, due to improved rooting depth of the crops following bahiagrass. Rooting depth can be improved as much as 10 times, as compared to conventional cropping systems (Katsvairo et al., 2005; Katsvairo et al., 2006). Improved water capture reduces irrigation needs from a normal application of approximately 30 cm of irrigation per year to as little as 5 cm, with similar or greater yields (Wright et al., 2004; 2005; 2006; 2007). This results in as little as 17% of the current water use for irrigation.

Most important findings of the sod-based rotation effects on soil properties and on crop growth and yields from our studies at Quincy in last several years have been published on Agronomy Journal (Katsvairo et al., 2006; Katsvairo et al., 2007a; Katsvairo et al., 2007b; Katsvairo et al., 2008a), Journal of Food Science and Agriculture (Katsvairo et al., 2008b), Proceedings of Southern Conservation Agricultural Systems Conferences (Marois et. Al., 2007; Wright et al., 2007; Zhao et al., 2007a; Zhao et al., 2007b), and Proceedings of Beltwide Cotton Production and Research Conferences (Katsvairo et al., 2007; Wright et., 2007; Wright et al., 2008; Zhao et al., 2008). To better understand crop growth and physiological responses to sod based rotation, we are currently investigating crop insects and diseases as affected by crop rotations in addition to crop yields. Preliminary results from the Quincy research site indicate that sod-based rotations can considerably reduce insect, disease, and weed pressure, improve crop water status, increase crop yields and water use efficiency.

Peanut

Results of our sod based peanut-cotton rotation with two bahiagrass kill dates (fall vs. spring) and different tillage studies at two locations (Marianna and Quincy, FL) have indicated that bahia kill date did not affect peanut yield and strip-till can reach high or equivalent yield compared to the intensive tillage method. Therefore, farmers have a wide window to kill bahiagrass for their peanut crop in sod based rotation using conservation tillage. Sod based peanut yields in 2006-2007 ranged from 4,000 to 4,500 lbs acre^{-1}, when using strip tillage, which is 60 to 80% higher than state average yield (about 2500 lbs acre^{-1}) of peanut in the Southeast USA (Zhao et al., 2007a). In our replicated plot studies, the sod based peanut yield was significantly higher than conventional peanut (Fig. 1). We also found that increase in peanut yield in sod based rotation is mainly associated with reduction in insect and disease pressure in normal and wet years (Fig. 2) and with mitigation of water deficit stress in dry years (Data not shown).

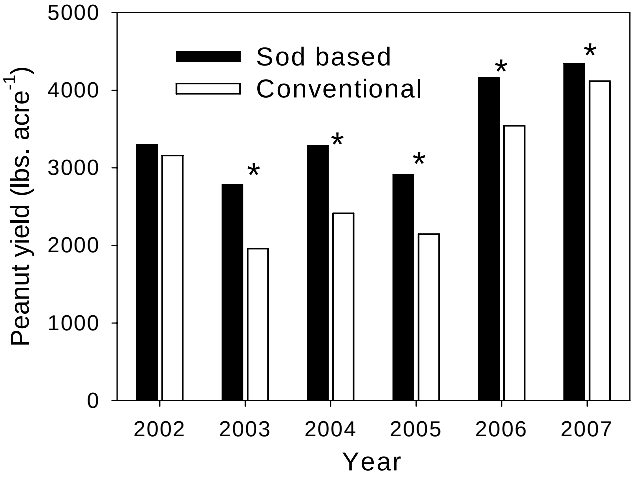

Fig. 1. Sod-based and conventional peanut yields in 2002-2007 at NFREC, Quincy, FL. The * indicates that the difference is significant.

Aflatoxin concentration in peanut kernels is the major concern for food safety and product quality. It is known that water deficit stress during pod development and maturity is a major factor increasing kernel aflatoxin level. Our preliminary results showed that sod based rotation greatly reduced peanut kernel aflatoxin concentration in a drought year especially for non-irrigated peanut (Fig. 3). Therefore, sod based rotation can reduce drought effect on non-irrigated peanut in the Southeast.

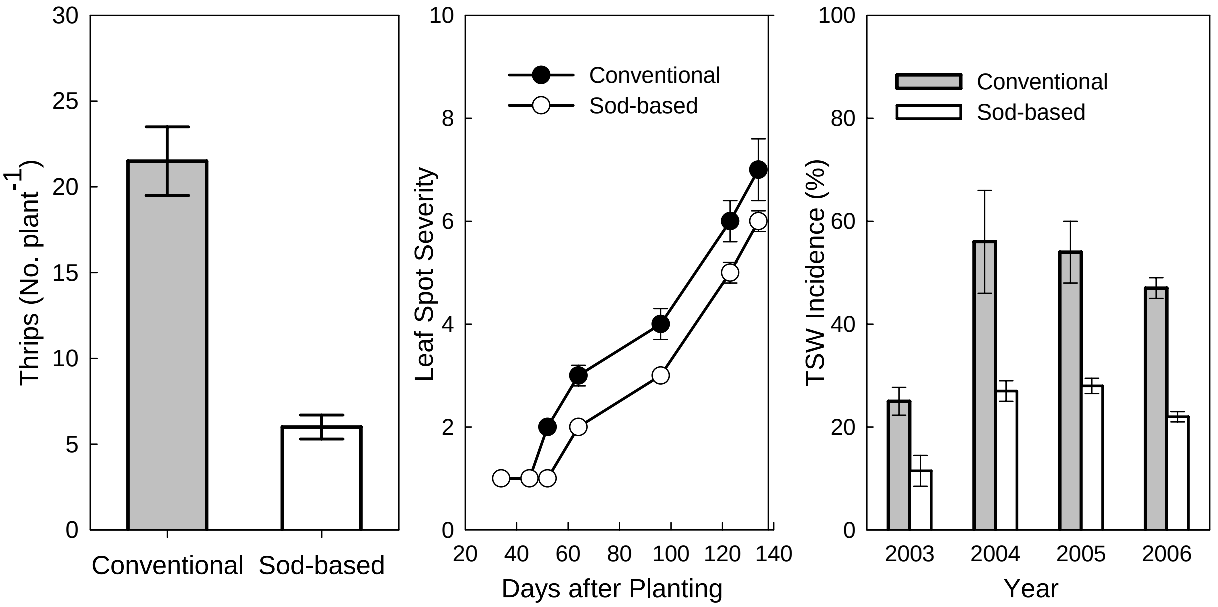

Fig. 2. Comparison of seedling thrip population, leaf spot severity, and tomato spotted wilt (TSW) incidence of peanuts grown in conventional and sod-based crop rotations in Quincy, FL.

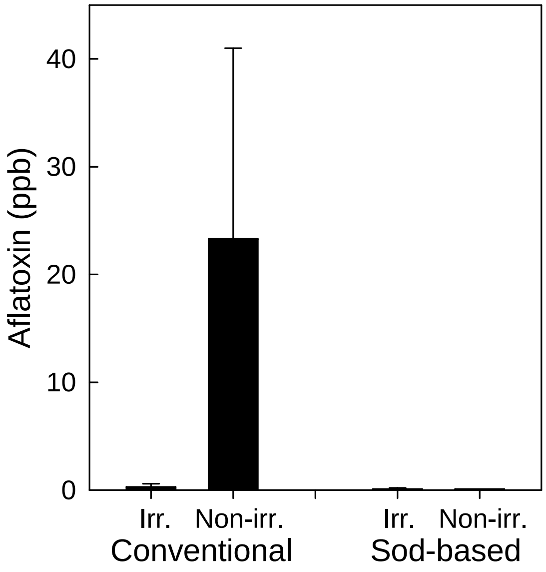

Fig. 3. Effects of irrigation and crop rotation on peanut kernel aflatoxin concentration in Quincy, FL in 2007. Note: 2007 was a very drought year in the Southeast.

Cotton

Florida mean cotton lint yield fluctuates around 700 lbs. acre^{-1} (USDA, 2005), whereas cotton lint yield in our sod-based rotation has reached 1510 lbs. acre^{-1} (Zhao et al., 2008a). Because sod based rotation improves soil quality, especially soil organic matter, nutrients, and water holding capacity, it is necessary to refine N fertilizer rate and reduce irrigation. Avoiding rank cotton growth by adjusting N, irrigation and application of Pix is the key step for high yield of the sod based cotton.

Currently, we found that the sod based rotation can greatly reduce cotton seedling disease, such as Rhizoctonia root rot compared to conventional cotton (Fig. 4). Additionally, the sod based cotton has significantly less weed, especially morningglory population than the conventional cotton (Fig. 4).

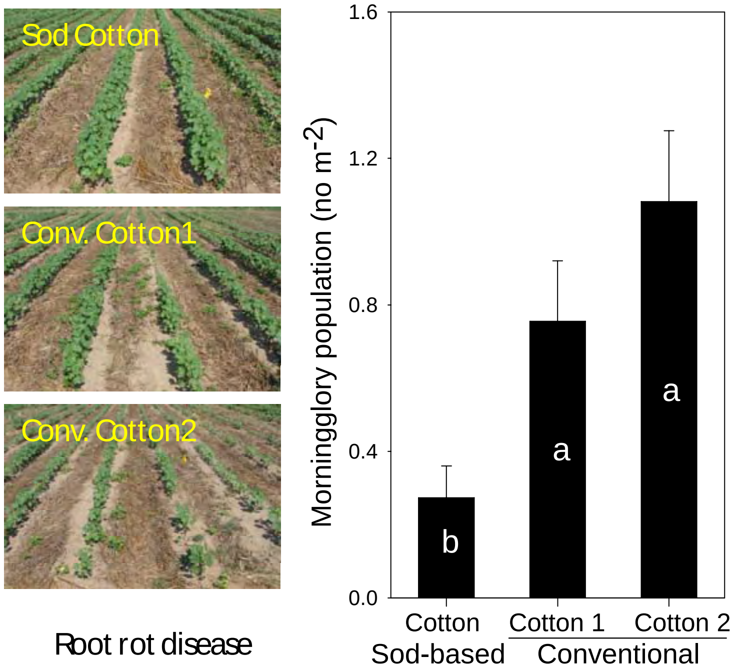

Fig. 4. Cotton Rhizoctonia root rot disease and morningglory population of the sod based and conventional cotton at Quincy, FL. in 2008.

o Economic analyses carried out on a sod-based rotation have shown profits are 2-4 times greater when the rotation is fully implemented as compared to the conventional rotation system. We expect that this system has the potential to add \$100-200 acre^{-1} profit for producers. A business management model for the sod-based rotation has been developed (Marois et al., 2001; Marois, 2003b) and modified based on our research data and farmer input. The model is available at the University of Florida's website (nfrec.ifas.ufl.edu/**sodrotation**.htm) for downloading. Typically, the model shows increased profits due to fewer inputs of irrigation, fertilization, pesticide and herbicide applications, and increased yields on row crops (Marois et al, 2001) and water use efficiency. The long-term positive impacts of the sod-based rotations on soil quality, environment, climate change, and agricultural sustainability are even more significant.

Bahiagrass and winter cover crops

Average yields (i.e. forage biomass) of first- and second-year bahiagrass in the sod based rotation are approximately 2200 and 7600 lb acre^{-1}, respectively. Oat winter cover crop shoot biomass at pre-heading stage can reach 4000 to 6000 lb acre^{-1}. Forage can be used for hay or grazing by cattle. Therefore, bahiagrass and cover crops can add value to the sod based system.

Yield Responses of Irrigated Native Buffalograss in the Southern Great Plains

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Summary: Buffalograss [*Buchloe dactyloides* (Nutt.)] a dominant grasses species of the North American shortgrass prairies is an excellent livestock forage with good drought tolerance. It has infrequently been utilized under irrigated conditions with N additions. Swine effluent (SE) and urea (UN) were used as N sources applied at loading rates of 56, 168, and 504 kg N ha^{-1} under irrigation. Seven annual N applications resulted in linear yield increases. Stand persistence at the high N loading rates was greater for SE applications, indicating the potential for the application of waste waters to this forage production system.

Nitrogen Fertilizer: Timing, Source, and Rate for a Winter Cereal Cover Crop

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Introduction

Conservation tillage is one component utilized throughout the United States to maintain a minimum of 30% residue on the soil surface. This residue, typically from previous crops, helps reduce soil erosion from water and wind, decrease labor and energy inputs, increase soil water availability for subsequent crops, and enhance soil quality (Kern and Johnson, 1993; Reeves, 1994). Growers in the Southeast also utilize conservation tillage, but soil quality benefits are enhanced by using a winter annual cover crop to supplement previous crop residues and maximize the amount of residue left on the soil surface. Decomposing cover crop roots also create channels that allows water to infiltrate the soil profile as opposed to running off the field (Williams and Weil, 2004). This combination of cash crop and cover crop residue contributes to soil organic matter, which improves the overall soil quality of the typically degraded soils in the region.

Rye (*Secale cereale* L.) is a popular choice for growers with multiple years of experience with conservation systems due to its wide adaptability to soil fertility levels, climate zones, and biomass production. However, in order to maximize the benefits of a conservation system, the biomass produced from the winter cover crop should also be maximized (Balkcom et al., 2007). Supplemental N fertilization is one agronomic practice that can be used to increase biomass production, but the cost of N fertilizers tempts some growers to eliminate this expense to reduce total N production costs, despite the benefits of more biomass.

An alternative N source to increase cover crop biomass production is poultry litter. Poultry litter is available to many growers and can usually be obtained at a lower price than commercial N, depending on hauling costs. The organic N fraction of poultry litter is not readily available, but will supply N over a longer time-frame as the litter is decomposed by soil microorganisms. The available N fraction of poultry litter could fertilize a cover crop, while the organic fraction that mineralizes over time could contribute to the N requirements of a subsequent summer crop. We will only focus on the cover crop in this proceeding.

Despite the benefits of increased biomass production, limited information exists on the optimal rates and times of application to maximize cover crop biomass production. Therefore, our objective was to compare N fertilizer sources, rates, and time of application for a rye winter cover crop to determine optimal biomass production for conservation tillage production.

Materials and Methods

This experiment was initiated in the fall of 2005 at the Wiregrass Research and Extension Center near Headland, AL on a Fuquay sand (loamy, kaolinitic, thermic Arenic Plinthic Kandiudults). The experiment remained in the same location each year with no re-randomization of the treatments.

The experimental design for the cover crop contained a split-split plot treatment restriction in a randomized complete block design with four replications. Main plots consisted of time of application (fall vs spring), subplots were N source (commercial fertilizer, and poultry litter), and sub-subplots were N rate (0 30, 60, and 90 lb N ac^{-1} as commercial fertilizer and 0, 1, 2, and 3 tons ac^{-1} as poultry litter on an as-sampled basis). Fall poultry litter treatments were applied on the same day the cover crop was planted, which corresponded to Nov. 19, 2005, Nov. 9, 2006, and Nov. 2, 2007. Commercial fertilizer was applied on Dec. 12, 2005, Dec. 4, 2006, and Nov. 19, 2007 after stand establishment. Based on soil test recommendations, 40 lb K_2O ac^{-1} was applied as KCl to all plots not receiving poultry litter at the initiation of the experiment. Spring applications of commercial fertilizer and poultry litter were applied on Feb. 8, 2006, Feb. 7, 2007, and Feb. 14, 2008. Poultry litter application rates were designed to approximate commercial fertilizer rates based on total and estimated available N supplied in the litter (Table 1). Sub-subplot size was 24 ft. (8-36 inch rows) wide and 40 ft. long.

Table 1. Total and estimated available N applied in the fall and spring from poultry litter on a dry weight basis at the Wiregrass Research and Extension Center in Headland, AL during the 2005-2006, 2006-2007, and 2007-2008 winter growing seasons.

		Rate (tons ac^{-1})							
	Time of	0	1	2	3	0	1	2	3
Crop year	application	Total N				Available N†			
		lb ac^{-1}							
2005-2006	Fall	0	76	152	229	0	38	76	115
	Spring	0	73	146	219	0	37	73	110
2006-2007	Fall	0	53	106	159	0	27	53	80
	Spring	0	69	138	207	0	35	69	104
2007-2008	Fall	0	64	127	191	0	32	64	96
	Spring	0	66	132	199	0	33	66	100

† Available N based on an estimate of 50% total N available during the first year of application.

A rye cover crop was drilled across the experimental area each fall at 90 lb ac^{-1}. Biomass samples were collected from two 2.7 ft^2 areas within each plot approximately 3 weeks before anticipated spring planting date and immediately preceding chemical termination of the cover crop in early April. The plant material collected was dried at 131 degrees Fahrenheit for 72 hours and weighed to estimate plant biomass of each plot.

All response variables were analyzed using the MIXED procedure (Littell et al., 2006) and the LSMEANS DIFF option to distinguish between treatment means (release 9.1; SAS Institute Inc.; Cary, NC). All data were analyzed by year. Cover crop data was analyzed with rep, timing, source, rate, and the interactions among timing, source, and rate as fixed effects in the model, while rep X timing X source were considered random. Treatment differences were considered significant if $P \leq 0.05$.

Results and Discussion

Average rye biomass measured across all three years of the experiment indicates that, regardless of N source, rate was highly significant (Table 2). Figure 1 illustrates the average biomass produced for each rate across both sources and time of application for all three years of the experiment. The red line at 4000 lb ac^{-1} is a minimum biomass level proposed by Reiter et al. (2003) for a high residue cereal cover crop conservation tillage system in Alabama. Figure 1 shows that rye biomass production is enhanced with N fertilizer and in order to achieve the minimum biomass level, an application of at least 30 lb N ac^{-1} is required. Additional N fertilizer can increase biomass production, but the high cost of N prohibits the cost effectiveness of this practice.

Biomass levels measured in 2007 produced a timing X rate interaction (Pr > F = 0.044) (Table 2) that indicates biomass levels increased with fall application of N across sources (Fig. 2). A similar trend existed for the other two growing seasons (Table 2), however, the results varied across the remaining years. In 2006, biomass levels were increased with fall application of N, but higher biomass levels were measured following spring application of N across N rates, regardless of source in 2008. Two out of three years suggests that if growers choose to maximize biomass production by utilizing a form of N fertilizer; a fall application would produce more cover crop biomass.

Table 2. F-values and significance values for fixed effects and their interactions for nitrogen timing, source, and rates during three experimental years at the Wiregrass Research and Extension Center in Headland, AL.

	2005-2006 growing season		2006-2007 growing season		2007-2008 growing season	
Effect	F Value	Pr>F	F Value	Pr>F	F Value	Pr>F
Timing	2.63	0.14	8.79	0.02	1.98	0.19
Source	0.01	0.94	1.51	0.25	12.6	0.01
Timing x Source	0.16	0.70	1.03	0.34	0.08	0.781
Rate	9.06	<0.01	59.8	< 0.01	43.4	< 0.01
Timing x Rate	2.12	0.12	2.98	0.04	2.24	0.10
Source x Rate	0.35	0.79	1.37	0.27	3.44	0.03
Timing x Source x Rate	0.19	0.90	1.88	0.15	2.68	0.06

A source X rate interaction (Pr > F = 0.027) was observed for rye biomass levels during the 2008 growing season (Table 2). Commercial N fertilizer produced higher biomass levels following N application when averaged across application time (Fig. 3). Although poultry litter rates were applied to approximate commercial N rates, the available N fraction of poultry litter is only an estimate (Table 1). A 50% estimate of total N within poultry litter is actually a conservative estimate. Other results with poultry litter in the region indicate that much of the total N applied is available (Mitchell and Tu, 2005), however, these results were based on litter applications during spring and early summer for subsequent summer crops when temperatures are warmer. Surprisingly, poultry litter produced a lower biomass response in 2008 after two years of application, despite the residual effect of an organic N source like poultry litter.

Conclusions

Poultry litter appears comparable to fertilizer as a source of N for a rye cover crop. An application of 30 lb N ac^{-1} produced sufficient biomass to meet a minimum biomass threshold, and a fall application of N was more beneficial during two out of three years. These results represent only one location over a 3-year period; therefore, these findings can not be expected to represent the entire Southeast. However, these results can be expected to provide general information related to N fertilizer and biomass production in the Southeast.

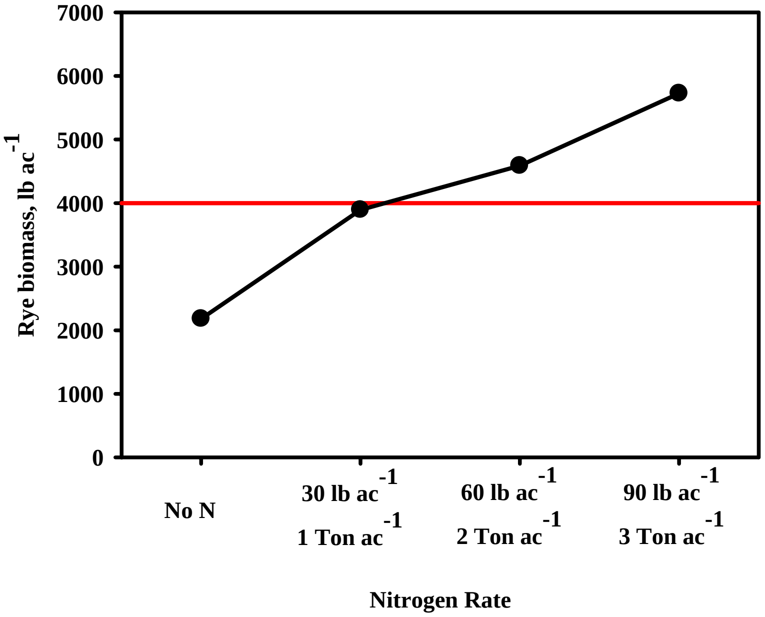

Figure 1. Average rye biomass production measured across N rates, regardless of source and time of application during the 2005-2006, 2006-2007, and 2007-2008 winter growing season at the Wiregrass Research and Extension Center in Headland, AL. The red line is a minimum biomass level for a high residue conservation system in Alabama proposed by Reiter et al. (2003).

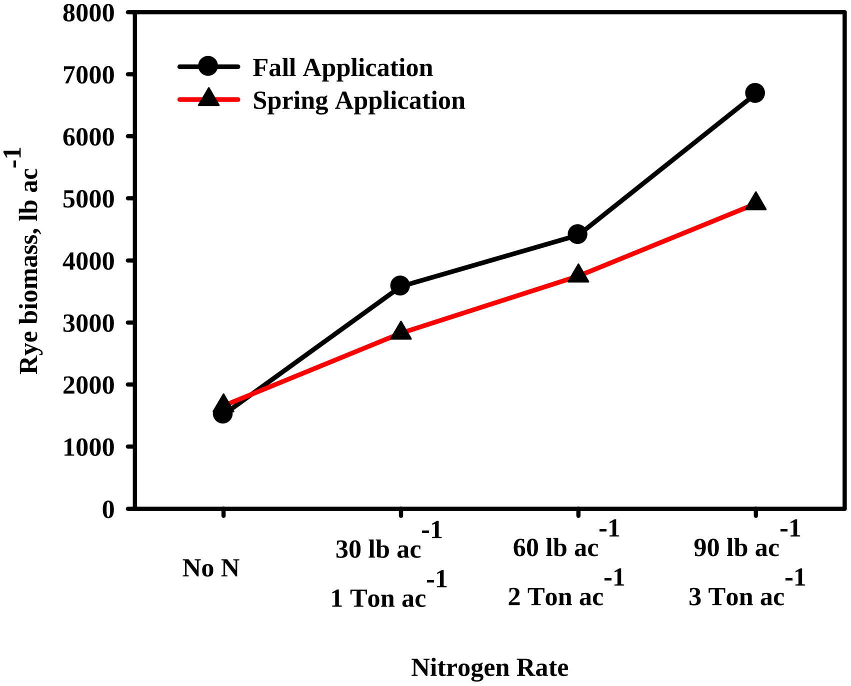

Figure 2. Rye biomass production measured following fall and spring application across N rates, regardless of source during the 2006-2007 winter growing season at the Wiregrass Research and Extension Center in Headland, AL.

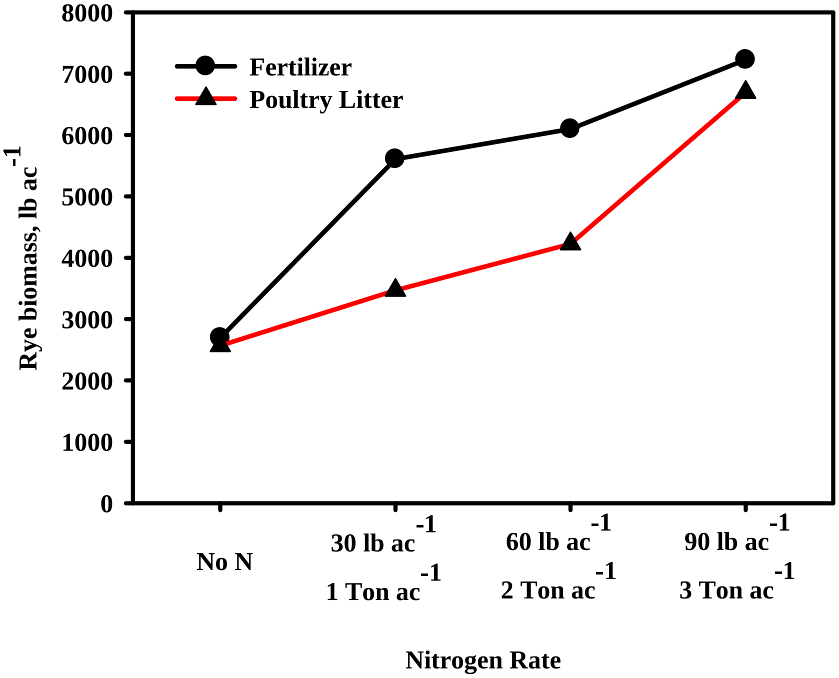

Figure 3. Rye biomass production measured between N sources across rates, regardless of time of application during the 2007-2008 winter growing season at the Wiregrass Research and Extension Center in Headland, AL.

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Improving Conservation Tillage Practices for Pearl Millet

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Introduction

Conservation tillage practices should reduce pearl millet production costs by saving time, fuel, and fertilizer, but there is little information available concerning recommendations. In this paper we summarize recent research, developments, and experiences in developing no-till practices and identifying improved varieties for more cost-effective production.

Stand Establishment

Stand establishment is the most critical stage for production. Planting depth control and soil contact are the greatest challenges to getting a good stand. Because of the small size of pearl millet seed (about 1/3 the size of sorghum), planting depth should be ½ to ¾ inches. Crop residue can cause the planter's depth wheels to ride up making it difficult to get the seed placed into the furrow. It is important to plant into soils with moisture sufficient for seed germination.

With conventional tillage, seeding rates of 4 lbs/ac in 21 inch rows are recommended (Lee et al, 2004). Rates ranging from 8 to 13 lbs/ac are necessary to assure adequate stands in no-till. Cost of hybrid seed can be prohibitive for using these higher seeding rates, but new varieties such as “2304” that allow seed to be saved should have lower seed costs.

Row spacing of 7.5, 15, and 22.5 inches were evaluated at Watkinsville GA in a split plot design, with tillage as main plots and legacy fertility treatment as sub-plots. Tillage treatments were conventional tillage vs. no-till. Legacy fertility treatments were prior fertilization with poultry litter vs. anhydrous N. Tifgrain 102 and 2304 were sown 18 Jul 2006 in 3 replications with 6 lbs seed/ac with a pre-emergence application of Callisto (3 oz/ac). Fertilizer was applied at 80 lbs N/ac. Grain was combine-harvested, and yields were corrected to 15.5% moisture.

Neither variety nor fertility effects were significant for stand or yield ($P \geq 0.31$). Stands and yields were greater in plots with conventional tillage ($P=0.03$, Fig. 1). In no-till plots, stands and yields were greater in 7.5 inch rows compared to the wider inch row spacings ($P<0.05$).

Although better stands were obtained with closer row spacing, plants in close rows may be more prone to lodging. Variety 2304 was planted 7 Jul 2007 in 7.5 and 15 inch rows at 8 lbs seed/ac on a farm in Tifton GA. Due to scheduling difficulties, harvest was delayed until after plants had begun to lodge. At harvest on 25 Oct 2007, numbers of erect and lodged stems were counted in five random 10 ft x 7 ft sections for both row spacings. Lodging in the 7.5 inch rows (39.9% of stems) differed (*P*=0.03) from lodging in the 15 inch rows (20.3%). Lodging may be reduced by timely harvest.

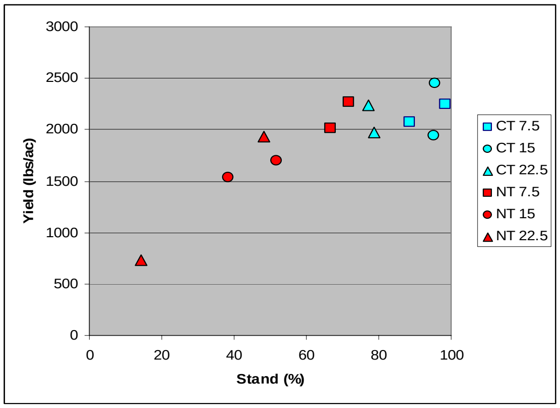

Figure 1. Stand establishment and yield of pearl millet in conventional tillage (CT) and no-till (NT) at three row spacings at Watkinsville, GA in 2006. Two data points for each treatment represent different varieties.

Weed Management

It is important to control annual grass weeds for a successful crop. Until recently, the only pre-plant or pre-emergence herbicide options were glyphosate or paraquat to control existing weeds. Callisto (mesotrione) was registered for use on pearl millet in 2008. Callisto applied at-plant at 3 oz/ac provides season-long control of crabgrass (*Digitaria* spp.), Texas panicum (*Panicum texanum*), and many broadleaf weeds. As with other pre-emergence herbicides, soil moisture from rain or irrigation is necessary to activate Callisto for best results.

Atrazine is an effective post-emergence herbicide when applied at the 2 to 3 leaf stage (Wright et al, 1995), but it has not been possible to get registration for pearl millet. The only herbicide registered for post-emergence broadleaf weed control in pearl millet is 2,4-D. Apply to emerged weeds at 3 to 4 weeks after emergence or when the crop is 8 to 12 inches tall. The broadcast rate for 2,4-D is 1 pint/ac of a 4-pound formulation or 0.5 lbs/ac active ingredient.

Hybrid Evaluations

Experimental pearl millets were evaluated for yield and grain composition at Watkinsville GA in a split plot design, with tillage as main plots and legacy fertility treatment as sub-plots. Tillage treatments were conventional tillage vs. no-till. Legacy fertility treatments were prior fertilization with poultry litter or anhydrous N. Varieties were sown 18 Jul 2006 in 3 replications with 6 lbs seed/acre in 15 inch rows with a pre-emergence application of Callisto (3 oz/acre). Fertilizer was applied at 80 lbs N/ac. Grain was combine-harvested, and yields were corrected to 15.5% moisture. Grain was evaluated for 100 grain weight, protein, fat, and starch.

Experimental hybrid (506 x 2304) was among the top yielding entries in each treatment (Table 1). Across all treatments, (506 x 2304) had 38% greater yield than Tifgrain 102. Hybrid (606 x 2304) had 30% greater yield than Tifgrain 102. Over all entries, yields were greatest with conventional tillage (Table 2), primarily due to poorer stand establishment in no-till (data not shown). Prior fertility treatment had no effect on yield. Grain from no-till plots had greater 100 grain weight and protein content, and less starch. Prior fertility treatment had a minor effect on grain quality. Grain from poultry litter plots had higher protein and lower starch.

Despite the greater yield potential of some experimental hybrids, management will play a key role in achieving that potential. Stand establishment is critical to a successful crop. No-till planting with in-row subsoiling increased yield 16% over conventional tillage (Wright et al, 1995). Poultry litter can be a beneficial fertilizer up to 2 tons/ac (Gascho et al, 2001). Fertilizer costs might be reduced if warranted by site-specific conditions.

Table 1. Yield of experimental pearl millets in tillage and fertilizer trials in Watkinsville, GA in 2006.

Entry	Grain yield (lbs/ac)				
	Overall mean	No-till poultry	No-till anhydrous	Conventional poultry	Conventional anhydrous
106 x 2304	2191 cd	2082 ab	2216 ab	2337 bcd	2127 cd
206 x 2304	2377 bc	2203 ab	1834 abc	2789 b	2681 abc
306 x 2304	1998 de	1910 ab	1741 abc	2231 cd	2110 cd
406 x 2304	2585 ab	2456 a	2406 a	2662 bc	2816 ab
506 x 2304	2750 a	2578 a	2041 abc	3465 a	2917 ab
606 x 2304	2595 ab	1992 ab	1502 c	3647 a	3240 a
99 x 2304	2434 abc	2457 a	2095 abc	2432 bc	2752 abc
2304	1820 e	1681 ab	1709 bc	1913 d	1978 d
Tifgrain 102	1991 de	1460 a	1609 bc	2586 bc	2307 bcd
lsd (*P*=0.05)	355	964	688	502	677

Table 2. Tillage and fertilizer treatment effects on pearl millet in Watkinsville, GA in 2006

Management main effect	Yield (lbs/ac)	100 Grain weight (g)	Protein (%)	Fat (%)	Starch (%)
Conventional	2610 a	0.63 b	11.1 b	5.0	63.9 a
No-till	1999 b	0.80 a	11.6 a	5.1	63.1 b
lsd (*P*=0.05)	168	0.02	0.1	NS	0.1
Poultry litter	2382	0.71	11.6 a	5.1	63.1 b
Anhydrous N	2227	0.71	11.1 b	5.0	63.9 a
lsd (*P*=0.05)	NS	NS	0.1	NS	0.1

Changes in Soil Carbon and Nitrogen

Pearl millet was no-till planted into rye residue on plot land previously in a cotton-cotton-peanut rotation at the University of Georgia Tifton. Tifgrain 102 and 2304 were planted 2 May 2005 and

15 June 2006 at 6 lbs seed/ac in 15 inch rows, with a post-emergence application of Atrazine 4L (1.5 pints/ac) + Agri-oil (1 pint/ac). Soil was sampled (0-2 cm) and evaluated for total soil carbon and nitrogen content in oven dried and ball-milled samples using a Carlo-Erba Model NA 1500 series II carbon-nitrogen analyzer.

Soil carbon and nitrogen increased with no-till pearl millet (Fig. 2). Spikes in both elements corresponded to the cropping period of pearl millet. In Brazil, soybean/pearl millet rotations are becoming increasingly popular for nematode control and soil conservation. Assessing the long-term effects of cropping systems, field data and computer simulations determined that soil carbon in no-till soybean/pearl millet rotations remain comparable to native savannah conditions, while soil nitrogen would increase compared to alternative systems (Corbeels et al, 2004).

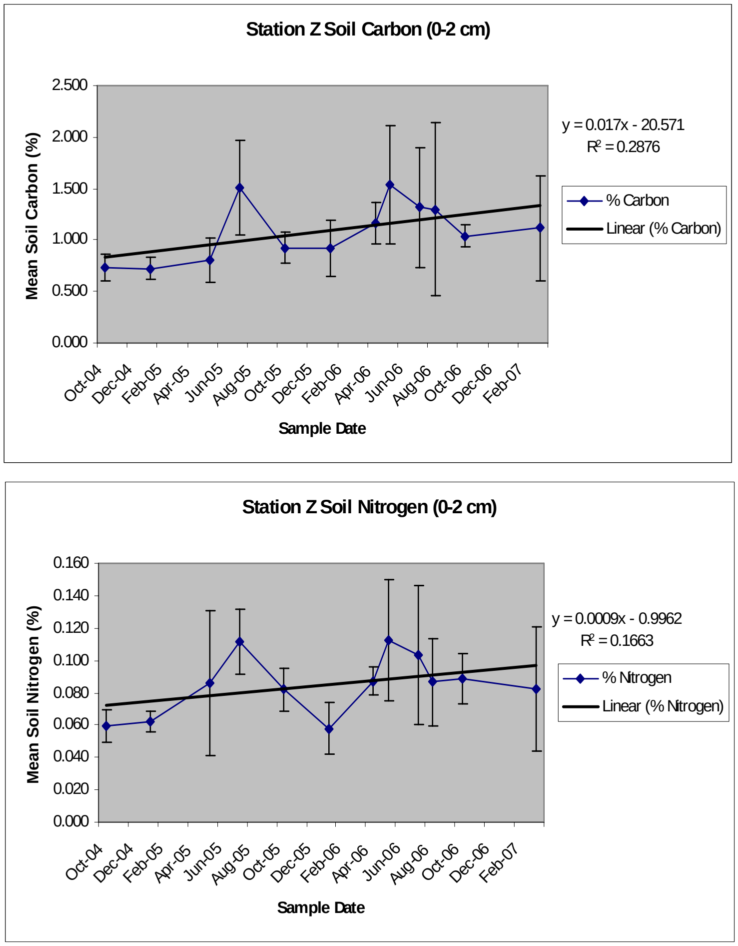

Figure 2. Changes in soil carbon and nitrogen from no-till rye/pearl millet at Tifton, GA in 2005 and 2006.

Double Cropping

In some circumstances a grass rotation is beneficial. In traditional conservation tillage, the rye cover must be killed before planting corn. In contrast, rye and pearl millet can be double cropped. From 2002-2005, rye yield in Georgia averaged 20.8 bu/ac and sold for $4.50/bu (IPM Center, 2006). Double cropping with rye would increase gross revenue $94/ac compared to spraying the rye cover with herbicide. Both rye and pearl millet can be grown on dryland with limited fertilizer, and planted and harvested with the same equipment.

Double cropping with wheat may be an acceptable alternative, but observations suggest that chinch bug (*Blissus leucopterus*) is greater in pearl millet following wheat, particularly in the Piedmont. Pearl millet does not affect wheat yields in Georgia (Buntin et al, 2007). Sorghum can have allelopathic effects and reduce subsequent no-till wheat yield compared to no-till wheat following pearl millet (Roth et al, 2000).

Conclusion

Stand establishment is critical for successful cultivation of pearl millet using conservation tillage practices. Close row spacing can improve yield, but may increase the potential for lodging. Callisto is now registered for use on pearl millet, providing an effective weed management option. New experimental varieties are being identified for their suitability in no-till systems. When pearl millet is included as a grass rotation, soil carbon and nitrogen levels can increase. Profitability can be improved by double cropping with rye instead of burning down the biomass cover.

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Adapting Conservation Tillage Approaches for California's Central Valley: Recent Progress of the Conservation Tillage Workgroup

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Introduction

Since the development and expansion of irrigation in California's Central Valley from the 1930's through 1963 when the California Aqueduct was constructed as part of the Central Valley Improvement Project, tillage practices in this region have changed very little. Unlike other regions of the world such as the Southeast and Midwest US, Canada, Brazil and Argentina, where various conservation tillage (CT) practices have been developed primarily as a means to prevent soil erosion losses, CT in California, until very recently, has been virtually nonexistent. Acreage under no-till, strip-till and mulch till has been under 2% in the annual crop production regions of the Central Valley during this time (Mitchell et al., 2007). During the past ten years, however, a number of new factors have been converging in the Central Valley that are now making CT systems and options increasingly attractive. Reducing diesel fuel and labor costs, as well as particulate matter and greenhouse gas emissions typically associated with tillage have now become important drivers influencing interest in CT systems today.

Conservation tillage residue management was first approved in California by the Natural Resources Conservation Service as an Environmental Quality Incentives Program (EQIP) practice in 2003. In 2004, the San Joaquin Valley Air Pollution Control District mandated the adoption of conservation management practices aimed at air quality improvement throughout the Valley and for the first time, practices that "eliminate or reduce the need to disturb the soil" were identified as an eligible conservation practice in this region. In 2008, Central Valley Regional Water Quality Control Boards limited the application of nitrogen (N) from manure to dairy silage fields to 140% of crop N removal and this is now also being seen as another incentive for the adoption of "CT-enabled" triple-cropping systems that theoretically may produce more silage and remove more N in a given time.

To respond to the recent need for information on CT systems in California, the Conservation Tillage Workgroup was established in 1998. Today, the CT Workgroup has over 1500 University, farmer, private sector and NRCS members who work together and exchange information and experiences on emerging CT systems. One of the primary means for the Workgroup to learn about CT practices has been to visit experienced farmers, researchers, and equipment companies in regions where CT systems have become well developed. Connections with the Southern Conservation Agricultural Systems Conference, the Georgia Conservation Tillage Alliance, the USDA Agricultural Research Service labs in Auburn, AL and Watkinsville, GA beginning in 1999 have been a valuable and significant educational opportunity for several California CT Workgroup members and our connections with these groups have been extended via numerous Workgroup mechanisms in the Central Valley. Our Workgroup's recent involvement with the North America Conservation Agricultural Systems Alliance (CASA) continues these types of longstanding and useful partnerships to bring information to our members.

Conservation Tillage in California Forage Production Systems

California's dairy industry is a huge contributor to the State's economy. Dairy products have been California's top agricultural commodity for a number of years (CDFA, 2004). They account for over 5 billion dollars in cash receipts, which is about 17% of the State's overall agricultural output in recent times. California dairies require year-round availability of inexpensive, locally-produced forage materials. Common dairy forage production systems consist of winter small grains seeded either individually or in mixes in November and December. These winter forages are then harvested as "green chop" the following March through May. In conventional production systems, fields may be disked and deep-ripped a number of times following the harvest of these winter forages, disked again, relisted or bedded and then preirrigated for spring corn planting. Turnaround time between winter small grain forage harvest and spring corn planting routinely takes about two weeks. Spring silage corn is then produced for late-summer harvest. Occasionally, corn or another forage crop such as milo or sorghum-sudan, may be double-cropped after an early planted corn crop with the second crop coming off in early fall. In most current production systems, intercrop tillage and seedbed preparation is done ahead of each successive crop. Such production systems, however, lend themselves quite well to a variety of conservation tillage approaches that have been developed in other production regions, and in recent years, a number of California dairy forage producers have begun experimenting with these reduced till forage production alternatives.

The primary motivation for CT in dairy forage systems is to save time, labor and fuel. This is accomplished by reducing primary, intercrop tillage or soil preparation operations such as disking, plowing, chiseling and ripping to the greatest extent possible while still achieving adequate productivity. In general, the earlier a crop such as corn is planted, the higher the yield. Corn stunt disease is also less severe in early corn than in later-planted corn. Minimizing or eliminating intercrop tillage can reduce the time between winter forage harvest and corn seeding from 2 – 3 weeks under conventional practices, down to 7 to 10 days or even less due to reduced time for tillage operations, and less water applied as preirrigation.

Using CT to reduce the time between successive forage crops is currently being done at a number of Central Valley dairies (Photo 1). Following the harvest of a typical winter small grain forage, a strip-till pass using a GPS-guided tractor may be done ahead of a pre-irrigation and planting , or no-till corn planting either before or after a surface flood irrigation.

Photo 1. Strip-till planted silage corn in wheat residue following manure application, Petersen Dairy, Turlock, CA, 2007.

The strip-till or no-till planted corn crop will typically mature several days earlier than a crop that has had traditional intercrop tillage and this may enable more reliable triple-cropping of a crop such as a no-till drill seeded sudangrass forage following corn (Photo 2). The reliability of CT-enabled triple-cropping and the ability of these systems to remove more applied manure N relative to conventional double-cropped forage systems is now being evaluated in a series of dairy farm studies.

Photo 2. No-till seeding of sudangrass into corn and wheat residues, Petersen Dairy, Turlock, CA 2007.

Conservation Tillage in Processing Tomato Production

Since the early 1990’s we have evaluated a variety of conservation tillage alternatives for processing tomato production. After demonstrating the feasibility of no-till transplanting tomatoes into a variety of crop and cover crop residues (Herrero et al., 2001), and early-season, but not season-long weed suppression by heavy cover crop mulches (Madden et al., 2004), we initiated a long-term tomato – cotton rotation study in Five Points, CA to compare CT and standard tillage practices with and without winter vetch/rye/triticale cover crops (Mitchell et al., 2007). This study has shown that no-till tomatoes can be established in high residues and that in-season cultivation is needed to suppress weeds in CT systems that reduce overall tillage passes by over 50% relative to traditional tillage systems (Photo 3).

Photo 3. No-till tomato transplanting into rye/triticale/vetch cover crop mulch, Five Points, CA 2007.

Because tillage operations, however, account for a relatively small part of the overall production budget for tomatoes (Figure 1), cost savings associated with CT tend to be relatively modest. Dust emissions from the CT tomato – cotton system have also been shown to be reduced by over 50% (Baker et al., 2005).

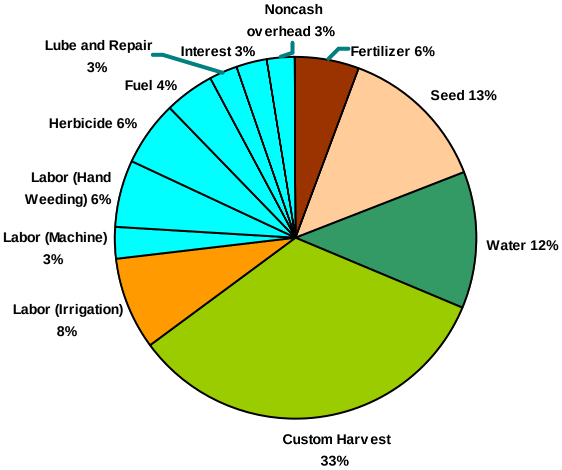

Figure 1. ST tomato production costs without a cover crop. The blue-shaded costs can be reduced by eliminating tillage operations, comprising 36 percent of total costs for the ST system without a cover crop. All other costs remain the same regardless of tillage practices.

The use of triticale cover crops and strip-till transplanted tomatoes has also been refined in subsurface drip-irrigated fields at a commercial scale in Firebaugh, CA (Photo 4).

Photo 4. Strip-tilling triticale cover crop ahead of processing tomato planting, Firebaugh, CA 2008.

Triticale is seeded on the tops of 5-ft. beds in October following two passes of a minimum till bed reconditioning tool following tomato harvest. The cover crop is then irrigated up and allowed to grown to a height of about 15 – 18 inches prior to a burn-down spray of glyphosate that is usually applied in February. A ground-driven strip-tiller shallowly mixes the triticale with the soil while applying a preplant herbicide to the centers of the beds before transplanting. This system has performed well for a number of years, however, a key to effective management is to stop cover crop growth before too much biomass is produced because excess residues can result in mechanical harvesting inefficiencies.

Future Conservation Tillage Systems in California's Central Valley

Coupling conservation tillage practices with overhead irrigation is a merging of technologies that is recently gaining attention in parts of California's Central Valley. During the past two years, a number of center pivot irrigation systems have been purchased and have been successfully used for a variety of crops including alfalfa, wheat and sugar beets. Reduced labor requirements for these systems have been documented. Work is currently under way to introduce CT production of increasingly high value crops into overhead irrigation systems and to evaluate whether such systems when coupled with conservation tillage practices can reduce irrigation requirements (Photo 5)

Photo 5. No-till corn seeding into wheat residues under overhead irrigation, Five Points, CA, 2008.

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Effects of rolling/crimping of cover crops on their termination, soil strength and moisture

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Introduction

Cover crops are a crucial part of conservation agriculture, but they have to be managed appropriately to optimize their benefits (Brady and Weil, 1999). Previous research identified benefits, such as increased water infiltration, reduced runoff, reduced soil erosion, and reduced soil compaction (Kern and Johnson, 1993; Reeves, 1994; Raper et al., 2000a; Raper et al., 2000b). Flattening and crimping of cover crops by mechanical rollers/crimpers originated in Brazil to successfully terminate cover crops without herbicides (Derpsch et al., 1991) and this technology is now receiving an interest within the farming community in the southern United States. Mechanical termination of cover crops using a roller/crimper requires waiting at least three weeks before planting a cash crop into rolled residue (Ashford and Reeves, 2003; Kornecki, et al., 2006). Ashford and Reeves (2003) indicated that when rolling was conducted at the appropriate plant growth stage (i.e., soft dough), the roller was equally effective (vs. chemical herbicides) at terminating the cover crop (94%) and that rye termination rates above 90% were sufficient to begin planting of cash crop due to accelerated rye senescence. To speed up termination, producers utilize herbicides as a supplement to rolling. However, in organic vegetable production, common herbicides cannot be used and multiple rolling/crimping events may be necessary. There is a concern, however, that multiple rolling might cause soil compaction which could be detrimental to water infiltration and plant/root development. A field study conducted in Cullman, Alabama evaluated the effects of multiple rolling/crimping events on cover crops termination, soil strength and soil moisture.

To determine the effect of multiple rolling operations on soil strength, termination rate and soil water content, two rollers, straight-bar roller and two-stage roller, were used in a replicated field experiment in the spring of 2007. Cover crop termination rates were evaluated one, two, and three weeks after rolling.

The objectives of this study were: 1. Determine the effectiveness of two different roller designs in terminating a single cover crop (rye) and mixture (rye, clover, hairy vetch) in multiple rolling operations, 2. Determine the effect of multiple rolling on gravimetric soil water content and soil strength (Cone Index, CI).

Materials and Methods

In spring of 2007 a replicated field experiment (factorial treatment arrangement) was conducted in Cullman, Alabama to evaluate multiple mechanical terminations of two cover crops (factor I): single (rye) and a mixture (rye, hairy vetch and crimson clover) using two different rollers (factor II). Rye and mixture was drilled in the fall of 2006 (the end of October) using a Tye grain no-till drill*. The experiment was conducted April 24, 2007 when rye was in the early milk growth stage (Nelson et al., 1995) which is a desirable growth stage for rye termination. The experiment was a randomized complete block design (RCBD) with four blocks (replications). Treatments were randomized within each block. Each experimental unit was 6-m long and 1.8-m wide. Randomly assigned cover crops were rolled once, two, and three times (factor III) and scheduled every other day from previous rolling application. Before rolling, soil samples were obtained to determine gravimetric soil water content and soil strength was measured using a mobile soil cone-index meter. Two 1.8-m wide rollers utilized in the experiment were: a straight-bar roller (Figure 1a) and two-stage roller (Figure 1b).

Figure 1. (a) Straight-bar roller (b) Two-stage roller/crimper

Rye and mixture injury, based on visual desiccation, was estimated on a scale of 0 (no injury symptoms) to 100 (complete death) (Frans et al., 1986), and was evaluated at one, two, and three weeks after rolling. The speed 6.4 km/h was chosen to match speeds commonly used in field chemical applications. Treatment means were separated by the Fisher's protected LSD test at α=0.1 probability level (SAS, 2001).

Results and Discussion

a. Cover crop termination rates

Termination rates for rye and mixture (rye crimson clover and hairy vetch) are shown in Table 1. One week after rolling, significantly higher termination rates were reported for cover crops (rye only and mixture) rolled three times compared with rolled once and no-rolled cover crops. Second week after rolling, lower termination rates were reported for rye, crimson clover, hairy vetch mixture compared to rye only. The main reason for lower rates was a new and active growth of hairy vetch that altered termination rates. Three weeks after rolling no significant differences in termination rates (90% and above) were reported between roller types and numbers of rolling events. Although, compared to rolled residue no rolled covers produced significantly lower termination rates (51% to 63%). It should be noted that two weeks after rolling rye three times by each roller type, rye termination rates were high enough (90% and above) to successfully establish a cash crop into rye residue (Ashford and Reeves, 2003).

Table 1. Rye and mixture termination rates (%) for roller types and number of rolling operations. **Same letters indicate no significant differences within each column.

Rolling Treatment	Cover Crop	Roller type	First week	Second week	Third week
Not Rolled	Rye	No roller	0.0 d	38.8 f	63.3 b
	Mixture	No roller	0.0 d	21.3 g	51.3 c
Rolled 1 time	Rye	Straight	66.3 c	80.0 bc	91.0 a
		Two-stage	68.3 bc	82.5 abc	91.3 a
	Mixture	Straight	67.5 bc	46.3 ef	92.0 a
		Two-Stage	68.8 bc	46.3 ef	94.5 a
Rolled 2 times	Rye	Straight	78.8 a	87.5 ab	90.0 a
		Two-stage	73.8 abc	86.3 ab	92.5 a
	Mixture	Straight	67.5 bc	52.5 e	95.0 a
		Two-Stage	75.0 ab	63.8 d	93.3 a
Rolled 3 times	Rye	Straight	81.3 a	91.3 a	93.3 a
		Two-stage	81.3 a	90.0 ab	93.8 a
	Mixture	Straight	77.5 a	63.8 d	92.5 a
		Two-Stage	77.5 a	72.5 cd	92.0 a
LSD at α = 0.1 Significance level			8.15	10.28	9.26

b. Gravimetric soil moisture content before rolling treatment
No significant differences in gravimetric water content reported between all treatments at each depth i.e. 0-15 cm and 15-30 cm. Average gravimetric water content in the top layer (0 to 15 cm) was 12%.

c. Soil Cone Index (CI) before rolling treatment application
No significant differences in soil cone index at the top layer (0 to 15 cm) was found between all rolling treatments (rolled + non-rolled), roller types and number of rolling operation (Figure 2). These results provided a good base to determine rolling treatment effects on soil compaction and soil gravimetric water content.

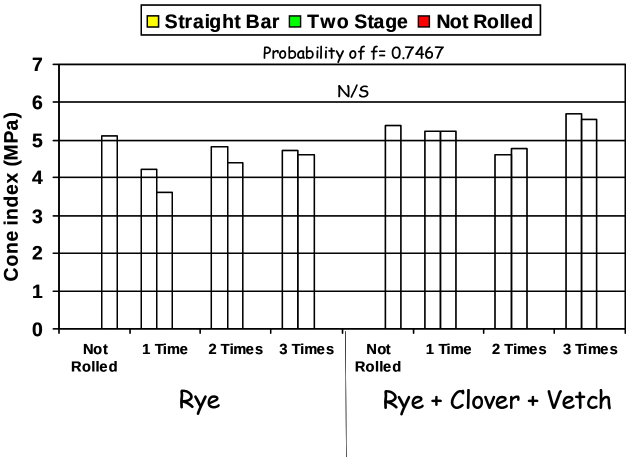

Figure 2. Soil Cone Index (CI) before rolling/crimping of both cover crops. No statistical differences between treatments found at α=0.1 significance level.

d. Gravimetric water content after rolling treatment application
There was a significant difference in soil gravimetric water content after rolling operation for different treatments. Compared with rolled cover crops, the lower gravimetric soil water content was associated with both non-rolled covers: rye and the mixture of rye crimson clover, hairy vetch (Figure 3). Significantly lower water content was most likely associated with the actively growing covers (rye and mixture) resulting in higher water usage. In addition, both non-rolled cover crops exhibited significantly lower termination

rates compared with rolled/crimped residue indicating actively growing covers which used more available water from soil than rolled/crimped residue.

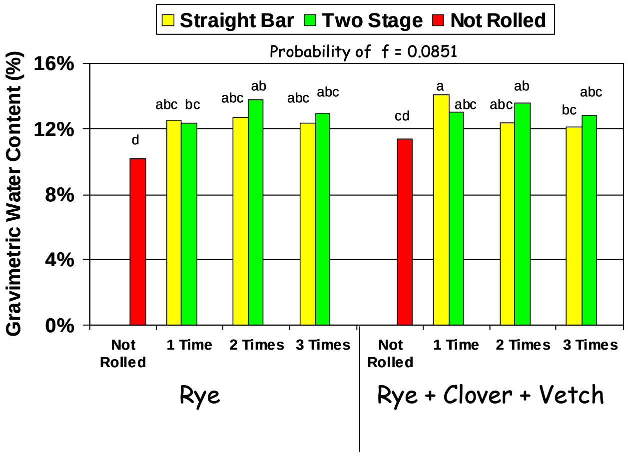

Figure 3. Gravimetric water content after rolling/crimping of both cover crops. Mean separation was performed using LSD (Fisher procedure) at α=0.1 significance level. Same letters indicate no statistical difference between all treatments (LSD=1.77%)

e. Cone Index (CI) after rolling treatment application

Compared to rolled/crimped rye and mixture treatments, significantly higher cone index were noted for both non-rolled residue (Figure 4). No significant differences in CI were found between non-rolled rye and mixture rolled twice by the straight bar roller. Except for the mixture rolled twice by the straight bar roller, all rolled covers exhibited a lower cone index while maintaining higher gravimetric soil water content. Significantly lower cone index for rolled cover crops residue indicates that rolling crimping operation for straight-bar roller designs does not increase CI, thus not elevating soil compaction. In contrast, the higher CI found with non-rolled cover crops is most likely associated with decreased soil water content due to reduced surface cover of standing cover crops and its evapotranspiration.

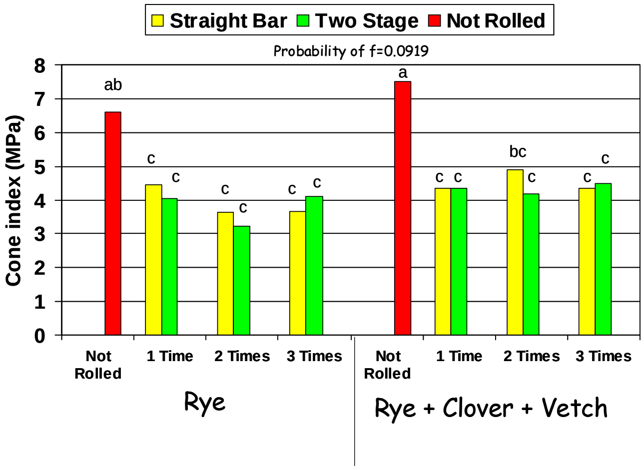

Figure 4. Soil Cone Index (CI) after rolling/crimping of both cover crops. Mean separation was performed using LSD (Fisher procedure) at α=0.1 significance level. Same letters indicate no statistical difference between all treatments (LSD=2.063 MPa)

Summary and Conclusion

1. Both roller types effectively terminated rye (> 90%) three weeks after rolling, which was above the recommended rye termination rates of 90% to plant a cash crop.
2. Rolling two or three times did not cause soil compaction, and rolled residue kept soil strength (Cone Index) significantly lower compared to standing cover crops.
3. Gravimetric soil water content after multiple rolling was significantly higher compared with standing rye and mixture covers. Multiple rolling can be beneficial for faster mechanical termination of single cover crops such as rye but not for mixtures. Mixtures which included hairy vetch, even after three rolling operations exhibited active growth two weeks after rolling.

Disclaimer:

*The use of trade names or company names does not imply endorsement by USDA-ARS.

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Satellite Mapping of Winter Biomass Distribution and Related Patterns in Soil Organic Carbon

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ABSTRACT

For years, winter cover crops have been used as a component of a reduced tillage and residue management system and hailed as conservation practice that improves soil quality through soil organic carbon accretion. Currently, rising fuel costs, high returns on winter wheat, and the demand for alternate energy crops make estimates of winter cover crop production a necessity. The objective of this study was to determine the accuracy of a satellite based method for predicting early spring winter biomass production.

To accomplish this task, 32 fields having a range in cultural practices were evaluated. Practices included: 1) conservation tillage in the form of strip tillage with winter rye (*Secale cereale* L., n = 38), winter wheat (*Triticum aestivum* L, n =30.) or weeds (n=10), and 2) conventional tillage (n=27) left fallow (Figure 1). The study area was located in the southern Coastal Plain of Georgia, proximate to the Little River Experimental Watershed near Tifton, GA. Soils classify primarily as fine-loamy, kaolinitic, thermic Plinthic Kandiudults, are grayish brown in color with loamy sand surface textures. To ensure a dynamic range in plant response potential, sample locations within each field were pre-selected using digital soil survey information and Landsat5 TM imagery collected during the 2007 growing season.

Satellite imagery for the current study was acquired via the Linear Imaging Self Scanner (LISS-3) 22 Feb. and 24 March 2008. Imagery has a spatial resolution of 23.5 m and acquires reflectance in four bands (0.52 – 1.70 μm). Two common vegetation indices, the normalized difference vegetation index (NDVI) and the greenness normalized difference vegetation index (GNDVI), as well as a middle infrared band (MIR) band ratio were calculated and used for statistical analysis (Table 1).

Ground truth data were collected proximate to each satellite acquisition as a measure of the winter cover crop at each of the pre-determined sample locations (n = 105). All samples consisted of a composite of five subsamples (with the exception of whole biomass, which was sampled discretely) within a 10 m radius of the sample point. Measurements included: above ground biomass (dry weight), leaf nitrogen content, plant height and gravimetric soil water content.

Preliminary analysis of ground truth variables indicate a strong correlation exists between plant attributes measured during sampling events one and two. Correlations ranged from r = 0.63 – 0.80 (alpha = 0.10) across all cover crop types. This relationship improved when cover crop types were analyzed discretely ranging from r = 0.51 – 0.92 for rye only. More importantly, remotely sensed data collected during the first sampling event was highly correlated with plant variables collected during the first and second sampling events, ranging from r =0.43 – 0.67

(alpha = 0.10). These relationships generally improved when the dataset was sorted by cover crop type as well.

A stepwise linear regression was used to evaluate the utility of using an early season image to predict winter cover crop biomass production, plant height and leaf N content using three remotely sensed vegetation indices. Winter biomass collected 24 March 2008 exhibited a strong linear correlation ($r^2 = 0.63$, alpha = 0.05) with vegetation indices calculated from the 22 Feb. 2008 image. When the data were sorted by cover crop this relationship improved for wheat only. Plant height and nitrogen content were best explained by vegetation indices when data were sorted by cover crop type, having coefficients of determination ranging from 0.25 – 0.83 and 0.30 – 0.32 for plant height and nitrogen content, respectively.

Data demonstrate the potential of satellite imagery to identify and forecast winter cover crop production in a southeastern Coastal Plain production system. Information from this study shows promise as a tool to develop estimates of potential feedstock for energy production from winter cover crops in a southeastern Coastal Plain watershed.

Table 1. Spectral specifications for the Linear Imaging Self Scanner 3 (LISS3).

Wavelength (µm)	Band	Spectrum Region
0.52 - 0.59	B2	Green
0.62 - 0.68	B3	Red
0.77 - 0.86	B4	Near Infrared
1.55 - 1.7	B5	Mid Infrared
	NDVI	(B5 -B3)/(B5+B3)
	GNDVI	(B5 -B2)/(B5+B2)
	MIR_{index}	B5/B3

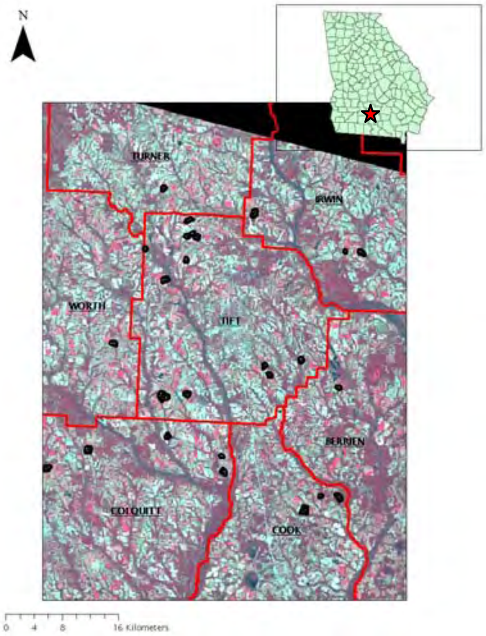

Figure 1. Site location map showing field boundaries county lines and state map inset.

Incorporating soil electric conductivity and optical sensing technology to develop a site-specific nitrogen application for corn in South Carolina

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Abstract

Development of variable nitrogen application in corn (*Zea mays* L.), based on soil electrical conductivity (EC) and optical-sensing technology, can help to improve nitrogen efficiency in corn, reduce the cost of applied fertilizer, and develop economically sustainable and environmentally sound corn production system for the southeastern Coastal Plain region. The long-term goal of this project is to develop procedures (algorithms) for site specific (variable-rate) application of nitrogen in corn production with the aim of increasing the farm sustainability and developing environmentally sound corn production system. The short-term objective is to determine the optimum nitrogen rates for corn in relation to optical sensing and soil spatial variability. The algorithm for variable N application in corn was originally developed at Oklahoma State University (OSU). However, due to high variability in soil type and texture, the OSU algorithm needs to be modified for Coastal Plain soils to account for these variations. During corn growth, a GreenSeeker™ optical sensor was used to measure the Normalized Difference Vegetation Index (NDVI). This information was correlated to soil EC measurements to help determine optimum side-dress N rates for corn production. The results from this preliminary study showed that there is a potential to use mid-season specific plant NDVI data for variable-rate application of N fertilizer for corn production in South Carolina. Also, the soil EC data need to be included in the N prediction equation for the Southeastern Coastal Plain region due to high soil variability and differences in crop productivity.

Introduction

Nitrogen is the most limiting nutrient for crop production (Fageria and Baligar, 2005) and has the greatest effect on grain yield (da Silva et al., 2005). Fageria and Baligar (2005) noted that crop response to applied N is an important criterion for evaluating crop N requirement for maximum economic yield. The management of N plays a key role in improving crop quality (Campbell et al., 1995) and optimal N management will be influenced by crop type and crop rotation (Grant et al., 2002). Previous research has shown that nitrogen (N) availability depends on seasonal changes in soil water content, temperature, soil structure, and organic matter distribution (Radke et al., 1985; Johnson and Lowery, 1985; Wagger, 1989; Ranells and Wagger, 1992). Fageria and Baligar (2005) stated that improving nitrogen use efficiency is desirable to improve crop yields, reduce cost of production, and maintain environmental quality.

Determination of the extent to which the crop will respond to additional N can help the growers to apply only what is needed. There have been numerous studies that showed high correlations between certain vegetation indices developed from spectral observations and plant stand parameters such as plant height, percent ground cover by vegetation, and plant population (Raun et al, 2005 and Stone et al., 1996). NDVI (Normalized Difference Vegetation Index) is used widely for mapping plant growth. NDVI is defined as (NIR - Red) / (NIR + Red). The Red and NIR values represent the reflectance in the Red and NIR bands, respectively. NDVI values range between –1 and +1 and higher positive values indicate increasing proportions of green vegetation. Researchers at Oklahoma State University have developed an algorithm for corn nitrogen fertilization based on optical sensors. The N fertilizer rates depends on making an in-season estimate of the potential or predicted yield, determining the yield response to additional nitrogen fertilizer, and finally calculating N required obtaining that additional yield (Raun et al, 2005). The results showed $36 to $39/acre profit in corn production while reducing N application rate by 45 to 70% compared to farmers practice. However, in the southeastern United States, due to high variability in soil texture, N is not uniformly utilized in the field, and application of N at one rate over the entire field is not cost effective and may decrease environmental quality.

Greater understanding of spatial-variability due to soil texture can help to obtain optimum yields for different soil zones. Standard procedures for N application on corn, based on soil spatial variability, are not available for the Coastal Plain soils. Therefore, there is a need to develop a site-specific N application based on soil spatial variability in order to decrease the cost and improve the profitability of farms in South Carolina, where corn is mostly grown under dryland conditions. A commercially available soil electrical conductivity (EC) measurement system (Veris Technologies 3100) can help to identify variations in soil texture across the field and create soil zone maps using global position system (GPS) and geographic information systems (GIS). This project will evaluate the effects of different soil zones (type and texture) on N use efficiency on corn production.

Methods and Materials

Tests were initiated in 2006 on Dothan loamy sand (fine loamy, kaolinitic, thermic Plinthic Kandiudult) at Clemson University's Edisto Research and Education Center (REC) near Blackville, SC. Prior to planting wheat as a cover crop in early December, the Veris soil electrical conductivity (EC) measurement system was used to identify variations in soil texture across the test field (Fig. 1).

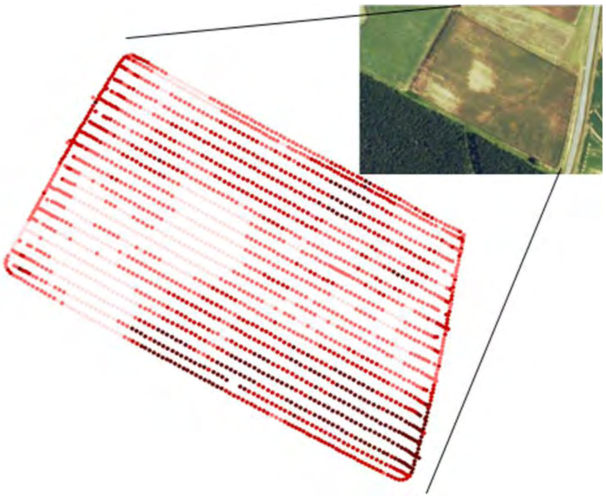

Fig. 1. Aerial image of the test field and soil electric conductivity (EC) map.

About two acres of the experimental area was divided into four different management zones using SSToollbox GIS software (SST Development Group, Inc, Stillwater, OK) based on the EC readings. Wheat cover crop was killed on 26 February 2007 and Pioneer 31G65 corn was planted at 28,000 seeds per acre using a one path strip-till planting system (Unverferth Mtg. Co., Inc., Falida, OH, and John Deere MaxEmerge Vaccum planters) on 14 March 2007. Nitrogen (25-S - liquid formulation of 25% nitrogen and 3.5% sulfur) was applied at planting at 0, 40, 80, 120 and 160 lb N/acre. Weed control was based on the South Carolina Extension recommendations. On 29 and 30 August, corn was harvested by hand and shelled using an Almaco small grain plot combine. Corn grain yield was adjusted to 15.5% moisture.

Plant Normalized Difference Vegetation Index (NDVI) was measured in each plot on 8 June using a GreenSeeker^{TM} Optical Sensor Unit (NTech Industries, Inc., Ukiah, CA). Previous research showed that NDVI is an excellent measure of plant growth and N requirements (Raun et al., 2005). In order to generate the algorithm, planting and emergence dates were recorded and used to compute the number of days from planting to sensing in each zone. For this method, we eliminated those days where Growing Degree Days (GDD) were equal or less than zero. The GDD values were calculated as: GDD = $[(T_{min} + T_{max})/2] - 50°F$; where T_{min} and T_{max} are the minimum and maximum temperatures, respectively. In Season Estimated Yield (INSEY), which is the Yield Goal with no added N, was calculated by dividing the plant NDVI by the number of days from planting to sensing (where GDD > 0). The Response Index (RI) was calculated by dividing the average NDVI readings from the high N plots by the average NDVI readings in the plots without N application. The predicted yield with added nitrogen (YP_N) was calculated as $YP_N = YP_0 * RI$, where the YP_0 is the predicted yield without added nitrogen. The predicted amount of N that is removed in the grain at harvest was computed for both YP_0 and YP_N by multiplying the grain yields by %N in the grain. The fertilizer N rate to be applied was computed by subtracting the predicted amount of grain nitrogen uptake in the YP_0 ($GNUP\_YP_0$) and YP_N ($GNUP\_YP_N$) and then divided the results by expected N use efficiency of 60%. The N use efficiency for corn may range from about 50 to 80%.

In 2008, we established corn plots at the Edisto and Pee Dee Agricultural Experiment Stations in Blackville and Florence, and six other corn producers from Orangeburg, Clarendon, and Sumter counties are cooperating in this project. All of these farms are located in the Coastal Plain region of South Carolina. These eight locations will help to develop algorithm for site-specific application of N fertilizer and improved nitrogen management system for corn.

The tests at Edisto REC (2007) were conducted utilizing a Randomized Complete Block design with four replications. Linear and non-linear regression models were used to determine the relationships present between corn yield, soil EC data, and NDVI using Procedures in SAS (SAS Inst., 1999). In addition, the relationship between actual corn yield and the In Season Estimated Yield (INSEY) was determined to develop an algorithm for N application. The INSEY was calculated by dividing NDVI by number of days from planting to sensing.

Results and Discussion

The established relationship between the harvested corn grain yields and In Season Estimated Yield (INSEY) shows a high correlation between yields and INSEY in this initial study (Fig. 2).

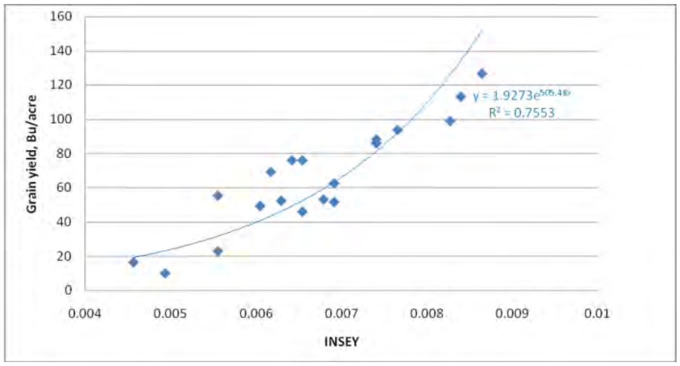

Fig. 2. Relationship between grain yields and In Season Estimated Yield (INSEY).

The INSEY index estimates the plant biomass produced per day when growth was possible. High correlations of early season NDVI readings with the plant biomass were also shown in the research conducted by Stone et al.

(1996). Additionally, Raun et al. (2002) showed that the plant NDVI readings and calculated INSEY can be used to predict corn yields. Our initial model will be used as a framework for developing the algorithm for corn producers in South Carolina.

The Response Index (RI) was calculated by deviding the average NDVI readings in plots with high N applications (0.6325) by the average NDVI readings in plots without N application (0.455). The RI value for the 2007 test was 1.39, indicating that we could likely achieve a 39% increase in yield if fertilizer N was applied. Additionally, we calculated the changes in potential yield of corn with additional N fertilizer (YP_N) by multiplying the yield without added N (YP_0) by Response Index (RI). (Fig. 3). The yield increase with additional N is limited to the maximum potential yield (YP_{MAX}).

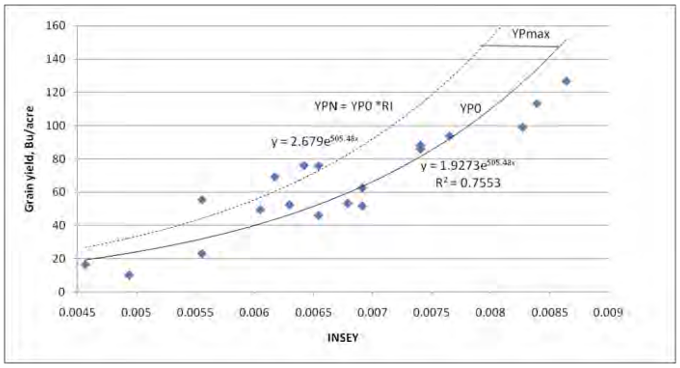

Fig. 3. The predicted yield potentials with N (YP_N) and without N application (YP_0). Yield increase with additional N is limited to the maximum potential yield (YP_{MAX})

The N recommendation was calculated by dividing the difference in grain N uptake of YP_N and YP_0 by the nitrogen use efficiency for corn (60%). Fig. 4 shows the predicted yields and calculated N rates. For example, for the 80 lbs/acre nitrogen applied at planting the average NDVI value measured 81 days after planting was 0.57. Using these numbers the calculated value of INSEY will be 0.007. The RI value for this location was 1.39 which can be used to predict yield potential with added N (YP_N) by multiplying the YP_0 by 1.39. The predicted yield potential (YP_N) should not exceed the maximum corn yield (YP_{MAX}) for a given region and management practices. In our case the YP_{MAX} was set at 150 Bu/acre for the “Savannah Valley Region” of South Carolina for dryland corn. Multiplying the YP_0 and YP_N values by 1.25% (percent of N in corn grain), we calculated N removals with corn grain. Based on the difference in grain removal and nitrogen use efficiency (60%), the fertilizer recommendation would be about 31 lbs N/acre for dryland corn under test field and rainfall conditions for 2007 growing season (dry year). Therefore, it is unlikely that corn would respond to significantly higher N fertilization rates in this location.

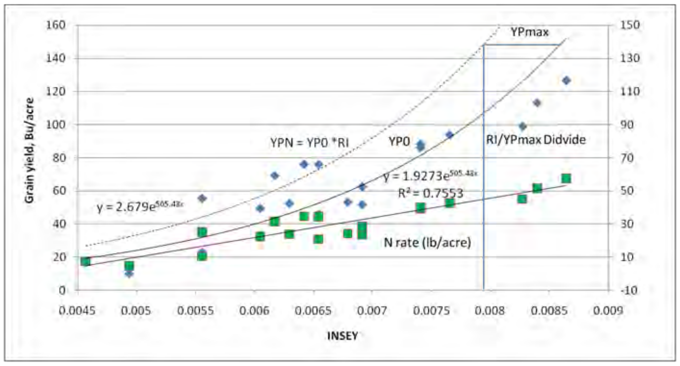

Fig. 4. The predicted yields and calculated N rates for corn experiments in 2007.

Considerable soil variation occurs within and across production fields in the Southeastern US which will have a major impact on fertilizer management strategies. Plant demand and response to N changes from year to year and mobile nutrients (such as N) are used, lost, and stored differently as soil texture varies. Therefore, the accuracy of the algorithm for predicting corn yield from INSEY values and recommended nitrogen prediction equation could be increased significantly by incorporating the soil electrical conductivity measurements into the yield-prediction algorithm (Fig. 5). The R^2 values significantly increased when different algorithm were developed for individual zones as determined by soil EC values.

The preliminary results show that different models (algorithms) could be developed for different soil zones. Work conducted by Khalilian et al. (2004) also showed strong correlations between soil EC maps and crop yield maps. In addition, EC values were strongly correlated with soil texture, water holding capacity, and plant vigor (Khalilian et al., 2007a and 2007b). Furthermore, the results showed that the soil EC data needs to be included in the N prediction equation for the Southeastern Coastal Plain region (Khalilian et al., 2008). Generally, soil EC data can be correlated to specific plant characteristics indicative of corn nitrogen requirements.

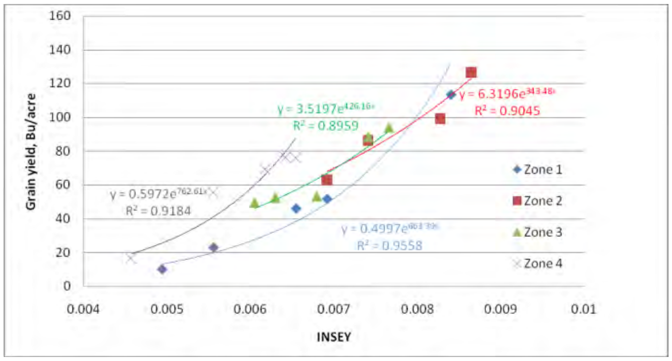

Fig. 5. Relationship between grain yields and In Season Estimated Yield (INSEY) for soil zones 1 (lowest electic conductivity) to 4 (highest electic conductivity).

Conclusion

The results from this preliminary study showed that there is a potential to use mid-season specific plant NDVI data for variable-rate application of N fertilizer for corn production in South Carolina. The Normalized Difference Vegetation Index (NDVI) measured during corn growth, using a GreenSeeker™ optical sensing technology, can be successfully correlated with corn grain yields to determine optimum side-dress N rates. However, the soil EC data need to be included in the N prediction equation for the Southeastern Coastal Plain region due to high soil variability and differences in crop productivity.

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Disclaimer

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Tillage and Timing of Bahiagrass Termination in a Sod Rotation for Peanut

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ABSTRACT

Intensive management of row crop agriculture has led to weathered soils and extensive inputs to prevent decline in productivity. Well managed rotations can have a positive impact on numerous aspects of production agriculture, and sod-based rotations for peanut have numerous advantages over standard rotations. This study was conducted to evaluate effect of tillage and timing of termination of bahiagrass in a sod rotation for peanut. Peanuts were planted into conventionally turned soil or strip-tilled into killed bahiagrass sod in 2006 and 2007. Termination of bahiagrass took place in either the fall or spring prior to the planting of peanut. Yields were not affected by when the bahiagrass was terminated, but peanuts in fall-killed bahiagrass had higher grade and stand (70.2 %TSMK; 4.5 seed/ft) than spring-killed bahiagrass (68.4 %TSMK; 3.9 seed/ft) in 2007. Conventional tillage resulted in higher yields (2006 = 6081 lb/ac; 2007 = 3623 lb/ac) and better stands (2006 = 5.2 seed/ft; 2007 = 4.6 seed/ft) than strip-till (2006 = 4950 lb/ac and 3.2 seed/ft; 2007 = 2807 lb/ac and 3.8 seed/ft) in both years. However, strip-tilled peanuts had higher grade (73.6 %TSMK) than conventional tillage (72.1 %TSMK) in 2006. Based on these results, there is slight favor in killing bahiagrass in the fall rather than in the spring, and conventional tillage has resulted in higher yields and stand. Further research is needed to improve stand and yield in strip-till management to garner its documented benefits.

Abbreviations: ai, active ingredient; TSMK, total sound mature kernels.

INTRODUCTION

There is growing interest in the sustainability of agricultural cropping systems. This is very true in the southeastern U.S. for peanut, where the majority of the U.S. crop is grown. Intensive management can be highly profitable in the short-term, but that can come at the expense of the environment and long-term profitability (Franzluebbers, 2007; Russelle et al., 2007). Soil health can diminish by means of erosion, depletion of nutrients and organic matter, loss of soil structure and tilth, and increase of pests like diseases, insects, nematodes, and weeds (Reeves, 1997). Improper crop rotation can single-handedly negatively impact all of these ecosystem factors. Conversely, adoption of good rotational practices can lead to increased yields (Godsey et al., 2007; Jordan et al., 2002; Katsvairo et al., 2007b; Lamb et al., 2007; Wright et al., 2007), improved soil conditions (Katsvairo et al., 2007a) and reduced erosion (Gantzer et al., 1990). It can also result in lower pest incidences (Brenneman et al., 2003; Tsigbey et al., 2007), and conservation of precious resources like water from improved soil moisture retention (Weil et al., 1993; Wilhelm et al., 2004) and strong root proliferation and penetration (Elkins et al., 1977; Long and Elkins, 1983).

Studies comparing sod-based rotations for peanut to standard cotton-peanut rotations have shown greater yields (Brenneman et al., 2003; Hagan et al., 2003; Katsvairo et al., 2007b) and profitability (Katsvairo et al., 2006), plus reduced incidence of tomato spotted wilt virus (TSWV) (Balkcom et al., 2007; Tsigbey et al., 2007) and improved root and soil conditions (Katsvairo et al., 2007a). However, planting peanuts into thick residue may have the potential for problems with stand establishment or emergence. The timing of termination of the preceding bahiagrass sod could have an effect on planting and emergence of peanuts since earlier termination would allow more time for bahiagrass stolons to decompose. Therefore, the objectives of this experiment were to evaluate peanut yield, grade, and stand in fall-killed and spring-killed bahiagrass in both conventional and strip-till management.

MATERIALS AND METHODS

This experiment took place at the University of Georgia Lang Farm in Tifton, GA. One field was established in bahiagrass in May 2004 and was planted to peanut on 24 May 2006. A second field was established in bahiagrass in November 2004 and was planted to peanut on 23 May 2007. The fall termination of bahiagrass took place on 12 November 2005 and 14 November 2006, respectively and the spring termination took place on 6 April 2006 and 11 April 2007, respectively. Bahiagrass was killed with 2 qts/ac of Roundup (ai = glyphosate). Additional weed control was achieved at peanut planting with 1 qt/ac Roundup, 1 qt/ac Prowl (ai = pendimethalin), 3 oz/ac Valor (ai = flumioxazin), and 0.45 oz/ac Strongarm (ai = diclosulam). Conventional tillage consisted of deep turning + disk prior to bedding. All plots were planted to ‘AP3’ peanut in single row pattern on 36 inch row spacing and a plant population of 87,120 seed/ac. Each plot consisted of six rows x 50 feet long. Routine maintenance of insects and diseases took place according to UGA Extension recommendations. The middle two rows of each plot were dug at optimum maturity as determined by pod blasting and profile board (Williams and Drexler, 1981). Pod weights were adjusted to 7% moisture for uniformity. Grades were determined by the method described by Davidson et al. (1982).

Statistical Analysis

Data were analyzed using MSTAT (Freed et al., 1987) statistical software. Analysis of variance was conducted to determine levels of significance and differences among treatment means were tested using Fisher's Protected Least Significant Difference Test (LSD) at $p \leq 0.05$ (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The timing of bahiagrass termination had no effect on pod yields (Table 1), which is similar to results reported by Zhao et al. (2007). However, unlike Zhao et al. (2007) but similar to Balkcom et al. (2007), there were significant differences between tillage effects, with strip-tilled peanuts yielding less than where conventional tillage had occurred in both years (Table 1). The final stand of peanuts likely played a major role in these yield differences, since conventionally tilled peanuts had more peanut plants at harvest than strip-till peanuts, and the strip-till plots were less than the target stand of four plants per foot of row in both years (Table 2). There was a difference in plant stand between the two termination timings in one of the two years, with a greater stand in fall-killed bahiagrass in 2007 (Table 2). Although yield differences were not detected, peanut grades followed the same treatment effect, with more total sound mature kernels (TSMK) coming from fall-killed bahiagrass in 2007 (Table 3). Despite lower yields in 2006, strip-tilled peanuts had a higher grade than conventional tillage peanuts (Table 3).

Recent reports have demonstrated reduced mechanical resistance through the soil profile when bahiagrass is terminated in fall compared to spring (Wright et al., 2006; Zhao et al., 2007). Less compacted soils may result in lower energy (and thus fuel) demand to pull implements through the soil. Earlier termination of bahiagrass would also allow more time for decomposition of root tissue, providing more root channels for the subsequent peanut crop to explore. The data from this experiment show direct improvement of stand and grade advantages in fall-killed bahiagrass compared to spring-killed, plus the aforementioned indirect benefits of fall-killing bahiagrass make it the wiser option in this system. In terms of tillage effect, conventional tillage has resulted in greater yields and stands than strip-till in the sod-based system. This is consistent with results by Balkcom et al. (2007), who also reported unfavorable economic returns in strip-tillage for the sod-based rotation for peanuts. Further studies are needed to investigate ways to make strip-till a more viable option in sod-based rotations to enhance the sustainability of this system.

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Table 1. Pod yield of peanut in a bahiagrass rotation as affected by kill timing and tillage.

	2006	2007
Kill Timing	------------- lb/ac ------------	
Fall Kill	5629 A	3276 A
Spring Kill	5402 A	3153 A
Tillage		
Conventional	6081 A	3623 A
Strip-Till	4950 B	2807 B

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$) according to Fisher's Protected Least Significant Difference Test.

Table 2. Plant stand at harvest in a bahiagrass rotation as affected by kill timing and tillage.

	2006	2007
Kill Timing	------ plants/ft of row -------	
Fall Kill	4.3 A	4.5 A
Spring Kill	4.1 A	3.9 B
Tillage		
Conventional	5.2 A	4.6 A
Strip-Till	3.2 B	3.8 B

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$) according to Fisher's Protected Least Significant Difference Test.

Table 3. Peanut grade in a bahiagrass rotation as affected by kill timing and tillage.

	2006	2007
Kill Timing	---------- % TSMK ----------	
Fall Kill	73.4 A	70.2 A
Spring Kill	72.4 A	68.4 B
Tillage		
Conventional	72.1 B	69.2 A
Strip-Till	73.6 A	69.4 A

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$) according to Fisher's Protected Least Significant Difference Test.

On-Farm Cost Analysis of Conservation Tillage Versus Conventional Tillage Peanuts in Creating Enterprise Budgets

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Summary: Georgia peanut farmers plant an estimated 175,000 acres of conservation tillage peanuts; with strip-tillage being the most popular method used. Often times, farmers want to know the economic costs and potential yields of a particular production practice before they make their planting decisions. The University of Georgia, Department of Agricultural and Applied Economics develops annual enterprise budgets to aid in this decision-making process. It is important to verify costs in the budgets with actual on-farm costs. During 2006, cost and yield data were collected on four farms in Pulaski County. All four farms were located within a one mile radius. Three farms used conservation tillage methods to produce peanuts, while one farm used conventional tillage methods. The UGA enterprise budget for irrigated, strip-tillage peanuts was considered comparable to actual on-farm operations and costs. Most significantly, the budget had higher chemical costs. Across farms, the conservation tillage farms had lower fixed costs than the conventional tillage farm. In addition, the conservation tillage farms had higher yields on average and therefore required a lower breakeven price to cover total costs.

NUTRIENT RELEASE RATES FROM ORGANIC MULCHES AND COVER CROPS

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ABSTRACT

Traditional organic vegetable production relies on tillage for weed control, but organic producers may adopt no-till if sufficient weed suppression can be achieved. A combination of high biomass cover crops with organic mulches may provide vegetable producers with multiple benefits, including improved weed control, but information on nutrient release from these residues is lacking. Information on the timely release of nutrients from organic residues will help producers make informed decisions regarding residue management, including adoption of conservation or conventional tillage. The objective of this study was to assess nutrient release rates and mass loss from organic residues (mimosa, lespedeza, straw, and soybean) under conventional and conservation tillage. The experiment used litterbag methodology and consists of a 2x4 factorial split plot design with four replicates. Nitrogen (N) and carbon (C) release and mass loss rates are presented. Buried residues decompose faster than surface residues; therefore more N is potentially available to spring crops from surface residues, which act as a slow release fertilizer, compared to incorporated residues. This study demonstrates that *in situ* cover crops and mulches may be utilized under conservation tillage for the enhancement of SOM and soil N status.

INTRODUCTION

Traditional organic vegetable production relies on tillage to achieve weed suppression, although other methods may be employed, such as flame weeding, hand weeding, etc. One alternative to tillage for weed control is the utilization of high biomass cover crops and organic mulches. Applied in sufficient quantities, high biomass residues, either grown as cover crops or applied as mulches, have been shown to suppress weeds, limit erosion and conserve soil moisture (Rathore et al., 1998).

Under conservation tillage, mulches are left on the soil surface, whereas a conventional tillage system may incorporate mulches at the end of the season. The two systems can be expected to release nutrients from organic residues at different rates, and thereby affect the soil nutrient status for succeeding crops. Nutrient release rates from organic mulches and cover crops need to be determined in order to optimize synchronicity with nutrient uptake by succeeding crops.

Previous work has demonstrated the feasibility of high biomass cover crop mulches under no-tillage production systems. No-till, herbicide-free broccoli production under high biomass cover crops was shown to produce similar yields compared to conventional tillage without a cover crop in Maryland and Virginia (Abdul-Baki et al., 1997). Such a system could achieve even greater weed suppression by using high biomass cover crops, such as forage soybean (*Glycine max L.*), in conjunction with organic mulches. Mulches may be grown *in situ* in order to minimize transportation costs. These mulches could be obtained from invasive species already present in the production area, such as lespedeza (*Sericea lespedeza*) and mimosa (*Albizia julibrissin*) cuttings, and utilized as mulch material before seeds become viable.

The objective of this study was to quantify mass loss and nutrient release rates from decomposing organic residues under conservation and conventional tillage. Information on timely release of nutrients from organic residues will help producers make informed decisions regarding residue management, including the adoption of conservation or conventional tillage.

MATERIALS AND METHODS

A field decomposition study is being conducted at the E.V. Smith Research Center Plant Breeding Unit (32.488ºN, 85.888ºW, 213 feet elevation) in S. Tallassee, AL on a Wickham fine sandy loam, 0 to 2 percent slopes (Fine-loamy, mixed, semiactive, thermic Typic Hapludults). Four organic residues, lespedeza, mimosa, oat (*Avena sativa*) straw, and soybean (*Glycine max* var. Stonewall, group VII) were obtained locally to supply residue. Air-dried residues were packed into nylon mesh bags measuring 7.87 by 3.94 inches with 0.00197 to 0.00236 inch openings at a rate equivalent to 3.0 tons ac^{-1} (0.4744 ounces per bag) on an air-dry basis.

Sealed litterbags were placed on the soil surface or buried at four inches depth on Oct. 9, 2007. The site was maintained under no-till for at least three years prior to placement. Conventional till plots were disked immediately before placement. The treatments were arranged in a randomized split-plot design with four replicates. Bags were retrieved from the field periodically at 0, 3.5, 7, 14, 28, 56, 112, and 224 days after application. The contents of each bag were oven-dried and weighed for dry matter determination. They were then ground to pass a 16 mesh sieve and analyzed for total C and N by LECO TruSpec CN (Leco Corp, St. Joseph, MI). Sample contamination by soil was accounted for by converting all data to an ash-free dry weight basis by ashing approximately 0.035 ounces of the samples in muffle furnace at 752^{o}F for 12 h and determining the ash free dry weight (Cochran, 1991).

Means, standard errors, and statistical significance of treatments were determined using Proc Mixed (SAS Institute Inc., 2003) at the 95% confidence level. Least squares estimates for nonlinear models were determined using four parameter double exponential decay models (Systat Software Inc., 2006).

RESULTS AND DISCUSSION

Decomposition of organic residue occurs in two phases. Initially, a labile portion of the residue, such as sugars, starches and proteins, is readily consumed by soil microbes, leaving behind a recalcitrant portion of the residue, such as cellulose, fats, waxes, lignin and tannins (Wieder and Lang, 1982). This recalcitrant portion is slowly decomposed and contributes to the development of organic matter in soil. Such a system is best described by double exponential decay models, with one exponential segment describing the labile portion and the other exponential segment describing the recalcitrant portion of the residue (Wieder and Lang, 1982). The double exponential decay model is represented by $Y = Ae^{-k_1 t} + Be^{-k_2 t}$, where Y = the nutrient or mass remaining, A = the labile portion, B = the recalcitrant portion, k_1 and k_2 are rate constants fitted to the data, and t = time in days after application. This model serves as the basis for comparison of N, C, and mass loss between conservation and conventional tillage in this study.

Mass loss from organic residues under conservation and conventional tillage is shown in Figure 1. Buried residue generally exhibits faster mass loss in both the labile and recalcitrant portions of all residues, as shown by the greater rate constants k_1 and k_2 for buried material compared to surface residue (Table 1).

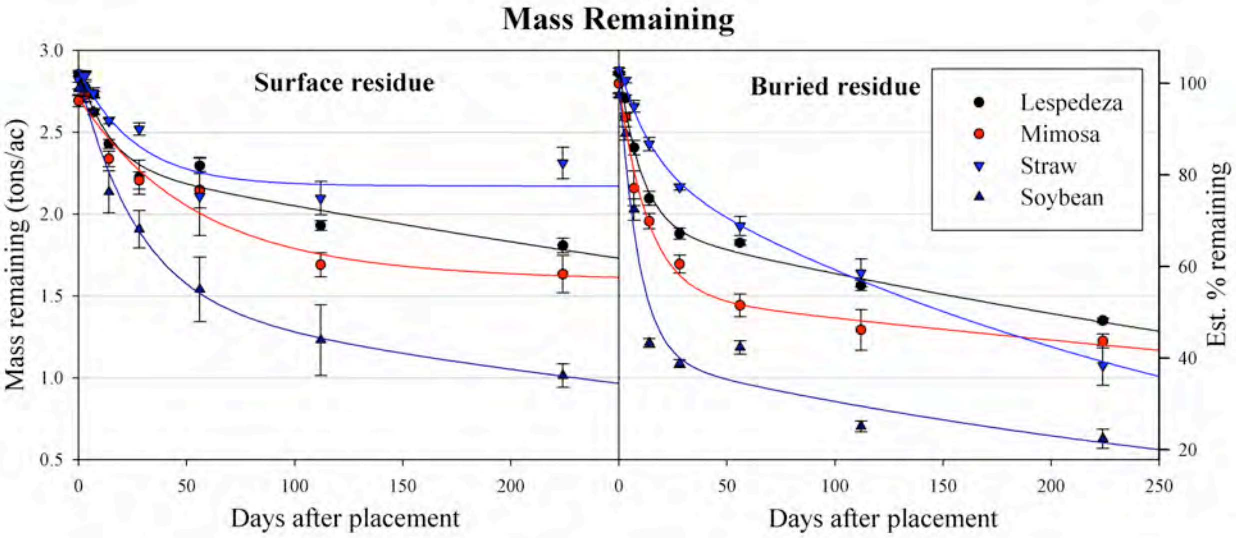

Figure 1. Mass loss from surface and buried residue on an oven dried basis. Residues were placed at an equivalent rate of 3.0 tons ac^{-1} on an air dried basis. The second Y axis represents the estimated percent mass remaining, with 100% representing the average mass of all oven dried residues at day = 0. Error bars represent standard errors of the mean.

Table 1. Double exponential decay coefficients obtained for surface and buried residue for the model $Y = Ae^{-k_1 t} + Be^{-k_2 t}$, where Y = mass or the nutrient loss, A = the labile portion, B = the recalcitrant portion, k_1 and k_2 are rate constants fitted to the data, and t = time in days after application.

Surface residue

	Mass (tons/ac)				N (lbs/ac)				C (lbs/ac)			
Coeff.	Lespedeza	Mimosa	Straw	Soybean	Lespedeza	Mimosa	Straw	Soybean	Lespedeza	Mimosa	Straw	Soybean
A	2.30	1.07	2.18	1.48	71.9	131.0	22.0	98.9	221	2052	625	1109
k_1	0.0011	0.019	4.26E-12	0.0017	0.0010	0.0005	2.18E-12	0.015	0.094	0.002	0.0164	0.0018
B	0.59	1.65	0.72	1.37	42.3	11.7	3.27	63.2	2125	237	1572	980
k_2	0.072	0.0001	0.038	0.037	0.0010	0.17	11.10	2.87E-13	0.0019	0.0486	8.95E-12	0.0277
Adj R^2	0.93	0.93	0.82	0.98	0.71	0.05	0.00	0.93	0.88	0.91	0.93	0.97
Buried residue												
A	1.92	1.51	2.31	1.13	106.6	37.81	-6.04	93.0	634	1540	2018	950
k_1	0.0016	0.001	0.0033	0.0028	0.0021	0.28	0.048	0.088	0.11	0.0028	0.0045	0.0041
B	0.98	1.28	0.60	1.71	13.0	116.4	27.28	68.1	1734	832	201	1171
k_2	0.097	0.075	0.068	0.11	0.12	0.0023	0.0012	0.0033	0.0026	0.096	0.091	0.12
Adj R^2	0.99	0.98	1.00	0.93	0.88	0.85	0.00	0.91	0.98	1.00	0.98	0.93

Nitrogen loss from organic residues under conservation and conventional tillage is shown in Figure 2. Buried residue generally exhibits faster N loss in both the labile and recalcitrant portions of all residues. This is evidenced by the greater rate constants k_1 and k_2 for buried material compared to surface residue (Table 1), though notable rate constant exceptions exist in cases where the curve fit (Adj. R^2) is exceptionally low, such as in the case of straw, which has a very low original N content and negligible labile N pool. For residues with a high N content, there is considerably more N potentially available to a spring crop from surface residue than buried residue. For example, at planting on May 1 (day 204), there is approximately 33 lbs ac^{-1} more N potentially available from surface soybean residue than incorporated soybean residue. Upon mineralization, N is subject to the competing processes of nitrification, immobilization, plant uptake, ammonium fixation, and volatilization. This study does not determine the fate of the lost N (i.e., the proportion mineralized, immobilized, etc.).

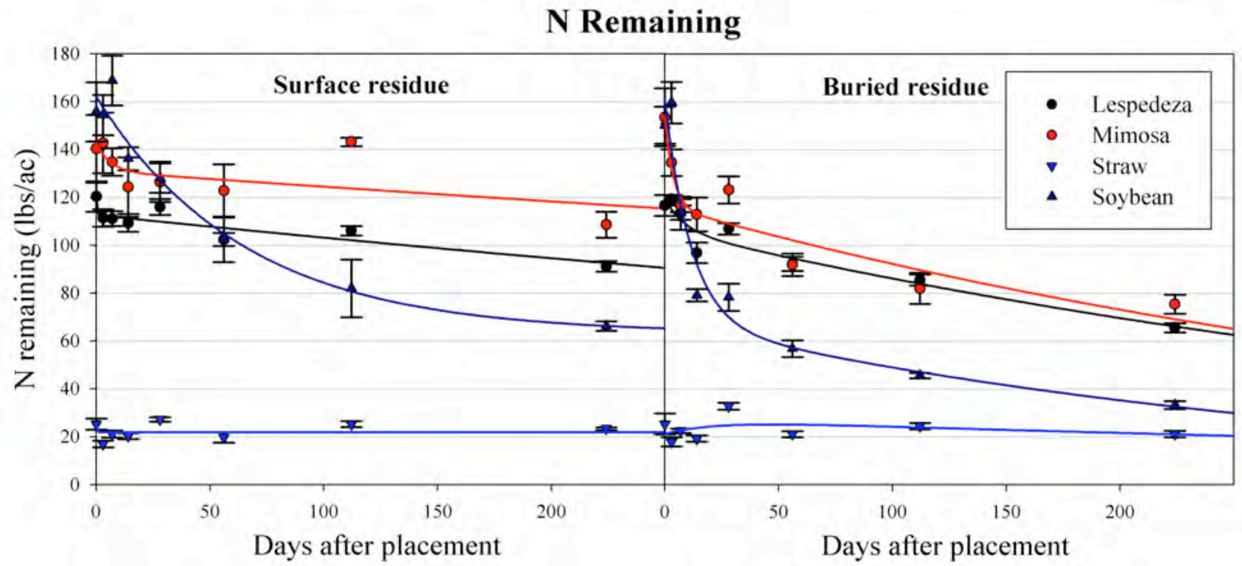

Figure 2. Nitrogen loss from surface and buried residue. Error bars represent standard errors of the mean.

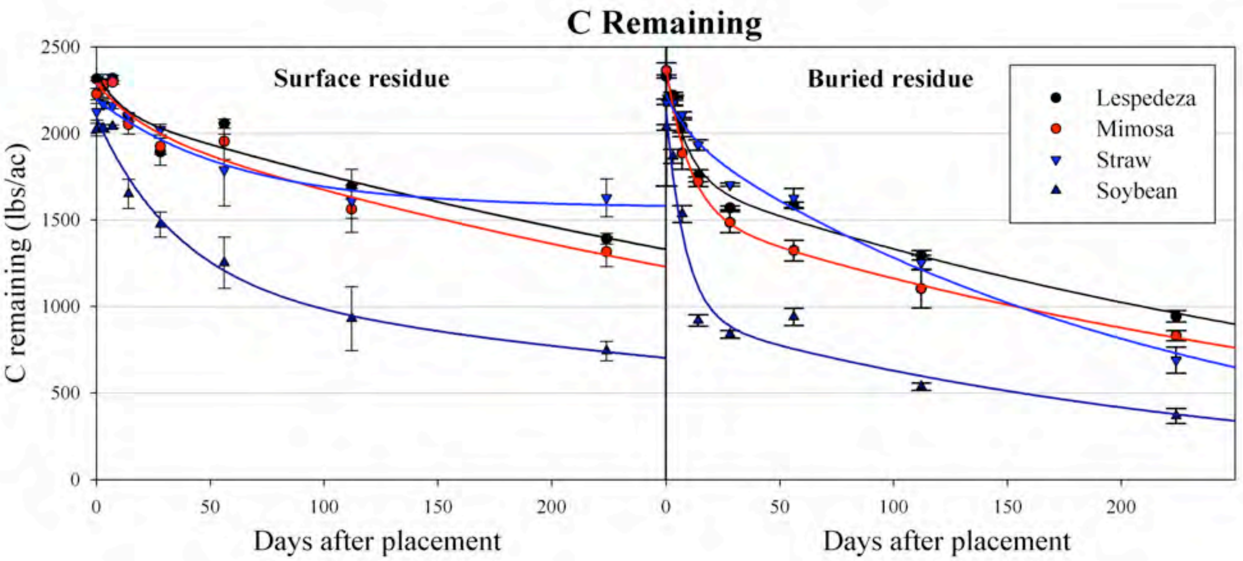

Figure 3. Carbon loss from surface and buried residue. Error bars represent standard errors of the mean.

Carbon loss from organic residues under conservation and conventional tillage is shown in Figure 3. Buried C loss models appear similar to buried mass loss models (Figure 1) because most mass loss is due to the respiration of C, which is then lost to the environment as CO_2. Buried residue exhibits faster C loss in both the labile and recalcitrant portions of all residues, as shown by the greater rate constants k_1 and k_2 for buried material compared to surface residue (Table 1). Carbon is therefore sequestered longer when residue is left on the surface compared to residue incorporation. This should result in greater soil organic matter (SOM) accumulation from surface residue over time. On a more speculative note, in an age when producers may be compelled to participate in a C market, conservation tillage practices may provide producers with a C offset or credit, while also enhancing SOM.

CONCLUSIONS

Buried residues decompose faster and release C and N quicker than surface residues. A winter cover crop may be able to recapture some of the N lost from buried residues in order to make it potentially available to spring crops. However, surface residues with a high N content retain N longer, and may provide more potentially available N to spring crops than buried residues. As such, surface residues may act as a slow release N fertilizer and contribute to organic matter accumulation on the soil surface. This study demonstrates that *in situ* cover crops and mulches may be utilized for the enhancement of SOM and soil N status. Further studies need to be conducted in order to determine the mineralized fraction of N lost from residues.

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UTILIZATION OF MULCHES INCREASE YIELD AND IMPROVE WEED CONTROL IN NO-TILL ORGANIC BROCCOLI

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ABSTRACT

Weeds are a major limiting factor in organic vegetable production systems. The objective of this study was to determine the effects of mulch, cover crop, and tillage on weed control and yield of organic broccoli. The trial was conducted during 2005 and 2006. The experiment was a split plot with four replications, where tillage (conventional or no-till) was the main plot, cover crop [pearl millet (*Pennisetum glaucum*), cowpea (*Vigna unguiculata*), or soy bean (*Glycine max*)] was the subplot, and mulch (black plastic film, wheat straw, and unmulched) was the sub-sub plot. The cover crops were sown in the summer of 2005 and the broccoli plants were grown in the spring of 2006. Weed control over the season was 82% and 74% for the conventional tillage and no-till, respectively. Among cover crops, pearl millet provided the highest weed control and cowpea the lowest. Wheat straw and plastic film mulch both had higher levels of weed control compared to unmulched soil. Broccoli top biomass was higher in conventional tillage than in no-till, it was not affected by cover crop, and it was highest in plastic mulch and lowest in bare soil. Total marketable yield was not affected by tillage or cover crop. Broccoli yields were lowest in unmulched soil. Weed control was the main factor that explained the increased yields of plants grown on mulches.

Key words: weed control, sustainable agriculture, mulches, no-till, organic agriculture

INTRODUCTION

Weeds are a major limiting factor in the production of organic vegetables, as shown by a survey of organic growers in the U.S.A. (Waltz, 1999). Weeds compete with the crop for water, light, and mineral nutrients and thus they may significantly reduce the growth and yield of the crops. This detrimental effect of the weeds on the crop is particularly considerable when weeds are not controlled on time. The methods of organic weed control include mechanical control, manual control, chemical control, and cultural control by utilizing mulches, which involve the use of organic mulches, cover crops, or plastic film mulches (Abdul-Baki and Teasdale, 1993; Lamont, 1994; Ngouajio, 2005; Phatak and Diaz-Perez, 2007; Snapp et al., 2005).

Small scale growers often use manual control and mechanical control to manage weeds, while larger growers utilize a diversity of weed control strategies. In industrialized countries, like the U.S., there is a tendency to more utilization of mechanical, cultural and chemical weed control methods because manual control is expensive due to the high labor costs, in addition to the increasing difficulty in finding farm workers.

Cover crops provide ample benefits, such as, erosion reduction, improvement of soil structure, increased soil organic matter, and reduction in the pressure by insect pests and plant pathogens (Díaz-Pérez et al., 2008; Phatak and Díaz-Pérez, 2007; Snapp et al., 2005). Cover crops in combination with reduced tillage, and the utilization of appropriate cultivars and planting dates can result in reduced incidences of insects, pathogens, nematodes, and weeds (Phatak and Díaz-Pérez, 2007).

There are relatively few studies on the effects of cover crops in combination with conservation tillage in organic vegetable production (Abdul-Baki et al., 1996; Morse, 1999; Teasdale et al., 1991). The objective of this study was to determine the effects of integrating the utilization of mulching, cover crops, and tillage on weed control and yield of organic broccoli.

MATERIALS AND METHODS

The study was conducted at the Horticulture Farm, Tifton Campus, University of Georgia, during 2005 and 2006. The experimental design was a split plot with four replications, where the main plot was tillage (conventional and no-till), the sub-plot was the cover crop [pearl millet (*Pennisetum glaucum*), cowpea (*Vigna unguiculata*), or soy bean (*Glycine max*)], and the sub-sub-plot was mulching (wheat straw, black plastic mulch, or unmulched). Wheat straw mulch was applied using one bail per 20-ft long bed section (6.2 ton/acre).

The cover crops were sown on July 2005 and were allowed to develop until they were destroyed by a frost in November of 2005. In 2006, two weeks prior to planting the broccoli to the field on 8 Mar., the residues of the cover crops were mowed with a flail mower.

The soil of the experimental site was fertilized with a total of 6.7 t/ha (5,982 lb/acre) of organic fertilizer (4N: $2P_2O_5$: $3K_2O$; MicroSTART 60, Perdue AgriRecycle, LLC, Delamarva, Delaware, EE.UU.) one week prior to transplanting the broccoli. Broccoli transplants (‘Packman’) were produced organically utilizing a substrate based on peat moss and was fertilized (1 part of organic fertilizer and 9 parts of substrate) with the MicroSTART 60 organic fertilizer.

Broccoli (‘Packman’) plants were planted at a 30-cm (12-inch) distance between plants within the rows, having two rows of plants per bed. Plot length was 20 ft. The distance from the center to the center of the beds was 180 cm (6-ft). The broccoli crop was drip-irrigated, with the drip tape being midway between the two rows of each bed. Due to the low incidences of insect pests and diseases, no insecticides or fungicides were applied. Broccoli plants were harvested several times from 29 Apr. to 23 May. 2006

The level of weed control obtained by the different treatments was determined visually, where 0% control represented total soil surface being covered by weeds, and 100% control was when total soil surface was weed free.

RESULTS AND DISCUSSION

Weed control

The percentages of weed control were 82% and 74% under conventional tillage and no-till, respectively. During the first weeks after transplanting the broccoli, the residue from the cover crops provided partial weed control. As the season progressed, the cover crop residues were gradually broken down and, consequently, the ability of the cover crop residues to control weeds was reduced. Among the cover crops, pearl millet provided the highest weed control (85%), followed by soy bean (76%), while cowpea (72%) provided the lowest weed control. At the end of the broccoli season, the amount of cover crop residue (dry weight) present on the soil surface was 3.6 ton/acre (pearl millet), 1.4 ton/acre (cowpea), and 0.7 ton/acre (soybean). The residue from pearl millet was the most persistent in the field, probably because grasses generally have a lower C/N ratio than legumes, and low C/N ratios result in reduced microbial activities in the soil. Among mulching treatments, wheat straw mulch and black plastic mulch provided higher percentages of weed control (94% and 89%, respectively) compared to unmulched soil (51%). The difference in weed control between wheat straw mulch and black plastic mulch was not significant.

Insect pests

The populations of insect pests were low, although there was an increment in the number of larvae of diamondback moth (*Plutella xylostella*) at the end of the broccoli growing season. There were no differences in the number of diamondback moth larvae among treatments.

Broccoli crop biomass

The aerial biomass of broccoli plants was higher under conventional tillage [127 g/plant (0.28 lb/plant)] than under no-till [111 g/plant (0.24 lb/plant)], and it was not affected by the type of cover crop used prior to planting the broccoli. Aerial biomass was highest in broccoli plants on black plastic mulch [130 g/plant (0.29 lb/plant)], followed by wheat straw mulch [120 g/plant (0.26 lb/plant)], and lowest in plants on unmulched soil [107 g/plant (0.24 lb/plant)]. This reduction in top growth was due, at least partially to the increased weed pressure in unmulched soil.

Yield

Marketable broccoli yield was unaffected by tillage and cover crop treatments, although it was affected by mulching. Broccoli yields were lowest in unmulched soils [3,123 kg/ha (2,788 lb/acre)], followed by soils covered with black plastic mulch [4,036 kg/ha (3,604 lb/acre)] and wheat straw mulch [4,684 kg/ha (4,182 lb/acre)]. The yield increase in plants on mulches was attributed to the increased levels of weed control obtained by the use of mulches.

CONCLUSIONS

- The level of weed control was the most important factor determining broccoli yield.
- Under no-till, the residue from the cover crop that preceded broccoli provided only a partial weed control.
- Utilization of either wheat straw mulch or plastic film mulch resulted in reduced weed populations both, in conventional tillage and in no-till systems.

- Weed control in no-till and reduced-till vegetable production systems may be improved by the use of either organic or inorganic mulches.

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Impacts of strip-tillage on herbicide loss from a Coastal Plain Soil

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Abstract

Because conservation tillage practices like strip-till commonly increase infiltration, they have the potential to increase agrichemical leaching and contribute to unforeseen impacts on water quality in landscapes where rates of lateral subsurface drainage (LSF) are high. The later is the case in much of the Coastal Plain. To answer this and other questions related to hydrologic and water quality responses to conservation-tillage during cotton and peanut production in the region, we began a long-term field study in 1999. Losses of two herbicides fluometuron and pendimethalin are reported as a function of tillage for the first 8-years of the study. When combined losses (surface and LSF) were evaluated ST was shown to consistently reduce off-site discharge of both compounds. However, ST did contribute to increased fluometuron LSF loss. Results showed that this transport pathway should be included when comparing potential water quality impacts of ST and other tillage systems.

Introduction and Methods

Over the past ten years we have produced cotton and peanut in rotation under strip- (ST) and conventional-tillage (CT) management and examined losses of water, nutrients and selected pesticides in surface runoff and subsurface drainage (LSF) at a study site in Tift County Georgia. In this report we focus on surface runoff and LSF losses of the herbicides fluometuron and pendimethalin. Commercially available formulations Cotoran 4L (fluometuron) and Prowl 3.3 EC (pendimethalin) were used and applied at label recommended rates. Prowl was applied preemergence to all crops except to peanut in 2004. Cotoran was tank-mixed with Prowl during applications to cotton. The 2001 cotton crop also received a post-directed Cotoran application. Crops, dates of planting, and harvest and herbicide applications are summarized in Table 1.

Table 1. Crops, planting and harvest dates and fluometuron and pendimethalin applications during 1999-2006.[†]

					herbicide applications (lb acre^{-1})	
year	crop	plant	harvest	date	fluometuron	pendimethalin
1999	cotton	6-May	16-Sept	6-May	1.0	0.4
2000	cotton	1-May	11-Sept	1-May	1.0	0.8
2001	cotton	7-May	5-Oct	7-May	1.0	0.8
				18-June	1.25	not applied
2002	peanut	10-May	10-Sept	10-May	not applied	1.0
2003	cotton	12-May	22-Oct	12-May	1.0	0.8
2004	peanut	10-May	15-Sept	10-May	not applied	not applied
2005	cotton	23-May	1-Nov	23-May	1.0	0.8
2006	peanut	16-May	27-Sept	16-may	not applied	1.0

[†] harvest date for cotton was date of machine picking and for peanut date of digging.

Research plots and tillage practices were established in 1999 at the University of Georgia Gibbs Farm. The soil is in the Tifton series with 3 to 4% slope. Fig.1 shows key features of the experimental setup.

The three ½ acre plots on the south side of the study area have been maintained continuously in ST and the three on the north in CT. During construction, plots were bermed to direct runoff to H-flumes installed at downslope corners. The flumes were used to measure runoff volume during each event and to collect water samples for nutrient and pesticide monitoring. LSF volumes were measured and water samples collected for analysis from H-flumes installed on outlets of 6-in tile drains installed at the downslope edges of each tillage block. An inceptor drain was installed at the upslope edge of the plots to direct upgradient LSF flow away from the study area. All herbicide residue analyses made in our laboratory used solid-phase extraction combined with high performance liquid chromatography-mass spectrometry (HPLC-MS) techniques.

Results and Discussion

Runoff, LSF, sediment, and the amount of each herbicide lost are summarized in Table 2.

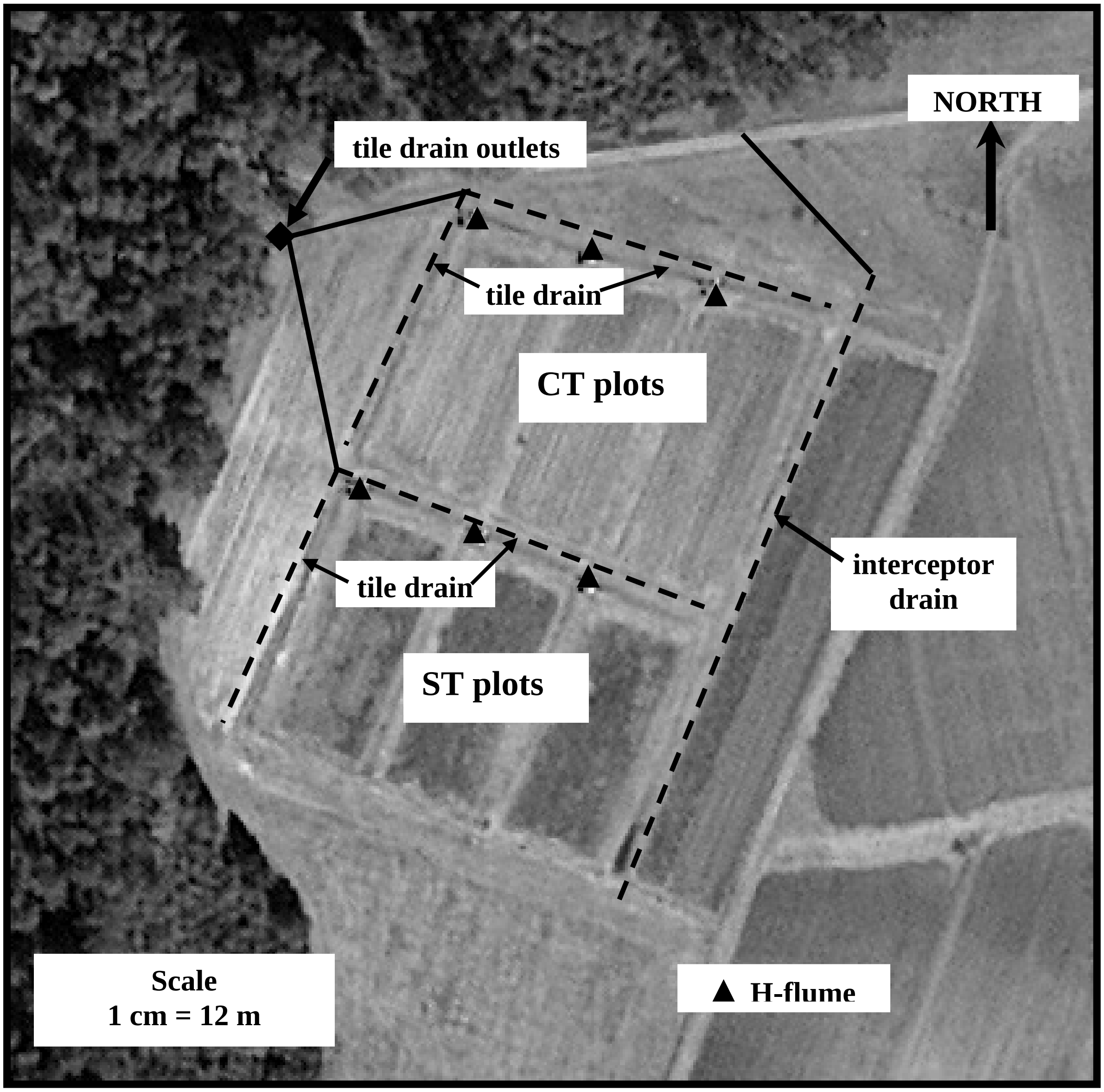
Table: 8-year summary (1999-2006) of runoff, LSF, sediment, fluometuron and pendimethalin losses.†

parameter	ST	CT
surface runoff (% rainfall + irrigation)	14	22
LSF (% rainfall + irrigation)	18	10
sediment (tons acre^{-1})	1.3	6.4
runoff fluometuron (% of applied)	0.2	0.8
LSF fluometuron (% of applied)	0.2	0.1
runoff pendimethalin (% of applied)	0.03	0.5
LSF pendimethalin (% of applied)	<0.01	<0.01

† fluometuron reported as sum of parent compound and its degradate desmethylfluometuron (DMF).

Results showed that ST when compared to CT decreased surface runoff volume by about 40% and that LSF volume from the ST-system was increased proportionally. On balance the amount of rainfall and irrigation lost from both systems was nearly equal (26-28 % of the total). The increased LSF from the ST-system doubled fluometuron loss. This compound and its degradate (DMF) are prone to leaching due to relatively high water solubility and low binding potential to soil. In the case of runoff, there was 4-fold greater fluometuron loss from the CT versus the ST-system primarily due to the CT-system's increased runoff volume. Pendimethalin was not detected in any of the LSF samples with estimated losses <0.01% of applied for both tillage systems. In contrast, runoff losses were much greater (about 16-fold) with the CT versus ST system. Pendimethalin's behavior is explained by its low leaching potential and tendency for transport with eroded sediment. As indicated the CT-system sediment loss was nearly 5-fold greater than the ST-system.

Figure 1. Study site features.



In summary, monitoring over 8-years showed that the net amount of water lost from both the ST- and CT-systems was about equal (about 25% of rainfall plus irrigation) with the ST-system exhibiting greater LSF and CT greater surface runoff. From a water quality perspective, the ST-system was clearly superior to the CT-system when combined (runoff and LSF) losses of the two herbicides were evaluated (Table 3). Finally results showed that LSF loss of herbicides like fluometuron which are prone to leaching may be increased in LSF, thus when tillage systems are evaluated this transport pathway should be taken into account.

Table 3. Combined (runoff and LSF) losses (% of applied) of fluometuron and pendimethalin.

Compound	ST	CT
fluometuron	0.4	0.8
pendimethalin	0.03	0.5

Increasing Farm Sustainability through the Use of Cover Crops for Weed Suppression in Non-Transgenic Conventional Cotton

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Introduction:

Increasing sustainability of farm operations will require that natural means of weed suppression be incorporated into the farming operation. One alternative is the proper use of cover crops. Cover crops not only supply nutrients (e.g. legumes fix nitrogen and cereal crops recycle nutrients), but also break pest cycles, provide needed soil organic matter, increase available water, and help suppress weeds. Proper use of cover crops may not totally eliminate the use of chemicals, but any reductions will lower the overhead and maintenance cost incurred by the farmer.

Transgenic cotton including the Round-up Ready varieties first appeared in 1997 and now occupies approximately 90% of the cotton planted in Georgia and the other southern states (Steve Brown, 2003). Within Georgia alone reduced tillage systems are used on approximately 600,000 acres. There is concern that continued reliance on RR cotton will continue to promote the spread of weed species with resistance to glyphosate (actual Round-Up chemical). Resistant weed species may require potentially more toxic herbicides to be used or growers will have to revert back to using plowing methods as a means of weed control. Either method of weed control will be detrimental in making these southern farms sustainable systems. Therefore the farmer needs an alternative method of weed control other than transgenic cotton varieties which relies or encourages over use of glyphosate.

Objectives:

To demonstrate that a Black Oat cover crop can be used and how effective the cover is in suppressing weed pressure in a conservation tillage system. Additionally the research will compare yield and quality differences in non-GMO modified and GMO cotton.

Materials and Methods:

The research objective as stated above was to use Black Oats as a cover crop to suppress weed pressure in conservation tillage systems. The plots were divided into seven treatments across three farms. To complete the objective stated above, the project was divided into three different parts: 1) planting Black Oats as a winter cover crop, 2) monitoring and measuring weed populations in the treatments during cotton production season, and 3) harvest and compare yields of cotton from each treatment.

Planting of cover crop:

The black oats were planted as soon as possible after the previous commercial crop was harvested. Planting of cover crops for both study years was middle to late November. The oats were planted at a rate of approximately 1 bushel per acre across all treatments. No irrigation was used to establish the stand in that there was ample moisture both years to get a good stand of

Black Oats. Nitrogen fertilizer was used in the second growing season to try and increase the cover crop biomass.

Monitoring and measuring weed biomass:

Monitoring and measuring weed biomass was facilitated by dividing each treatment into three sections to be used as replications of the treatment. Weed populations were measured every other week from planting to either harvest or a point where the farmer decided that no yield was possible. To ensure that sample collection was not biased due to the amount of weeds, a random grid was established prior to the first sampling date and was maintained through out the growing season. To better accomplish this, each replication within each treatment was divided into 10 blocks and 9 sections within each block. The weeds were sampled by locating the randomly selected Block and Section, standing at the corner of the section and tossing a 1/10th square meter square into the section. The number of weeds were then counted and noted. This was repeated in all selected Blocks and Sections. The same random numbers were used for all treatments for a given date. If the 1/10th square meter was completely filled with a weed a value of 50 was entered, otherwise the number of weeds was entered based on the number of stems not vines.

Harvest and compare yields from each treatment:

During harvest of the cotton, the replications were harvested separately, weighted and a sample collected for quality analysis. The weights were measured through the use of scales placed under the wheels and tongue of a boll buggy. The analysis consisted of the standard tests (i.e. Gin turnout, mic, elongation, strength, uniformity, length, rd, b, and color grade).

Results and Discussion:

Monitoring and measuring weed biomass:

The weed population varied from treatment to treatment with a significant difference in only one treatment across years. This treatment was the no-herbicide treatment on the farm that had been using the conservation tillage system for ten plus years. In the first year of the study, the number of weeds was no different from that of the farm using round-up ready cotton, but was significantly different from the farm that had only been using conservation tillage with weeds as a cover crop. The weeds that were present in the first year on the T4 and T5 farm was mainly pigweed with some morning glory and grass. In the second year grass formed a complete mat even prior to the cotton emerging in the Treatment 5 plot. It can be seen in Figure 1 that the number of weeds is shown as 500 per m^2 in T5, but most of that was grass that covered the whole sampling area and the 50 per 1/10th square meter was noted so as to not overpower the other data on the graph. Likewise, on T1, T2 and T3 for both years the weeds were hard to control and a majority of the weeds were pigweed. The farmer in year one mowed the plots once he decided he had lost the complete crop and in the second year, we stopped the test at a point that he determined the amount of pigweed specifically had reached a point that the yield from any one of the plots would be less than the cost of harvesting the cotton, so he again mowed the plots prior to us knowing he had mowed them.

Overall, the T1, T2 and T3 plots that had winter weeds as a cover crop prior to planting a commercial crop, even with the addition of black oats for two years, were hard to manage and ultimately resulted in the test being so overcome with weeds that the harvest would have cost more than the return from the sale of the cotton. The major weed in both years in the control, no

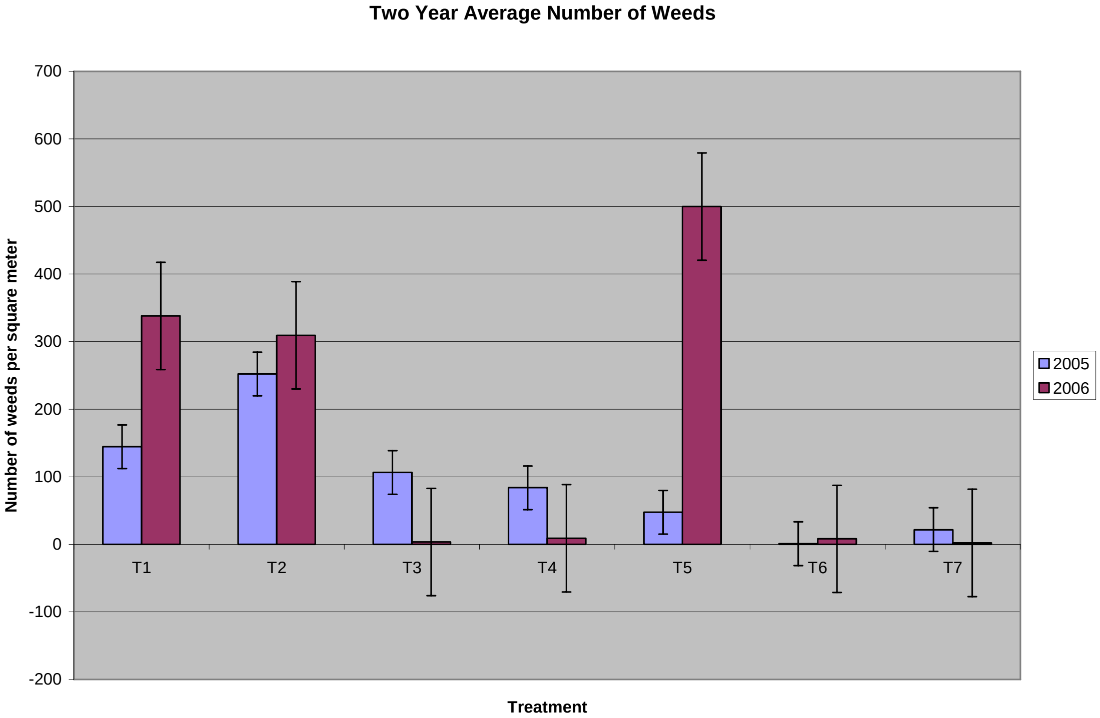

Figure 1. Weed population per square meter in given treatment. The T5 treatment had complete coverage of grass across the entire treatment area, so a count of 500 indicates complete coverage.

herbicide use and a threshold application was pigweed with some morning glory and grasses. With the reduced herbicide application, the soil system was not able to suppress the weeds and some of the pigweed reached heights of at least 6 feet and had diameters at the soil surface of approximately 3 inches. This made it impossible for the cotton to grow and the cotton picker to pass through the plots. In T4 and T5, the continual use of conservation tillage with high biomass at time of planting appears to have had some impact on the suppression of weeds. The fact that in the second year of T5 the grass overtook the plots can not be explained by the research team. However, T4 performed as well as T6 and T7, which used a cover crop and round-up ready cotton seed, on suppressing the weed population.

Harvest and compare yields from each treatment:

The average lint yields from each treatment can be seen in Figure 2. As can be seen, the regular use of herbicides on T4 helped the plants yield more than T5. Both treatments were planted on land that had been in conservation tillage for ten plus years and the use of herbicides, the older chemistry in this case, has a significant difference on the yield. These chemicals allow the planting of conventional non-transgenic cotton, but still require a regular spray pattern. It was also suggested by the County Extension Agent and co-project director that the use of a pre-emergence herbicide can have large benefits on controlling and suppressing weeds, thereby reducing the amount of herbicides needed in the growing season. The lint yield in the

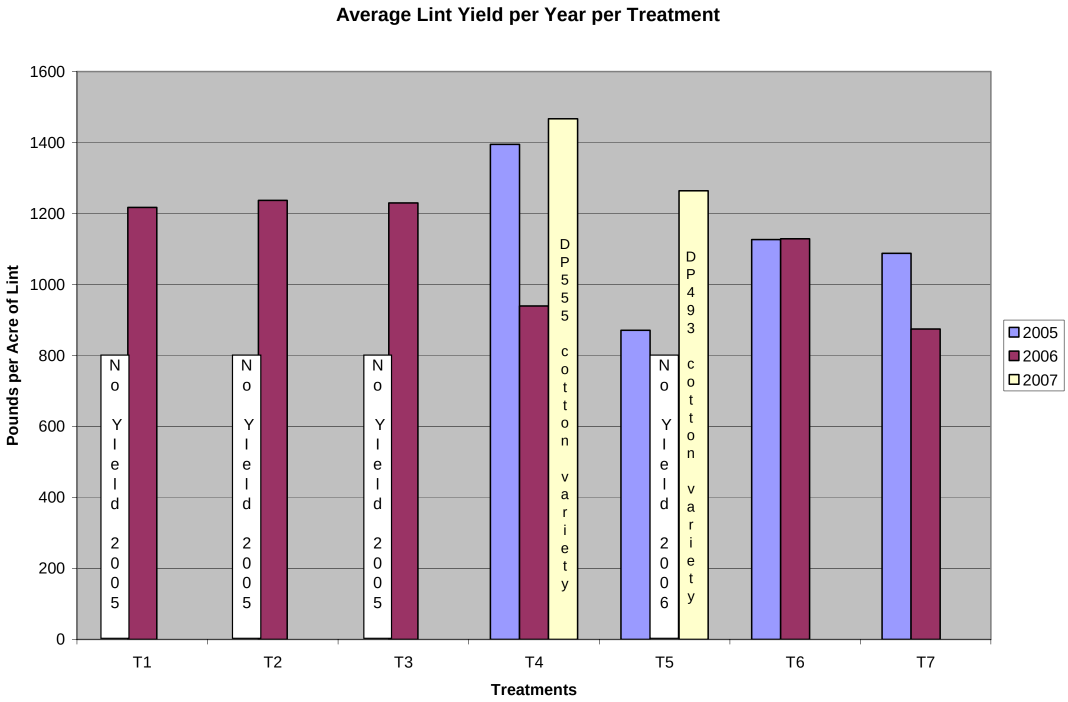

Figure 2. Lint yields from all treatments for two years of study. A third year was conducted on one of the study field s (yellow bars on T4 and T5).

conventional cotton (DP493[1]) was not significantly different from that of the genetically modified cotton (DP555[1]).

This equal or greater lint yield is good for the farmer in that the yield is just as high, the cost of the herbicide may not be different, but the seed for the genetically modified seed at the time this was written was as high as 5 times more per bag than the conventional seed. This would lead to potentially being a larger profit or less out of pocket costs for the farmer. However, our cooperating seed dealer stated that the amount of conventional seed was low to non-existent in 2007 and is expected to be that way in the future.

When comparing the cotton quality parameters there was no significant difference across any treatment for either year as can be seen in Figure 3. This shows that the farmer will and does not loose quality when planting conventional cotton verses the transgenic cotton.

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[1] The use of specific cotton seed does not in any way suggest that The University of Georgia promotes or specifically endorses this specific product. The product was used in the study and the use of names is only supplied for purposes of reporting data.

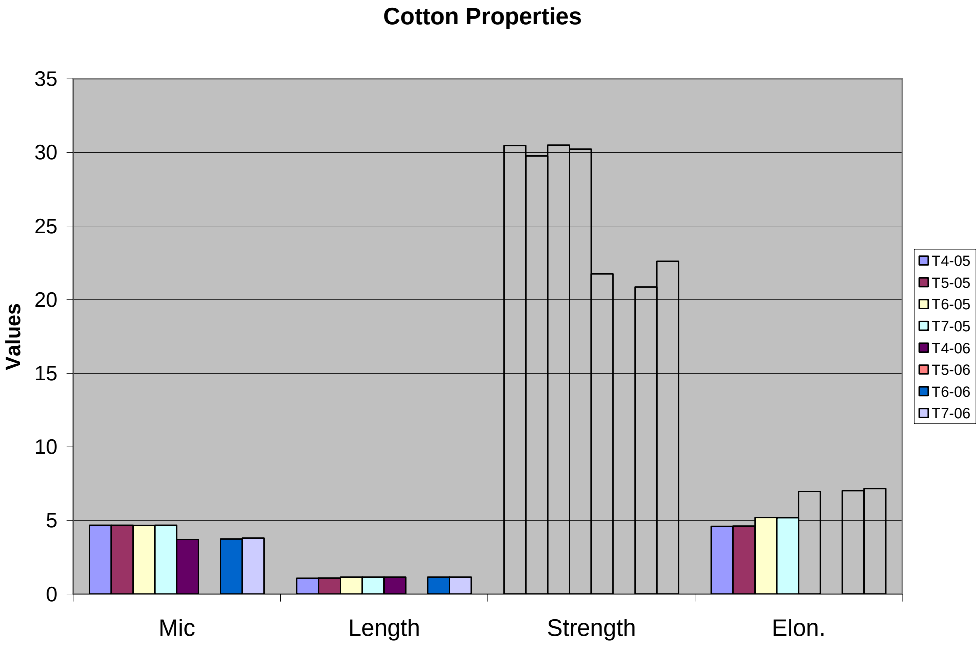

Figure 3. Cotton quality parameters of collected cotton samples from both years of study.

Conclusions

The data indicates that the use of cover crops in conservation tillage systems has an affect on the suppression of weed growth. The yields collected during this research were similar in plots that used conventional cotton seed as compared to Round-Up ready cotton variety seed. The cotton quality was also similar and showed no difference between seed varieties as well as across years. Therefore, to assist in reducing the potential spread of resistant weeds, the use of conventional cotton with "old chemistry' technology may need to be further explored. However, it has been suggested by some seed distributors that the availability of conventional seed are I short supply. The use of conventional seed and chemistry needs to be further researched and if the results are similar to that shown here, the use of conventional seed could prove more sustainable for the farmer in conservation tillage systems as well as provide a means to help suppress the chemical resistant weeds.

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Planting and Termination Dates Affect Winter Cover Crop Biomass in a Conservation-Tillage Corn-Cotton Rotation: Implications for Weed Control and Yield

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Abstract

Use of the winter cover crops is an integral component of the conservation systems in corn (Zea mays L.) and cotton (*Gossypium hirsutum* L.). A field experiment was initiated in 2004 to evaluate weed suppression provided by winter cover crops in a conservation tillage corn and cotton rotation. Rotation for winter cover crops included clover (*Trifolium incarnatum* L.) preceding corn and rye (*Secale cereale* L.) preceding cotton. The winter cover crops were planted at five different planting dates based on thirty year average historical air temperature. Winter cover crop termination dates in the spring were 4, 3, 2 and 1 week prior to cash crop planting, also based on thirty year average historical soil temperature. Results showed a dramatic impact on biomass production with even a week's delay in winter cover crop planting and corresponding reduction in summer annual weed suppression. More than ten times difference in biomass produced by clover was observed at all the locations, when clover was planted on the earliest and terminated on last date compared to late planting and early termination. Rye produced almost eight times or more biomass in the same comparison. Weed biomass was 1551 kg ha^{-1} corresponding to rye biomass of only 274 kg ha^{-1} at Shorter in 2004. Weed populations in corn were low compared to cotton at all site years but weed control was not as predictable as in cotton. The data for the corn grain and cotton lint yield showed no significant relationship between cover crop biomass and the cash crop yield.

Introduction

Use of conservation tillage systems for cotton and corn production has become increasingly popular in the last two decades primarily to address concerns of decreasing air and water quality and soil productivity. Use of high residue cover crops is an integral component of conservation tillage systems. Cover crop residue provides soil with a cover which plays a vital role in reducing erosion, improving infiltration, soil moisture retention, carbon sequestration, increasing soil organic matter and nutrient recycling (Blevins et al. 1971; Bradley 1995; Kaspar et al. 2001).

Effective weed management throughout the growing season is a critical component in cotton production. Cotton can not compete effectively with weeds early in the season and presence of weeds late in the season can reduce the harvest efficiency and adversely impact lint quality. Approximately 90% of the cotton grown in United States in 2001 received herbicides (Anonymous 2002). Development of herbicide resistant weed species and shift in the weed populations are the results of such extensive chemical control. Practical alternatives to the intensive herbicides use in cotton offers potential economical as well as environmental benefits.

Winter cover crops also play an important role in weed suppression. Weed control by cover crops use is gaining more importance in today's conservation tillage systems since several weed species are acquiring resistance to herbicides. Previous research has shown that early season weed control by cover crops in conservation tillage systems is comparable to chemical control (Teasdale and Mohler, 1992; Johnson et. al. 1992). The degree of weed control provided by a cover crop depends on the management strategies. Living mulch cover crops suppress weeds by competition and by changing the light transmittance and soil temperature regimes (Teasdale and Dughtry, 1993). When killed, cover crop residues act as a physical barrier and create conditions difficult for weed seeds to emerge and establish. Previous research has shown that cover crops also suppress weeds through chemical allelopathic effects; however, field activity has not been widely documented due to difficulty of isolating the allelopathic effects from the physical mulch effects in field situations (Inderjit et al. 2001; Putnam et al. 1983).

Cereal rye (*Secale cereale* L.) and soft red winter wheat (*Triticum aestivum* L.) are the two most common winter cover crops recommended for cotton production in the southeastern United States. Both have been shown to possess allelopathic activity against weeds (Akemo et al., 2000; Perez and Ormeno-Nunez, 1991). Black oat (*Avena strigosa* Schreb.) has recently been introduced in the southeastern U.S. through a joint release between Auburn University and The Institute of Agronomy of Paraná, Brazil, and is currently marketed as "SoilSaver black oat" (Bauer and Reeves 1999). Recent research by Price et al. (2006) and Reeves et al. (2005) evaluated black oat as compared to rye and wheat in conservation-tillage cotton and soybean. Results showed that black oat biomass and weed suppressive potential is comparable to rye and greater than wheat, allowing for reduced herbicide input. Crimson clover, Austrian winter peas (*Pisum sativus* subsp. a*rvense*) and hairy vetch (*Vicia villosa* Roth) are the recommended cover crops for corn and they have also been shown to possess allelopathic activity (Stoll et al 2006).

Crop rotation is also an important for cotton production in the southeast since continuous cotton production causes many problems including increased soil borne pathogen populations. Lack of herbicide chemistry rotation also results in increased number of resistant weed species. Crop rotation can be an effective tool in reducing the buildup of problematic weeds thereby keeping their population under control. Using crop rotations with an effective herbicide program can help alleviate these problems. Rotations with corn are typical, due to the lower production costs, ease of production, and because corn is a non-host to many cotton pathogens.

Although weed control benefits associated with cover crops can be improved by increasing the amount of residue in the field, this can also result in some negative effects. High residue can interfere with cash crop establishment and can also deplete soil moisture (Teasdale, 1993). The dense residue can also lead to a decrease in soil temperature which can severely impact the cash crop yield. Therefore having an optimum amount of residue on the soil is maximizing the benefits of cover crops.

Historically, cover crop planting and termination have occurred at the discretion of growers' schedules and weather conditions. Research has shown that a winter cover's planting date and termination date has influence on both quality and quantity of residue production, and hence may affect subsequent weed suppression. A field study was conducted to determine optimum dates for planting and terminating cover crops so as to maximize biomass production and soil coverage, early season annual weed suppression, and cash crop yield.

Materials and Methods

Field experiments were conducted from autumn of 2003 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center at Shorter, Al and Tennessee Valley Research and Extension Centers at Belle Mina, AL through corn harvest in 2006. An experiment was also conducted at the University of Florida's West Florida Education and Research Center at Jay, FL from autumn of 2004 to corn harvest in 2006. The soil types were Compass loamy sand (coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults) at E.V. Smith, Decatur silty loam (fine, kaolinitic, thermic, Rhodic Paleudult) at Tennessee Valley and Dothan sandy loam (Fine-loamy, siliceous, thermic Plinthic Kandiudults) at Jay Florida. The experimental design was a randomized complete block with three replicates having a split block restriction on randomization. Each plot had four rows of corn or cotton and both phases of the rotation were present each year.

The experiment involved two cover crops: rye preceding cotton and clover preceding corn rotated annually at each site. We examined five different planting dates and four different termination dates. Horizontal strips consisted of five cover planting dates and vertical strips consisted of four cover termination dates. Both covers were established with a no-till drill at 2 and 4 week prior to, 2 and 4 week after the 30 year average date of the first 0 C freeze. The rye seeding rate was 41 kg ha^{-1} and 56 kg of nitrogen (N) as ammonium nitrate was applied to rye in fall after establishment. The clover seeding rate was 11.4 kg ha^{-1}.

In the spring, covers were terminated at 4, 3, 2, and 1 week prior to cash crop planting with glyphosate at 1.12 kg ae ha^{-1} plus 2,4-D amine (0.20 kg ai ha^{-1}) utilizing a compressed CO_2 backpack sprayer delivering 140 L ha^{-1} at 147 kPa. Rye was flattened prior to glyphosate application with a mechanical roller-crimper to form a dense residue mat on the soil surface. Cover biomass from each plot was measured immediately before termination. The above-ground portion of rye and clover was clipped from one randomly-selected 0.25-m^2 section in each plot, dried at 60^0 C for 72 hours, and weighed.

The cotton varieties DP 444 BG/RR, ST 5242 BR and DP555BRR were planted at E.V. Smith, Tennessee Valley and Jay Florida, respectively. The corn variety Dekalb 69-72RR was planted at all the locations. Cash crops were planted with a four-row planter equipped with row cleaners and double-disk openers. Since both the E.V. Smith and West Florida sites had a well-developed hardpan, the experimental areas were in-row subsoiled prior to planting with a narrow-shanked parabolic subsoiler, equipped with pneumatic tires to close the subsoil channel. Weed biomass was determined in two 0.25-m^2 sections as described above when cotton reached the 4-leaf and corn reached 8-leaf growth stages. At this stage glyphosate was applied at 1.12 kg a.e. ha^{-1}. Plots were then kept weed-free until harvest utilizing Alabama Cooperative Extension System recommended herbicide applications. Though evaluations also included soil coverage by cover, cash crop stand establishment and height, and cash crop yield, in this paper we are only reporting the weed suppression provided by the two covers.

Results and Discussion

Different weather conditions encountered at the three locations resulted in large differences in biomass production. Maximum clover biomass production (5447 kg ha^{-1}) was observed at Shorter, AL in 2005 when crimson clover was seeded four weeks prior to the average first day of a 0 C freeze and terminated four weeks prior to planting the cash crop corn. The least biomass production

(0.72 kg ha^{-1}) was observed at Belle-Mina, AL in 2004 when the clover was seeded at the last establishment date (4-wk post 0 C freeze) and terminated four weeks prior to corn planting. Clover however suffered severe winter damage at Belle-Mina in 2004 and the biomass production was significantly low compared to other locations. At the southernmost location Jay, maximum clover biomass (1566.33 kg ha $^{-1}$) was produced when clover was planted four weeks prior to 0 C freeze and terminated three weeks prior to cash crop planting in year 2006.The lowest clover biomass observed at this location was 78 kg ha^{-1} in 2005 (Table 1).

Rye biomass was maximum (10953 kg ha $^{-1}$) in year 2004 at Belle-Mina when covers were planted on the first planting date and terminated only a week prior to the cash crop cotton planting. Biomass production was in general less at this location in other two years. At shorter the maximum biomass production was 8522.67 kg ha $^{-1}$ in year 2006 when rye planted two weeks before 0C freeze and terminated a week prior to cash crop planting. The lowest biomass produced at Shorter was 140 kg ha $^{-1}$ when covers were planted on the last planting date and terminated on the first planting date. At our southernmost location (Jay), rye biomass production was better in 2006 compared to 2005. Maximum observed rye biomass at this location was 7468 kg ha $^{-1}$ when rye was planted four weeks prior to 0 C freeze and terminated two weeks before the seeding of cotton (Table 3).

Weed control in corn was not as predictable as it was in cotton. Dry weights of weeds were however low in corn compared to cotton at all site years. This is likely due to the earlier sampling time in corn when fewer summer annual weeds have emerged. The cover crop biomass observed at these locations can explain some of the results observed for weed control. The lowest biomass observed was 0.67 Kg ha $^{-1}$ corresponding to clover biomass of 2453 kg ha $^{-1}$ at Shorter in 2006. Maximum weed biomass (407.33 kg ha $^{-1}$) in corn was observed at Belle-Mina in 2006 corresponding to clover biomass of 405.33 kg ha $^{-1}$ (Table 2).

In general, there was an increase in weed biomass in cotton with earlier termination and late planting of the rye cover crop. Maximum weed dry biomass observed was 1551.33 kg ha^{-1} corresponding to rye biomass of only 274.67 kg ha $^{-1}$ in 2004 at Shorter (Table 4). Less weed dry biomass was observed corresponding to a high rye cover crop residue. Our observations of decrease in weed biomass by corresponding increase in cover crop biomass agree with other research findings (Teasdale et al. 1991). Yenish et al. (1996) also reported better early season weed control by crimson clover than rye in no till systems.

None of the winter cover crop planting or winter cover crop termination dates had any effect on the establishment of the two cash crops through the heavy residue (data not shown). As the cash crop stands were not affected by the presence of the heavy winter cover crop residue on plots with earlier planting and later termination dates, there was no significant difference in the cotton lint and corn grain yields.

Conclusion

In general, winter cover crop biomass increased with the earlier planting and later termination and weed biomass decreased with increasing biomass. Observations indicate that high cover biomass should decrease early season weed interference and facilitate flexibility of POST application timing.

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Table 1: Effect of planting dates (PD) and termination dates (TD) on crimson clover biomass (kg ha $^{-1}$)

Planting Date	Termination Date	2004		2005			2006		
		Shorter	Belle Mina	Shorter	Belle Mina	Jay	Shorter	Belle Mina	Jay
PD 1	TD 4	821.33	4002.67	4910.67	1662.67	869.333	5002.67	3210.67	2756
PD 1	TD 3	1856.00	2841.33	4284.00	2204.00	461.333	4424.00	1965.33	2792
PD 1	TD 2	2877.33	2380.00	4358.67	2049.33	394.667	4942.67	1253.33	1566.77
PD 1	TD 1	1678.67	2221.33	5446.67	1796.00	677.333	3674.67	1186.67	1378.67
PD 2	TD 4	2944.00	2648.00	4710.67	2020.00	864.000	4701.33	1636.00	1510.68
PD 2	TD 3	1265.33	1432.00	3584.00	2928.00	336.000	4306.67	2085.33	1066.66
PD 2	TD 2	3032.00	1042.67	3722.67	2410.67	289.333	3954.67	2020.00	836
PD 2	TD 1	1297.33	616.00	3289.33	1985.33	381.333	2777.33	1272.00	502.66
PD 3	TD 4	980.00	830.67	1424.00	896.00	357.333	2496.00	1084.00	906.66
PD 3	TD 3	2037.33	822.67	1478.67	1133.33	149.333	1881.33	962.67	522.66
PD 3	TD 2	1409.33	462.67	612.00	917.33	152.000	2024.00	576.00	265.33
PD 3	TD 1	465.33	300.00	728.00	834.67	260.000	1429.33	405.33	164
PD 4	TD 4	2606.67	510.67	449.33	394.67	156.000	1153.33	588.00	358.66
PD 4	TD 3	1068.00	364.00	537.33	320.00	76.000	848.00	513.33	200
PD 4	TD 2	320.00	212.00	249.33	152.00	90.667	724.00	237.33	158.66
PD 4	TD 1	1288.00	128.00	198.67	184.00	89.333	496.00	185.33	102.67
PD 5	TD 4	1946.67	190.67	246.67	102.67	122.667	781.33	96.00	189.33
PD 5	TD 3	350.67	118.67	141.33	233.33	64.000	465.33	130.67	141.33
PD 5	TD 2	818.67	64.00	120.00	66.67	78.667	300.00	77.33	112
PD 5	TD 1	538.67	0.72	1149.33	82.67	93.333	152.00	34.67	84

Std Err = 441.44

Table 2: Effect of planting dates (PD) and termination dates (TD) on weed biomass (kg ha $^{-1}$) in corn

Planting Date	Termination Date	2004		2005			2006		
		Shorter	Belle Mina	Shorter	Belle Mina	Jay	Shorter	Belle Mina	Jay
PD 1	TD 4	30.00	64.67	24.67	32.67	27.33	4.67	10.00	10.67
PD 1	TD 3	16.00	59.33	85.33	17.33	21.33	0.67	18.00	35.33
PD 1	TD 2	6.67	108.00	33.33	17.33	22.00	2.00	77.33	16.67
PD 1	TD 1	50.67	93.33	104.67	42.00	33.33	57.33	340.00	250.00
PD 2	TD 4	19.33	69.33	90.67	10.00	104.67	4.67	37.33	85.33
PD 2	TD 3	22.67	74.00	124.00	34.67	28.00	2.67	18.67	8.67
PD 2	TD 2	12.67	142.67	78.67	153.33	66.67	12.67	216.00	52.67
PD 2	TD 1	56.00	126.67	188.00	44.67	87.33	51.33	203.33	84.00
PD 3	TD 4	31.33	134.00	89.33	184.67	34.67	15.33	123.33	34.00
PD 3	TD 3	191.33	182.67	198.00	24.00	22.00	10.00	75.33	17.33
PD 3	TD 2	79.33	170.00	140.00	299.33	28.67	46.00	152.00	43.33
PD 3	TD 1	29.33	131.33	117.33	161.33	83.33	126.00	407.33	44.67
PD 4	TD 4	45.33	108.67	66.67	427.49	23.33	21.33	75.33	33.33
PD 4	TD 3	48.67	185.33	89.33	73.85	12.00	19.33	150.00	411.33
PD 4	TD 2	126.00	172.00	86.00	177.33	102.00	35.33	196.67	35.33
PD 4	TD 1	78.67	145.33	117.33	4.67	74.00	323.33	262.67	89.33
PD 5	TD 4	72.00	282.67	144.67	129.33	33.33	143.33	118.00	255.33
PD 5	TD 3	100.00	188.67	84.00	62.00	29.54	50.00	102.67	31.33
PD 5	TD 2	115.33	118.00	46.67	156.67	51.33	60.00	154.00	61.33
PD 5	TD 1	147.33	159.33	182.67	192.67	107.33	177.33	339.33	306.00

Std Err = 62.89

Table 3: Effect of planting dates (PD) and termination dates (TD) on rye biomass (kg ha^{-1})

Planting Date	Termination Date	2004		2005			2006		
		Shorter	**Belle Mina**	**Shorter**	**Belle Mina**	**Jay**	**Shorter**	**Belle Mina**	**Jay**
PD 1	TD 4	4506.67	10953.33	5234.67	6734.67	3713.33	6252.00	7942.67	5333.33
PD 1	TD 3	7534.67	10277.33	4960.00	6680.00	4273.33	6549.33	5520.00	7468.00
PD 1	TD 2	6800.00	8545.33	5690.67	3772.00	3876.00	6904.00	7465.33	4174.67
PD 1	TD 1	3421.33	5737.33	5438.67	3061.33	2557.33	5002.67	4656.00	3049.33
PD 2	TD 4	5488.00	8997.33	4678.67	8741.33	2566.67	8522.67	5166.67	6500.00
PD 2	TD 3	6157.33	9369.33	6374.67	5709.33	4556.00	6532.00	4356.00	6370.67
PD 2	TD 2	5733.33	7086.67	5024.00	4418.67	2964.00	5670.67	4169.33	5358.67
PD 2	TD 1	2833.33	5953.33	3496.00	2060.00	1842.67	4349.33	2620.00	3134.67
PD 3	TD 4	4888.00	8933.33	2477.33	3496.00	3478.67	8053.33	3554.67	5806.67
PD 3	TD 3	4850.67	6706.67	3344.00	3349.33	3078.67	5224.00	2644.00	5249.33
PD 3	TD 2	5765.33	5744.00	2584.00	2692.00	2122.67	4681.33	1896.00	4497.33
PD 3	TD 1	1873.33	4950.67	2033.33	1913.33	1554.67	3529.33	1822.67	3226.67
PD 4	TD 4	3024.00	6934.67	745.33	3254.16	1674.67	2554.67	4336.00	3926.67
PD 4	TD 3	3616.00	3710.67	533.33	2200.00	1957.33	2880.00	4074.67	4301.33
PD 4	TD 2	3693.33	3517.33	488.00	1749.33	1576.00	3012.00	2248.00	3222.67
PD 4	TD 1	784.00	3836.00	304.00	1117.33	1540.00	1766.67	1682.67	1945.33
PD 5	TD 4	2030.67	4654.67	292.00	1402.67	1630.67	1792.00	2624.00	2633.33
PD 5	TD 3	1497.33	2042.67	234.67	898.67	1774.67	1305.33	2601.33	3460.00
PD 5	TD 2	1302.67	2408.00	184.00	833.33	1222.67	1652.00	1838.67	2822.67
PD 5	TD 1	274.67	1490.67	140.00	517.33	1552.00	730.67	1198.67	1908.00

Std Err = 743.99

Table 4: Effect of planting dates (PD) and termination dates (TD) on weed biomass (kg ha^{-1}) in cotton

Planting Date	Termination Date	2004		2005			2006		
		Shorter	**Belle Mina**	**Shorter**	**Belle Mina**	**Jay**	**Shorter**	**Belle Mina**	**Jay**
PD 1	TD 4	103.33	38.67	87.33	20.00	33.33	56.00	58.67	18.00
PD 1	TD 3	37.33	33.33	179.33	82.00	58.00	65.33	115.33	32.00
PD 1	TD 2	158.67	14.67	410.67	153.33	8.00	34.00	412.67	71.33
PD 1	TD 1	966.00	38.67	477.33	278.00	93.33	91.33	268.00	91.33
PD 2	TD 4	68.67	13.33	168.67	32.67	49.33	2.67	197.33	10.00
PD 2	TD 3	258.67	20.67	394.00	95.33	40.00	26.00	207.33	42.00
PD 2	TD 2	212.00	60.00	314.67	339.33	37.33	65.33	536.67	53.33
PD 2	TD 1	734.00	121.33	646.67	262.00	73.33	119.33	878.67	86.67
PD 3	TD 4	26.00	591.33	134.67	135.33	62.67	8.00	342.00	22.67
PD 3	TD 3	311.33	186.67	533.33	202.00	54.00	31.33	862.67	62.00
PD 3	TD 2	522.00	247.33	462.00	371.33	78.67	74.00	1457.33	120.00
PD 3	TD 1	1019.33	599.33	629.33	390.67	124.67	117.33	1118.67	148.00
PD 4	TD 4	197.33	341.33	160.67	202.67	51.33	10.67	256.00	28.00
PD 4	TD 3	340.67	238.67	362.00	112.67	50.67	80.00	492.00	46.67
PD 4	TD 2	321.33	224.00	441.33	483.33	44.00	113.33	546.00	89.33
PD 4	TD 1	1036.00	197.33	902.67	391.33	67.33	121.33	178.67	177.33
PD 5	TD 4	123.33	452.67	151.33	612.67	125.33	10.00	505.33	20.67
PD 5	TD 3	759.33	284.67	476.00	258.67	50.67	167.33	444.67	73.33
PD 5	TD 2	1445.33	276.67	522.67	638.67	74.00	34.00	824.67	79.33
PD 5	TD 1	1551.33	366.67	361.33	404.00	96.00	142.00	882.00	88.00

Std Err = 160.89

Effects of Different Winter Cover Crops on Conservation Tillage Tomato Quality and Yield

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Abstract

The increased use of conservation tillage in vegetable production requires more information be developed on the role of cover crops in weed control, tomato (*Lycopersicon esculentum* L) quality and yield. Three conservation-tillage systems utilizing crimson clover (*Trifolium incarnatum* L.), turnip (*Brassica rapa* L.) and cereal rye (*Secale cereale* L.) as winter cover crops were compared to a conventional black polythene mulch system, with and without herbicide, for weed control and tomato yield. Herbicide treatments included a preemergence (PRE) application of metalochlor (1.87 kg a.i. ha^{-1}) either alone or followed by an early postemergence (POST) metribuzin (0.56 kg a.i. ha^{-1}) application followed by a late POST application of clethodim (0.28 kg a.i. ha^{-1}). All covers were flattened with a mechanical roller/crimper prior to chemical termination. Without herbicide, weed control provided by cover crop residues ranged from 0 to 91% 4 WAT, depending on cover and weed species. Clover controlled yellow nutsedge (*Cyperus esculentus* L.) and smallflower morningglory (*Jacquemontia tamnifolia* L.) 48 and 50%, respectively, while providing only 1 to 2% control of smooth pigweed (*Amaranthus hybridus* L.), tall morningglory, wild radish and leafy spurge (*Euphorbia esula* L.). Turnip residue provided ≤ 34% control of all the weeds. Rye provided 81 to 91% control of Virginia buttonweed (*Diodia virginiana* L.) and smallflower morningglory Griseb.) respectively, whereas large crabgrass (*Digitaria sanguinalis* (L.) Scop.) control was only 11%. Neither cover crop nor the polythene mulch system provided adequate large crabgrass or wild radish (*Raphanus raphanistrum* L.) control without herbicide. Tomato stand establishment was not affected by any cover crop residue treatment compared to plastic mulch. Tomato yield was least in non treated control and was maximized with inclusion of the POST application. Pooled over herbicide treatments yield was less following either crimson clover or turnip cover crops compared to rye or the polythene mulch system. Averaged across cover crops, both herbicide programs resulted in better yields compared to the non-treated check.

Introduction

Tomato production systems typically utilize conventional tillage, a bedded plastic mulch culture, and multiple herbicide applications to keep fields weed free. Intensive use of synthetic chemical in their production has raised consumer and ecological concerns. Use of plastic mulches in sustainable or organic production systems is also not universally perceived as sustainable. Therefore, alternative production practices that decrease tomato production inputs while maintaining yields and quality are desired. Use of high residue cover crops combined with reduced tillage systems may produce such results.

Southeastern US receives adequate rainfall in the winter months, thus timely planted winter cover crops can attain relatively high biomass before termination. Cover crops can enhance overall productivity and soil quality by increasing organic matter and nitrogen content (Sainju et al., 2002), as well aid in water conservation by increasing soil water infiltration rates (Arriaga and Balkcom, 2005). Additionally, previous research has shown that weed control can be provided by high residue cover crops in both field and vegetable crops (Teasdale and Abdul-Baki 1998; Creamer et al., 1997; Price et al., 2006). Winter cover crop biomass can affect subsequent early season weed suppression (Saini et al., 2006; Teasdale and Mohler, 2000).

Adoption of cover crops in tomato production has been limited as transplanters have problems penetrating heavy residue and there are valid concerns for excessive residue interfering with soil reception of soil-active herbicides. Studies have reported favorable results with use of cover crops in tomato production management systems. Abdul-Baki and Teasdale (1993) obtained higher yields with hairy vetch in no tillage systems compared to plastic and paper mulches under conventional tillage systems. Akemo et al. (2000) studied the effect of spring sown cover crops on tomato production in Ohio and concluded that tomatoes grown following cover crop systems produced better yields. Teasdale and Abdul-Baki (1998) concluded that weed control achieved by cover crop mixtures was better compared to legume monocultures, but herbicides were always required to attain effective weed control and maintain tomato yields. Massiunas et al. (1995) also concluded that when tomatoes were grown following a rye cover crop additional control measures were required to achieve season long weed control. Teasdale and Abdul-Baki (1998) concluded that new equipment and management strategies are required to avoid yield losses and to fully utilize the potential of cover crops and their mixtures.

Objectives of this study were to evaluate: 1) tomato stand establishment utilizing a prototype high residue transplanter, 2) weed control and tomato performance in three different high residue conservation tillage systems.

Material and Methods

The experiment was conducted in the fall of 2004 and 2005 at the North Alabama Horticulture Experiment Station, Cullman, AL and in fall 2005 at Tuskegee University's George Washington Carver Agriculture Experiment Station, Tuskegee, AL. The soils were Hartsell fine sandy loam at Cullman and Marvyn fine sandy loam at Tuskegee. The experimental design was a randomized complete block with four treatment replicates. The plot size at both locations was 2.5 by 6 m containing a single row of tomatoes with 0.46 m spacing between the plants.

The three winter cover crops consisting of cereal rye (*Secale cereale* L.), crimson clover (*Trifolium incarnatum* L.) and turnip (*Brassica rapa* L) were compared to black polythene mulch for their weed suppressive potential and effect on yield and grade of fresh market tomatoes. Winter cover crops were planted with a no till drill each fall. Rye was seeded at a rate of 100 kg ha^{-1}, whereas clover and turnip were seeded at 28 kg ha^{-1}. Nitrogen was applied at a rate of 67.25 kg ha^{-1} on rye and turnip plots in early spring of each year. To determine the winter cover crop biomass production, plants were clipped at the ground level from one randomly selected 0.25 m^2 area per replicate immediately before termination. Plant samples were dried at 65 C for 72 hours and weighed. The winter cover crops were terminated each spring with a mechanical roller crimper prior to a chemical application of glyphosate at 1.12 a.e. kg ha^{-1}. The rolling process produced a uniform residue cover over the plots.

Four cover systems (three winter cover crops plus plastic) were evaluated with and without herbicide for weed control. Herbicide treatments included a preemergence (PRE) application of metalochlor (1.87 kg a.i. ha^{-1}) either alone or followed by an early postemergence (EPOST) metribuzin (0.56 kg a.i. ha^{-1}) application followed by a late POST (LPOST) application of clethodim (0.28 kg a.i. ha^{-1}). The PRE application was applied one day before transplanting, the EPOST application was applied 14 days after transplanting, and the LPOST application was delayed until tomatoes were near mid-bloom. Tomato cv. 'Florida 47' seedlings were transplanted on 4th April in 2005 and on April 9th in 2006 at Cullman and April 19 th at Tuskegee.

Seedlings were planted with a modified RJ No-till transplanter (RJ Equipment, Blenhiem, Ontario) (Figures 1 and 2), which had a subsoiler shank installed to penetrate the heavy residue and disrupt a naturally occurring compacted soil layer found at both experimental sites at a depth of 30-40 cm. Additionally, two driving wheels were utilized (one wheel on each side of the tomato row) instead of the original single wheel at the center of the row, to improve stability. This modification also helps to minimize re-compaction of the soil opening created by the shank. The plastic-mulch plots were conventionally tilled utilizing a tractor mounted rototiller prior to bedding and plastic installation; tomatoes were hand transplanted in the plastic mulch each year. Water was applied to all the plots immediately after transplanting. Thereafter, the plots were irrigated every other day using a surface drip tape as needed. General production practices included staking and fertilization (preplant application of 13-13-13 achieving 88.5 kg of N ha^{-1}) and then 7.8 kg of calcium nitrate per hectare was applied once every week with the irrigation system.

Weed control was determined by visual ratings (0% = no control, 100% = complete control) 28 days after the EPOST herbicide treatment (DAT). All weed species present were evaluated for control (as a reduction in total above ground biomass resulting from both reduced emergence and growth) and the combined average for each rating and treatment was calculated. Ripe tomatoes were hand harvested weekly over the entire plot area and fruits separated according to size into small, medium, large, and extra large categories.

Non-normality and heterogeneous variances are usually encountered with percent control data that span a large range. Data were arcsine transformed to achieve normality of residuals and among treatment homogeneity of variances. The data were subjected to analysis of variance as implemented in SAS PROC MIXED. Difference between treatments means were determined by single degree of freedom contrasts.

Results and Discussion

Twelve weed species were evaluated in this experiment (Table 1). Only three weeds were present in more than one field location. A cover by location and treatment by location interactions were significant for both large crabgrass [*Digitaria sanguinalis* (L.) Scop.] and yellow nutsedge (*Cyperus esculentus* L.). Herbicide treatment effects were significant for most weeds except ivyleaf morningglory (*Ipomoea hederacea* Jacq.), Virginia buttonweed (*Diodia virginiana* L.), and smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.]. The cover by treatment interaction was significant only for tall morningglory [*Ipomoea purpurea* (L.) Roth] and leafy spurge (*Euphorbia esula* L.). Lack of cover by herbicide treatment interaction for most weeds indicates the absence of weed control synergism. The three way interaction was not significant for any of the weed species present in multiple locations. Only significant main and interaction effects will be discussed in the remainder of the paper.

There were no differences in weed control provided by clover and turnip residue at 4 WAT as is evident from the contrasts (Table 2). Pooled over all the herbicide treatments, clover residue provided 48% control of yellow nutsedge and 50% control of smallflower morningglory. All other weed species were controlled ≤ 30%. Turnip residue did not provide adequate control of any of the weeds providing 34% control of goosegrass [*Eleusine indica* (L.) Gaertn.] and 32% control of both smallflower morningglory and broadleaf signalgrass [*Urochloa platyphylla* (Nash) RD Webster]. Neither clover nor turnip residues adequately controlled other weed species evaluated in the experiment. Rye residue was the most effective at suppressing weeds. Rye provided good control of Virginia buttonweed (81%), smallflower morningglory (91%) and yellow nutsedge (76%), but provided ≤ 31% control of large crabgrass, wild radish (*Raphanus raphanistrum* L.) and smooth pigweed (*Amaranthus hybridus* L.). When compared to clover and turnip, rye provided significantly higher control of most weeds. Smooth pigweed, pokeweed (*Phytolacca americana* L.), wild radish and large crabgrass were not controlled adequately (≤ 50%) by any winter cover residue. Weed control achieved with rye cover crop was comparable to plastic mulch. Plastic could not control Virginia buttonweed, smallflower morningglory and wild radish (≤ 9%). The control of only large crabgrass was significantly higher compared to rye.

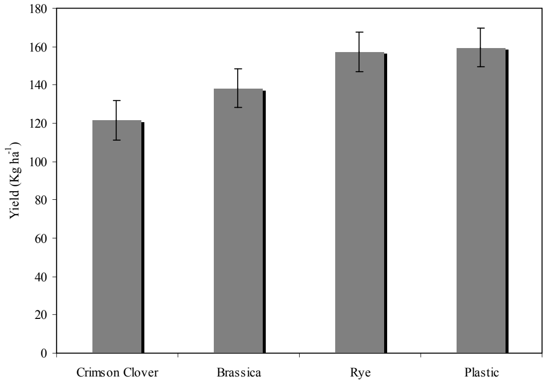

Fig 1. Effect of winter cover crops on tomato yield

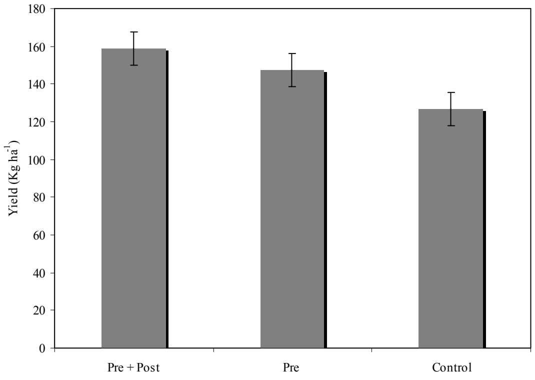

Fig 2. Effect of herbicide treatments on tomato yield

The effect of herbicide treatments on weed control was predictably more pronounced than the effect of cover crops. None of the weed species present were controlled adequately season-long without herbicides (Table 3). Weed control improved with application of the PRE herbicide with the exceptions of Virginia buttonweed and smallflower morningglory. Control of these weeds did not increase and was marginal even following the POST application. Control of broadleaf signalgrass, goosegrass, and yellow nutsedge improved significantly and was excellent (≥ 90%) with the inclusion of the POST herbicide application, whereas in other weed species the post application did not improve weed control. Reflecting the lack of season long weed control, weed control was minimal in treatments without herbicides.

Tomatoes were harvested only at the Cullman location in 2004 and 2005. Tomato plants were lost at Tuskegee due to an irrigation system failure immediately prior to fruit maturation. There was no interaction of year with winter cover crop and herbicide treatments nor was there a winter cover crop by herbicide interaction. Thus, the model reduces to a main effects model for winter cover crop and herbicide treatment effects. Pooled over herbicide treatments, the tomato yield was similar following rye cover and plastic mulch systems and the lowest fruit yield was observed in systems with a crimson clover winter cover crop (Figure 1). Averaged across winter cover crops, both herbicide programs resulted in better yields compared to the non treated check (Figure 2). Highest yield was obtained with the system containing both PRE and POST herbicides (Figure 2). This indicates that late season competition from weeds is as important as early season weed interference in maintaining yields.

Our study indicates that winter cover crop residue can provide early season weed control with supplemental use of EPOST herbicides. However, total reliance on winter cover crop for weed control was not sufficient and in all cases herbicides were required to provide season-long weed control and to maintain tomato yields.

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Table 1: Analysis of variance for weed control[a]

Effect/Source	CYPES	AMAPA	DIGSA	BRAPP	ELEIN	PHTAM	PHBPU	EPHES	IPOHE	DIQVI	IAQTA	RAPRA
Environment (E)	0.401	**0.044**	**<0.001**									
Cover [C]	0.186	0.104	0.388	**0.003**	**0.006**	**0.001**	**<0.001**	**<0.001**	0.074	**<0.001**	**<0.001**	**0.015**
C x E	**0.090**	0.173	**0.021**									
Treatment (T)	**0.021**	**0.006**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.496	0.157	0.058	<0.001
T x E	**0.001**	0.376	**<0.001**									
C x T	0.268	0.981	0.143	0.307	0.254	0.762	**0.009**	**0.004**	0.968	0.788	0.891	0.763
C x T x E	0.762	0.447	0.410									

Weeds were present in:

Year	Location											
2005	Cullman	Cullman		Cullman	Cullman	Cullman	Cullman	Cullman				
2006	Cullman	Cullman	Cullman						Cullman			
2006	Tuskegee	Tuskegee	Tuskegee							Tuskegee	Tuskegee	Tuskegee

Table 2. The effect of cover crops on weed control. Data are combined over herbicide applications[a]

	Weeds Cullman 2005							Weeds Tuskegee 2006			
Cover	BRAPP	ELEIN	PHTAM	EPHES	AMACH	PHBPU	CYPES	DIQVI	DIGSA	IAQTA	RAPRA
Percent control											
Crimson clover	30	25	14	2	1	1	48	29	15	50	1
Raphanus sativus	32	34	6	0	9	9	28	15	15	32	2
Rye	66	62	42	48	22	52	76	81	11	91	31
Plastic	70	64	74	64	53	66	72	0	52	1	9
P-values from contrasts:											
Clover vs. Raphanus	1.00	0.89	0.90	0.75	0.64	0.35	0.60	0.80	1.00	0.83	0.99
Clover vs. Rye	0.03	0.03	0.36	**<0.001**	0.11	**<0.001**	0.32	0.04	0.95	0.13	0.02
Clover vs. Plastic	0.01	0.02	0.01	**<0.001**	**<0.001**	**<0.001**	0.46	0.03	0.01	0.02	0.57
Raphanus vs. Rye	0.05	0.13	0.12	**<0.001**	0.65	0.01	0.03	0.00	0.96	0.02	0.03
Raphanus vs. Plastic	0.02	0.11	**<0.001**	**<0.001**	0.01	**<0.001**	0.05	0.19	0.01	0.14	0.76
Rye vs. Plastic	0.98	1.00	0.35	0.65	0.16	0.71	1.00	**<0.001**	**<0.001**	**<0.001**	0.26

Table 3. Effect of herbicide treatments on weed control. Data are pooled over all covers[a]

	Cullman 2005					Tuskegee 2006			
Treatment	BRAPP	ELEIN	PHTAM	AMACH	CYPES	DIQVI	DIGSA	IAQTA	RAPRA
Percent control									
PRE + POST	94	93	70	47	90	13	80	31	35
PRE	62	58	36	18	70	23	8	26	1
Untreated control	1	0	3	1	9	41	0	67	2
P-values from contrasts:									
POST vs.control	**<0.001**	**<0.001**	0.05	0.02	0.09	0.41	**<0.001**	0.74	**<0.001**
PRE vs. control	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.06	**<0.001**	0.06	**<0.001**
POST vs.PRE	**<0.001**	**<0.001**	0.01	0.01	**<0.001**	0.26	0.04	0.03	0.77

[a] Abbreviations: CYPES, Yellow nutsedge, AMAPA, Palmer amaranth, DIGSA, Large crabgrass, BRAPP, Broadleaf signalgrass, ELEIN, Goosegrass, PHTAM, Pokeweed, PHBPU, Tall morningglory, EPHES, Leafy spurge, IPOHE, Ivyleaf morningglory, DIQVI, Virginia buttonweed, IAQTA, Smallflower morningglory, RAPRA Wild radish.

Possible Effects of Corn Stover Removal on Soil Erosion in Iowa: A Panel Data Analysis

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Summary

This study uses the Iowa Soil Properties and Interpretations Database for the years 2005-07 and National Resources Inventory of Iowa for the year 1997 – the sub-county level data points (across a decade time frame) can help understand how soil erosion, soil nutrients and organic matter have changed over time with a focus on the impacts of emerging cropping patterns and changing agricultural residue cover on fields. The temporal data will be used to fit regression models using panel data analytic methods. The results can provide estimates of changes to soil erosion, nutrient or organic matter in the next 10-15 years upon removal of residues on a large scale basis for cellulosic ethanol production.

Introduction

Cellulosic materials - such as dedicated energy crops, agricultural residues, organic portion of municipal solid wastes, forestry and paper mill residues (EERE) - for ethanol production have begun to get more attention as alternative feedstocks for ethanol production. While the conventional feedstock – corn – has come under criticism for the environmental problems associated with intensive cultivation and larger use of fertilizer and pesticides, the possible environmental issues caused by cellulosic feedstocks are not fully known yet. See Table 1 for a summary of the few major issues in this regard:

Table 1. Issues associated with cellulosic feedstocks for ethanol production.

Cellulosic Feedstock	Advantages	Concerns or Issues
Dedicated energy crops	Low input production, possible high yields	Requires high yield levels (6 to 8 tons/ac/year) to become competitive, creation of new supply chains and infrastructure
Agricultural residues	Readily available, existing harvesting equipments can be modified to collect residues as well	Possible soil erosion and loss of soil nutrients due to residue removal
Forestry and paper mill residues	Sustainable supply, cheaper source of biomass	Limited in quantities

This analysis studies the extent of soil erosion possibly resulting due to residue removal for cellulosic ethanol production in the state of Iowa. The recent analyses on soil erosion have focused on modeling the field level soil movements using sophisticated models; while the micro level soil erosion is interesting and important, the removal of agricultural residues can also have a much broader geographical impact on erosion in agricultural lands – where a group of counties supplying corn stover (or wheat straw) to a cellulosic ethanol plant might face severe erosion due to continuous removal of residues over long periods of time. This shows that there are two dimensions – spatial (geographic) and temporal (over time) – for soil erosion in Iowa; both these components are to be incorporated while studying the impact of residue removal and possible soil erosion across Iowa.

Universal Soil Loss Equation (USLE)

The soil loss due to water erosion can be captured by the product of six major factors (NSERL, 2008; Stone and Hilborn, 2000):

(1) USLE = R * K * LS * C * P,

where USLE is the direct soil loss due to water erosion in metric tons per acre per year, R factor accounts for rainfall runoff erosivity (given for a field), K factor accounts for soil erodibility (given for a field), L factor stands for the slope length (usually in feet), S factor stands for the slope of the land (in percentage),[1] C factor captures the cover management activities and P factor accounts for conservation related support practices. Of these, the P factor is usually not observed directly but computed implicitly based on the amount of soil loss (USLE). The USLE equation was originally designed to study the soil erosion over large areas of land; the recent revisions RUSLE (IWR, 2002), RUSLE2 (NRCS) build upon the same above factors but with a focus on micro level field soil erosion.

The objective of this analysis is to analyze the impact of C factor on the soil loss amounts (USLE). The analysis would reveal what changes in crops, soil cover and tillage practices would result due to residue removal and how that would affect soil erosion. The relationship between C and USLE should control for the other soil erosion factors (R, K, L, S, and P) as well. Hence, the soil loss over large geographic areas (a group of counties or at state level) can be forecast by analyzing the spatial and temporal changes in these six factors.

Data and Methods

This study uses two datasets that cover almost 92 - 100 per cent of Iowa cropland for two time points – 1997 and mid-2000. See table 2. The factors C and P were not available directly for the latter time period. The C factor values for the latter year (2007) were estimated based on the crop portfolios and tillage practices; the average crop portfolios for the years 2002-07 were used, following the simplified procedure suggested in Stone and Hilborn (2000). Since P values are not usually observed directly, it was assumed to be the same during the time period of 1997-2007. This assumption may not be as limiting as it seems since the changes in conservation related support practices are slow to occur and it would take more than a decade (around 20 to 30 years) to discern significant changes. With all the six factors known for both the time periods, the USLE soil loss for the recent year 2007 can be predicted using the above said equation (1).

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[1] L and S factors change with changes in cultivation such as terrace or contour cultivation.

Table 2. Summary of data sources on soil erosion factors.

Year of latest update	Source	Cropland acreage accounted for in Iowa (total cropland in million acres)	Number of data points	Soil erosion factors
1997	National Resources Inventory – 1997	28.8	23,278	USLE, R, K, L, S, C and P
Mid 2000†	ISPAID – Version 7.2	31.2	8,738	K
	NRCS – EFOTG			R, L, S

† ISPAID database is continually updated – the factors for most of the counties were updated over the period of 2002 – 07. We call the latter time period as 2007 scenario to reflect the latest changes in the data.

This dataset assembled for all cropland, pasture, hay, and conservation reserve land in Iowa over two time points provides us with a panel data which could be analyzed using standard panel data analytic techniques. The 1997 data (NRI, 2000) contained 21,302 field level observations accounting for 28.8 million acres of Iowa crop land; the latest year data (Miller et al, 2006) contained 8,738 observation covering 31.2 million acres. The field level data were aggregated in to county level data to enable matching the observations over two time periods. The average values for all the six factors and soil loss at county level were derived using the particular crop land acreages as the weighting factor. The simple forms of panel data regressions were conducted to analyze how the changes in cropping patterns and tillage (C factor) would affect soil erosion.

Table 3. Typical range of values for the various soil erosion factors.

Factor	Min	Max
R	150	175
K	0.1595	0.368
LS†	0.177	2.411
C	0.053	0.317
P	0.053	0.317

† $LS = [0.065 + 0.0456(S) + 0.006541(S)^2] \times (L \div 72.5)^{NN}$

NN values range from 0.2 to 0.5, depending on the slope value S

Preliminary Results

Table 4 presents the regression coefficients quantifying the impacts of R, K, LS, C and P factors on the soil loss (USLE). The focus is to analyze the impacts of C factor (cropping pattern and management practice) on the soil erosion; the presented results are preliminary.

Table 4. Regression coefficients for the relationship between soil loss and R, K, L, S, C and P factors.†

	Simple Regression			Panel Data Regression		
Column I	***II***	***III***	***IV***	***V***	***VI***	***VII***
			Pooled Data	Random Effects‡	Between Effects	Fixed Effects§
Time Period	1997	2007	Both time periods			
Dependent Variable	USLE97	USLE07	USLE97 and USLE07			
R	**0.049**	0.012	**0.028**	0.0002	**0.035**	**-0.14**
K	**24.296**	5.536	**10.304**	**10.084**	*11.751*	**20.244**
LS	**4.598**	**6.268**	**5.617**	**5.559**	**5.845**	**6.929**
C	**31.967**	**23.173**	**26.2289**	**16.791**	**30.609**	3.442
P	0.865	2.471	1.1854	1.659	1.581	-279661¶
Constant	**-19.914**	-9.773	**-12.555**	-6.765	-15.508	249757.2
R^2	0.8328	0.6951				
Wald Chi-Sq statistic				367.75	59.48	54.82
All Regressions were significant						

† The numbers in **bold** fonts were significant at 1% level; *italics* at 5% level

‡ Random effects estimator is a weighted average of Between Effects and Fixed Effects estimators

§ Fixed estimators are not relevant in this case since P factor was assumed to be the same in both time periods – note, C factor is insignificant in the case of fixed effects due to relatively less changes in the cropping patterns.

¶ Poorly estimated P factor coefficient

The data available for the two time periods (1997 and 2007) were used to fit two separate regressions for the two time points – these results are presented in the columns ***II*** and ***III*** of table 4; the results for pooling the data (ignoring the panel data format) of all 99 Iowa counties over the two time periods are given in column ***IV***. The panel data regression (Park, 2008) results are presented in the columns ***V***, ***VI*** and ***VII***; among the panel data regressions, the Between Effects estimators (***VI***) compute the coefficients based on inter-county variations of agricultural practices, soil erosion factors and soil losses; the Fixed Effects estimates (***VII***) compute the impacts of soil erosion within the county based on the different levels of erosion at two different time points. The Random Effects coefficient estimates (***VIII***) are a weighted average of Between and Fixed Effects estimators. It is important to note that the Fixed Effects coefficient estimates are computed by taking the difference of the factors at two different time points – As mentioned above, the P factor was assumed to be the same over the study period; this causes the coefficient estimate to be a large negative but non-significant negative number (-279661); leaving out the P factor does not change the other estimates appreciably as shown in the following table 5.

Table 5. Regression coefficients for the relationship between soil loss and R, K, L, S, and C factors.

	Column VIII	*IX*	*X*
	Random Effects	Between Effects	Fixed Effects
Dependent Variable	USLE97 and USLE07		
R	-0.0004	**0.034**	**-0.139**
K	**9.941**	*12.769*	**20.355**
LS	**5.362**	**5.447**	**6.936**
C	**16.543**	**29.594**	3.452
Constant	*-4.933*	**-13.699**	**16.017**

In all the above equations, the coefficient estimated for the C factor can capture the impacts of various types of crops grown and the tillage practices adopted, while other factors remain unchanged. For a unit change in the value of C factor, the soil erosion would change by the amount of the coefficient value. It should be noted that the C factor varied between the range of 0.053 and 0.317 – hence a unit change (change by the value of one) will not usually occur. The following table reproduced from Stone and Hilborn (2000) summarizes how the two sub-factors used in computing a simple estimate of C factor value.

Table 6. Sub factors used to compute C factor.

Crop Type	**Column A**
Grain Corn	0.4
Silage Corn, Beans & Canola	0.5
Cereals (Spring & Winter)	0.35
Seasonal Horticultural Crops	0.5
Fruit Trees	0.1
Hay and Pasture	0.02
Tillage Method Factor	**Column B**
Fall Plow	1
Spring Plow	0.9
Mulch Tillage	0.6
Ridge Tillage	0.35
Zone Tillage	0.25
No-Till	0.25
C factor = product of one value from A and one value from B	

Source: Stone and Hilborn (2000)

One particular C factor can be approximated by multiplying one value from column A and one value from column B. Hence, a silage corn crop (or soybeans) with fall plow tillage would have the highest C factor value of 0.5 (A = 0.5; B = 1; C factor = A*B = 0.5) while the pasture lands with no tillage would have the least C factor value of 0.005 (A = 0.02; B = 0.25; C factor = A*B = 0.005). Note that the computed C factor values (Table 3) for the state of Iowa are within this wide range.

In the following description, we make two assumptions: the impact of removing the residues of corn for grain crop would have the same impact on soil erosion similar to that of land under corn crop for silage. In the latter corn for silage, most of the biomass would be removed from the land. Hence the A value would be 0.4 if the farmer does not remove the residues and it will become 0.5 if he decides to remove residues (leaving less residues on the soil). This is plausible since removing residues of grain corn is equivalent to removing most of the biomass as in the case of silage corn. Hence, the C factor will increase due to an increase in the value of A. If the tillage practice (column B) changed as well, then it would affect the net value of C factor.

To illustrate, consider a piece of land that is currently under hay and pasture use (A = 0.02) under zone tillage (B = 0.25) which has a C factor value of 0.005 (A*B); if the farmer decides to grow corn and removes residues (A becomes 0.5, corresponding to corn for silage) with mulch tillage (B = 0.6), then the new C factor value would be 0.3. Hence, C factor value increased by 0.295. When the other factors (R, K, L, S and P) remain the same, for this amount of increase in C factor, the soil erosion would increase by (16.791 * 0.295) = 4.95 tons per acre per year; the value 16.791 comes from the Random Effects estimator in column ***V***. That is, the land with no erosion due to pasture management is now eroded at a level equaling the state level average erosion. Note that the average level of soil erosion in crop land was 4.9 tons per acre per year in 1997 and around 4.7 tons per acre per year in mid 2000.

Table 7 illustrates the other interesting scenarios where the soil erosion would change due to removal of agricultural residues for cellulosic ethanol production. The first two rows (i) and (ii) show that when there is no change in crops grown or tillage practices patterns, the soil erosion may increase between 0.67 and 1 ton per acre per year. This can constitute an increase in soil erosion by 10-25% in soil erosion due to residue removal with no changes in other factors. The last row (iv) shows that with proper management, even with the residue removal the soil erosion can be controlled and reduced. This shows that the soil erosion is closely tied with the kind of management and tillage practices. Hence, if the agricultural residues are removed for cellulosic feedstock purposes, the soil erosion may worsen in certain situations based on the crops grown and tillage practices. There is also evidence that the conservation measures can partly ameliorate the soil erosion. The extent of soil erosion will closely depend on the practices adopted in the individual fields. It should also be noted that the above estimates of soil erosion changes are the changes that can be seen in the fields where residues are removed compared to the state level average (not necessarily a temporal comparison – same field, different time points). Although the results hint at considerable improvements in soil erosion issues, this result should be subject to more rigorous analysis.

Table 7. Scenarios of crops and tillage practices and resultant soil erosion in Iowa.

Row	Current crop and tillage (C factor)	Future crop and proposed tillage (C factor)	Change in C factor	Change in soil erosion†
I	Grain corn with mulch tillage (0.24)	Grain corn (with residues removal) with mulch tillage (0.3)	(0.3-0.24) = +0.06	(16.791*0.06) = +1
Ii	Cereals (wheat crop) with no tillage (0.09)	Wheat crop (with residues removal) with no tillage (0.13)	(0.13 – 0.09) = +0.04	(16.791*0.04) = +0.67
Iii	Pasture land with no tillage (0.01)	Corn crop (with residues removal) and no tillage (0.13)	(0.13 – 0.01) = 0.12	(16.791 * 0.12) = +2.01
Iv	Grain corn with spring plow (0.24)	Grain corn (with residues removal) with no tillage (0.13)	(0.13-0.24) = -0.11	(16.791*(-0.11)) = -1.84

† Assuming that the Random Effects coefficients in column ***V*** (Table 4) or ***VIII*** (Table 5) are correct estimates

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Monitoring Biomass for Use as Bio-Fuels

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Summary: Cellulose is seen as the next biomass for alternative energy production, especially ethanol. The residue from cover crops is seen as a possible source of cellulose. However, removing biomass from fields could prove detrimental to soil organic matter. This project was designed to monitor soil organic matter as it is affected by the removal of 0, 50 and 100% of rye cover crop residue. Data will be presented to show how much material can be removed from a typical field and the associated effect this has on soil organic matter.

Can Pyrolysis Chars Increase Corn Yield and Sequester Carbon in Conservation Tillage Systems?

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ABSTRACT

Pyrolysis is the thermochemical conversion of biomass under low oxygen conditions. Pyrolysis produces gases, biooils, and char products, all of which can be used as fuels. There is also considerable interest in the use of the char byproduct as a soil amendment. There is evidence that char may be beneficial to plant growth, improve soil conditions, and contribute to stable soil carbon. If char can sequester carbon and benefit crop yields in Southeastern soils, char amendments may work well with conservation tillage systems to improve soil quality. We evaluated the effect of soil amendment with peanut hull and pine chip pyrolysis char in a Tifton soil on corn (*Zea mays*) yield, soil nutrient status, and stable soil carbon over two growing seasons as a preliminary indication of how pyrolysis char might be used in row crop production systems.

Microplots (6 x 7 ft) were amended with peanut hull and pine chip pellet char produced at 400^{o} C with steam as a carrier gas. For each char type, a completely randomized design with four replicates was used with char rate (0, 5 tons ac^{-1}, 10 tons ac^{-1}) and N fertilizer (with and without) as treatment factors. Soil samples were taken before plots were amended, at week 4 and 16 after planting, and at harvest during the first year, and again before planting and after harvest the second year. Soils were analyzed for total C, N, S, pH, N, NH4-N, NO3-N, and Mehlich I P, K, Ca, Mg, Mn, and Zn. Soil moisture and CO_2 efflux from the soil surface were periodically measured during the growing season. Corn yield and aboveground biomass was determined by hand-harvesting.

Analyses of the char indicated that a significant amount of nutrients could be added with the peanut hull char at the 5 tons ac^{-1} rate (190 lbsN ac^{-1}, 2.3 lbs P_2O_5 ac^{-1}, and 59.8 lbs K_2O ac^{-1}). Nutrient additions with the pine chip char were low, and no differences in available nutrients were seen; however, peanut hull char addition did increase Mehlich I nutrients in the soil and in corn tissue, particularly in Year 1. Char addition increased soil organic carbon. Although small increases in CO_2 evolution were seen in the field following char incorporation, there were no significant effects of char rate on CO_2 efflux. There were no significant effects of char rate on corn yield during either Year 1 or Year 2. There was a response of corn biomass compared to the control to the highest peanut hull char rate during Year 1. Although no yield increases were seen in this study, we also did not see yield decreases. Ongoing work is investigating the potential for N immobilization at higher char rates. We conclude, though more work is needed

to evaluate char effects within a longer rotation in a conservation tillage system, there is potential to apply char before transitioning to conservation tillage to sequester carbon and improve soil quality.

MAXIMIZING COTTON PRODUCTION AND RYE COVER CROP BIOMASS THROUGH TIMELY IN-ROW SUBSOILING

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ABSTRACT

Most tillage and fertilizer practices attempt to maximize cash crop yields and do not focus on increasing cover crop yields. This project was conducted to determine the optimum time to perform in-row subsoiling in order to maximize cash crop and cover crop production. Two implements (Paratill or a KMC Rip/Strip) were used to perform in-row subsoiling at 6-week intervals beginning in the late fall in actively growing cover crops. Results indicated that maximum yields occurred for the cash crop and the cover crop by performing in-row subsoiling late in the spring after the cover crop had been terminated. All in-row subsoiling treatments were found to be superior to no-tillage which exhibited reduced plant growth, infiltration, and increased soil compaction.

Keywords. Tillage, In-Row Subsoiling, Soil compaction, Cover Crops, Biomass

INTRODUCTION

Soil compaction has been shown to reduce cotton (*Gossypium hirsutum* L.) yields in the Southeastern U.S. (Camp and Lund, 1964; Schwab et al., 2002; Raper, 2005c). In-row subsoiling is one of the most common methods used to remove compacted soil conditions (Box and Langdale, 1984; Busscher and Sojka, 1987; Raper, 2005b). Subsoiling disrupts compacted soil profiles, improves infiltration, increases soil moisture storage, and allows roots to proliferate downward to obtain adequate soil moisture and potentially improve crop yield (Raper and Bergtold, 2007). However, the shape of the subsoiler shank can have a large effect on the amount of soil disturbed both aboveground and belowground (Raper, 2005a). Increased belowground soil disruption coupled with reduced aboveground disruption have caused many producers to consider bentleg shanks as the preferred method of in-row subsoiling while maintaining conservation compliance.

Mostly ignored in the quest to improve crop production has been the impact and timing of tillage practices on cover crop production. In-row subsoiling is often recommended to be performed when timing is most plentiful, in the spring prior to planting or in the fall after harvest. The impacts of in-row subsoiling on cash crop and cover crop production is not often considered. However, maximum environmental and productivity benefits have been associated with large amounts of cover crop biomass (Reeves, 1994). Improved weed control, increased infiltration, decreased evaporation, increased water storage, improved soil quality, and reduced soil compaction have all been found as benefits of cover crops. During periods of extreme drought, many producers have even allowed their cattle to graze cover crops as a food source.

The ability to quickly produce a biomass crop may even have future implications for bioenergy. As the U.S. develops the capability to develop fuel from cellulose, one source of biomass that should not be overlooked is cover crops. Many producers in the Southeastern U.S. should be able to grow large biomass cover crops that could exceed yields of 4-5 t/ac with the plentiful rainfall that is mostly available during winter months. However, adequate research must be conducted to ensure that soil quality does not degrade as a result of this potential bioenergy crop. Therefore, an experiment was planned to determine if benefits in cash crop yields, cover crop yields, or soil properties could be improved through proper timing of in-row subsoiling.

Specifically, the objectives of this study were to:

- compare two different in-row subsoiling implements (Paratill and KMC Rip/Strip in-row subsoilers), and
- determine the optimum time of the year to conduct in-row subsoiling operations in order to maximize cash crop yield, cover crop yield, and soil properties.

MATERIALS AND METHODS

This experiment was begun in the fall of 2004 at the E.V. Smith Research Center in Shorter, Ala. (South-central Alabama) on a Compass loamy sand soil (coarse-loamy, siliceous, subactive, thermic Plintic Paleudults) which is a Coastal Plain soil commonly found in the southeastern U.S. and along the Atlantic Coast of the US. These soils are typically prone to subsoil compaction and usually require annual in-row subsoiling. This experiment focused on a continuous cotton production system which produced crops during 2005, 2006, and 2007.

Two implements were evaluated for this experiment. A Paratill, which is a bentleg subsoiler, (Bigham Brothers, Lubbock, TX) was compared against a Rip/Strip in-row subsoiler (Kelley Manufacturing Company, Tifton, GA) with a straight standard angled with the horizontal at 45°. Tillage depth for the experiment was maintained at 41 cm for both implements.

The timing of in-row subsoiling was the major subject of the experiment and was varied from late fall until spring prior to planting. Four times were selected beginning in mid-December and then spaced approximately 6 weeks apart. These times were mid-December, late-January, early-March, and late-April.

The experimental design was a randomized complete block with a 2x4 factorial arrangement of treatments augmented with an additional control treatment of no-deep tillage. The two factors investigated were: 1) in-row subsoiling implement (Paratill or Rip/Strip) and 2) timing of in-row subsoiling (four times). Treatments were replicated four times (36 plots) with each 4-row plot being 100 cm rows wide (4 m) by 15 m long.

After the cotton was harvested in the fall, a rye (*Secale cereale* L.) cover crop was planted and grown throughout the winter months. During the cover crop growing period, the in-row subsoiling was conducted until the following spring when the cover crop was terminated using glyphosate and rolling. Auburn University Extension recommendations were used to apply all fertilizers, herbicides, insecticides, and defoliants. The center two rows were harvested and weighted to obtain seed cotton yield. Rye was sampled by taking two 0.25 m square frames and oven-drying at 55° C until constant weight to remove moisture.

Soil strength was determined by use of cone index measurements (ASAE Standards, 2004b; ASAE Standards, 2004a) which were obtained with the Multiple-Probe Soil Measurement System (Raper et al., 1999). These measurements were taken with all five-cone index measurements being equally spaced at a 0.25-m distance across the soil with the middle measurement being directly in the path of the shank.

Data was subjected to ANOVA using the Statistical Analysis System (Littell et al., 1996). Preplanned single degree of freedom contrast and Fisher's protected LSD were used for mean comparisons. A significance level of $P<0.1$ was established a priori.

RESULTS AND DISCUSSION

COVER CROP BIOMASS

The amount of rye cover crop produced in spring of 2005 did not vary significantly ($p \leq 0.12$) based on the implement used or the timing of in-row subsoiling conducted during the preceding winter months (fig. 1; left). The only significant contrast that was noted was that December in-row subsoiling was more advantageous than March in-row subsoiling ($p \leq 0.07$; 2109 kg/ha vs. 3138 kg/ha, respectively). A trend was also noted that smaller amounts of cover crop biomass were produced by the no-till system as compared to a majority of the in-row subsoiling treatments.

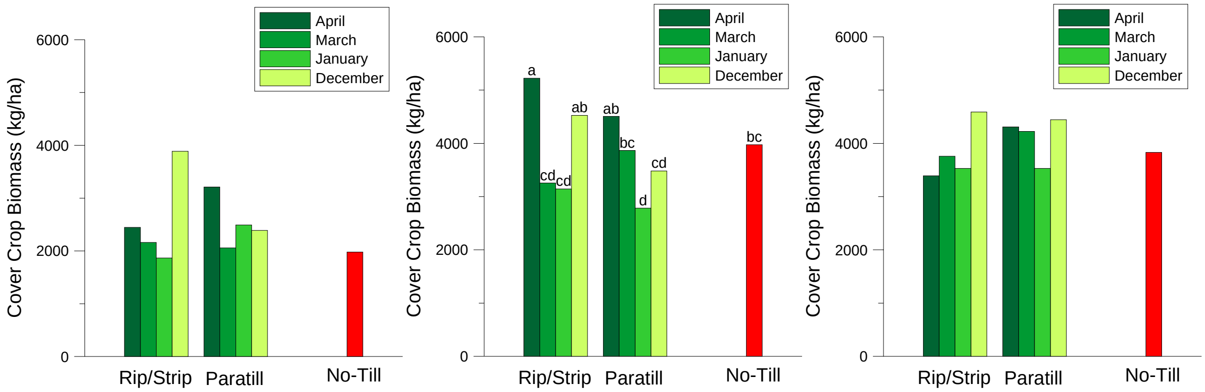

Figure 1. Rye cover crop biomass produced in 2004-2005 (left), 2005-2006 (center), and 2006-2007 (right). When present, letters indicate statistical significance ($\text{LSD}_{0.1}$).

Cover crop biomass results from spring of 2006 gave a greater amount of statistical differences (fig. 1; center). The implements were again found to not be significantly different ($p \leq 0.16$). The cover crop yield (4865 kg/ha) resulting from the last date of in-row subsoiling (April) was found to be statistically greater than March in-row subsoiling ($p \leq 0.01$), January in-row subsoiling ($p \leq 0.01$), or December in-row subsoiling ($p \leq 0.03$). December in-row subsoiling was also found to be greater statistically than January in-row subsoiling ($p \leq 0.01$).

Measurements of rye cover crop biomass taken in spring of 2007 again found no differences based on in-row subsoiling implement ($p \leq 0.50$). The only statistically significant contrast that was identified was that December in-row subsoiling was found to be superior to January in-row subsoiling ($p \leq 0.02$; 4518 kg/ha and 3530 kg/ha, respectively).

Two points are noted when these data are examined. The first point was that decreased cover crop yields result when in-row subsoiling was not applied. Rye roots suffered from similar rooting restrictions as cash crop plants even though they grew during winter months when rainfall was more plentiful. The second point was that in-row subsoiling provided during the middle growth stages of rye (January and March) was detrimental to maximum cover crop production. In-row subsoiling provided nearest the planting of the rye cover crop maximized production and was found to be superior to in-row subsoiling performed in January in 2 of the 3 years. Once the roots started to grow and proliferate, significant damage was done to the plants by performing in-row subsoiling. Waiting until the cover crop has been terminated (April in-row subsoiling) was also noted to produce good cover crop yields. It was interesting to note that this timing of in-row subsoiling was actually the closest tillage operation prior to planting of the rye cover crop which occurred less than 6 months later.

CASH CROP YIELD

Seed cotton yield from 2005 was not found to be affected by any treatments ($p \leq 0.50$), including in-row subsoiling implements (fig. 2, left; $p \leq 0.70$). In 2006, seed cotton yield was reduced by lack of timely rainfall and was again not affected by any treatments (fig. 2, center; $p \leq 0.16$), although all tillage treatments did have yields greater than the no-till treatment (1152 kg/ha). In 2007, seed cotton yield was found to be affected by tillage treatments (fig. 2, right; $p \leq 0.06$). Seed cotton yields from April in-row subsoiling (3758 kg/ha) was found to be greater than either January in-row subsoiling ($p \leq 0.02$; 3280 kg/ha), December in-row subsoiling ($p \leq 0.03$; 3280 kg/ha), or no-till ($p \leq 0.02$; 3242 kg/ha). March in-row subsoiling (3670 kg/ha) was also found to be greater than no-till ($p \leq 0.10$; 3242 kg/ha).

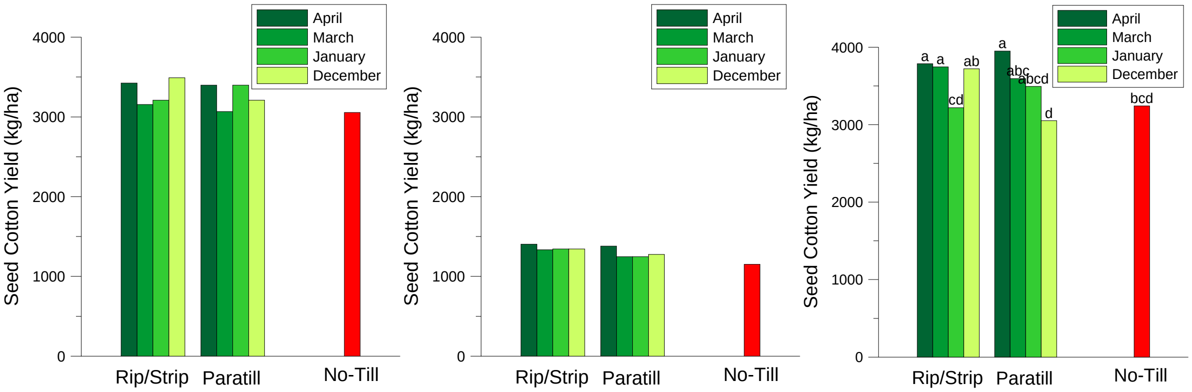

Figure 2. Seed cotton yield produced in 2005 (left), 2006 (center), and 2007 (right). When present, letters indicate statistical significance ($LSD_{0.1}$).

The greatest seed cotton yields occurred with the timing of in-row subsoiling as close as possible to planting. In most years, longer periods of elapsed time between in-row subsoiling and planting caused seed cotton yields to be reduced. Also, the smallest seed cotton yields were found with no tillage which indicated that significant soil compaction existed that must be removed prior to planting.

CONCLUSIONS

- Cover crop production was maximized by performing an in-row subsoiling operation either near the time of planting or after termination of the previous cover crop.
- Cash crop production was maximized by performing in-row subsoiling as close to planting as possible.
- No differences were noted between in-row subsoiling implements.
- The best time to perform in-row subsoiling should be based on maximum production of both the cash and cover crops. For our soils and climate, similar maximum production levels of cover crops were found with either early winter in-row subsoiling or post cover crop termination in-row subsoiling. Maximum growth of the cash crop was mostly found with post cover crop termination timing. Our recommendation would therefore be to perform in-row subsoiling late

in spring after cover crop termination in order to maximize performance of the cash crop without sacrificing cover crop yields.

DISCLAIMER

The use of trade names or company names does not imply endorsement by USDA-ARS.

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Why Mix Cattle and Crops?

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Introduction

The Southern Piedmont region of Georgia is composed of a mixed agricultural land use of row cropping, small grains, pasture-based cattle production, and confined poultry production. Significant opportunities are available to Georgia landowners to reap the ecological and economical benefits from rotation and integration of these operations on the same farm. Historical land use patterns over the past century in Georgia indicate a cattle inventory between 1 and 2 million head and currently low corn acreage at <1 million acres compared to >4 million acres prior to World War II. However, the recent rise in corn grain price due to the demand for corn to produce ethanol has driven a much greater need to supply corn from other regions of the country, including the Piedmont region of Georgia.

Although there is a perception that cattle grazing crop-residue stubble or cover crops will compact soil in Piedmont soils of Georgia, it is the condition and management of the surface soil that dictates whether animal trampling will compact soil and cause environmental deterioration and agronomic loss. For example, with grazing of Coastal bermudagrass, the impact of animal traffic on soil compaction was insignificant due to the accumulation of an organic matter-enriched surface soil layer (Franzluebbers et al., 2001). Establishment of perennial pasture on eroded soils in the Piedmont region may be one of the most effective strategies to improve soil organic matter (Franzluebbers, 2007a). In addition, conservation tillage in combination with pasture-crop rotation has been shown to significantly reduce soil erosion and improve water quality from agricultural runoff (Garcia-Prechac et al., 2004). Initial data from this proposed conservation tillage/pasture-crop rotation experiment have been collected and are validating many of the hypotheses focused on balancing agronomic production and environmental quality (Franzluebbers and Stuedemann, 2006, 2007). However, multiple-year data are needed to adequately quantify the agronomic, soil quality, and economic impacts of conservation-tillage systems in rotations of crops and pastures (Russelle et al., 2007).

Hypotheses for this research are:

1. Rotation of crops with pastures will yield agronomic and environmental benefits
2. Conservation tillage will preserve rotation benefits for an extended period of time
3. Cover crops can be grazed by cattle and increase farm profitability
4. Rotation with legume cover crops can reduce purchased N fertilizer requirement, while providing a high quality forage component

Since conservation-tillage systems operate most effectively with high-biomass producing cover crops, utilization of these cover crops as forage for cattle could increase the economic benefit to an integrated farming system. Economic information gathered from a diversity of sources throughout the USA suggests that integration of crops and livestock could be more profitable than either operation by itself (Katsvairo et al., 2006). The effect of cattle grazing cover crops on farming-system production and economics in the southeastern USA has not been adequately investigated, but this information could greatly improve recommendations and decisions for optimizing agricultural land use for profitability and environmental quality.

The objectives of this experiment were to quantify (1) cash/feed grain and stover production, (2) changes in soil quality, and (3) economic returns of crop/grazing systems in response to tillage, cover crop management, and source of N inputs. Specifically, we wanted to answer the following:

1. What are the effects of cattle grazing on subsequent cash/feed grain performance and soil quality?
2. How does cash/feed grain respond to no tillage under high surface soil organic matter conditions?
3. Can legume cover crops realistically provide adequate N to a subsequent cash/feed grain crop, particularly when grazed as forage by cattle?
4. How long will the benefits of rotating crops with pasture persist under no tillage compared with disk tillage?

Materials and Methods

The experimental site was located at the research station of the USDA–Agricultural Research Service in Watkinsville GA on a set of 18 plots (1.7-acre each, ~30 acres total) on Cecil sandy loam with 2 to 6% slope. The experiment evaluated tall fescue treatments from 1981 to 2001, during which time organic C of the surface 4" of soil more than doubled. In May 2002, the experimental paddocks were converted to either sorghum/rye or wheat/pearl millet cropping systems and managed with either disk or no tillage with four replications of these four main treatments. Paddocks were subdivided to exclude grazing from 1/3 of the area and allow grazing of the cover crop on the remainder. In 2005, corn replaced sorghum. In 2006, all cropping systems were converted to a rye / corn – wheat / soybean cropping system. During the summer, half of the plots were planted to corn and half planted to soybean. A new treatment, N management, was also introduced in 2006 to evaluate (1) typical inorganic N fertilizer input and (2) low inorganic N fertilizer input supplemented by legume cover crops as a source of biologic N fixation. Management details during the first 3 ½ years were reported in Franzluebbers and Stuedemann (2007).

Round-Up-Ready corn hybrid was planted in April and fertilized with split application at planting and at 12-15" height. Treatments evaluated were:

1. Grass cover crop mowed and disked into soil prior to corn fertilized with typical inorganic N input (DT – ungrazed – typical inorganic N)
2. Grass cover crop grazed by cow/calf pairs and soil disked prior to corn with typical inorganic N input (DT – grazed – typical inorganic N)
3. Grass cover crop rolled and corn no-till planted with typical inorganic N input (NT – ungrazed – typical inorganic N)
4. Grass over crop grazed by cow/calf pairs and corn no-till planted with typical inorganic N input (NT – grazed – typical inorganic N)
5. Legume + grass cover crop mowed and disked into soil prior to corn fertilized with low inorganic N input + biological N (DT – ungrazed –inorganic+biological N)
6. Legume + grass cover crop grazed by cow/calf pairs and soil disked prior to corn with low inorganic N input + biological N (DT – grazed –inorganic+biological N)
7. Legume + grass cover crop rolled and corn no-till planted with low inorganic N input + biological N (NT – ungrazed –inorganic+biological N)
8. Legume + grass cover crop grazed by cow/calf pairs and corn no-till planted with low inorganic N input + biological N (NT – grazed –inorganic+biological N)

Grass cover crop was ryegrass (Bulldog Grazer, 60 lb acre^{-1}) / rye (Wrens Abruzzi, 60 lb acre^{-1}) and legume + grass cover crop was clover (15 lb acre^{-1} of 38.5% Dixie Reseeding crimson clover, 38.5% Dalkeith subterranean clover, and 23% Bigbee berseem clover) / rye (Wrens Abruzzi, 30 lb acre^{-1}). Corn (Pioneer 31 G65, 32000 seed acre^{-1}) was harvested in autumn and cover crops or wheat (Coker 9663, 130 lb acre^{-1}) established soon thereafter. Following wheat harvest in early June, soybean (Roundup-Ready S76-L9, 45 lb acre^{-1}) was planted for bean production during the remainder of the summer. Fertilizer was applied as 46-23-26 lb N-P_2O_5-K_2O acre^{-1} at planting to all corn treatments and an additional 45-0-0 lb N-P_2O_5-K_2O acre^{-1} at sidedress to the corn treatment with typical inorganic N input. No sidedress N was applied to corn with legume N input. Fertilizer was applied as 46-0-0 lb N-P_2O_5-K_2O acre^{-1} to all wheat plots, as well as to ryegrass / rye cover crop.

This study also evaluated changes in soil organic matter, water infiltration, and soil compaction in response to tillage management, cover-crop management, and source of N inputs. Description of methods and the responses were reported in Franzluebbers and Stuedemann (2006; 2007b; 2008a, b).

Results and Discussion

During the first 4 years of research, net return over variable costs from grain only systems averaged \$11.33 acre^{-1} (Table 1). By including cover crops and grazing cattle into the production system, variable costs increased 32 ± 7%, but net return over variable costs increased considerably to an average of \$122.20 acre^{-1} (Table 1). Investing in cattle and cover crops improved economic return by an average of more than \$100 acre^{-1} during the first 4 years of evaluation.

Table 1. Economic analysis of four production scenarios evaluated across a 4-year period from 2002 to 2005 (Franzluebbers and Stuedemann, 2007).

	Sorghum (corn) / rye		Wheat / pearl millet	
Item	DT	NT	DT	NT
	--------------- \$ acre^{-1} ---------------			
Grain only system				
Variable cost	115.30	115.17	93.90	101.23
Crop value	122.13	153.13	100.17	95.50
Net return over variable cost	6.83	37.96	6.27	-5.73
Grain + cattle system				
Variable cost	160.00	159.16	118.58	127.67
Crop value	131.75	117.50	103.25	97.83
Calf gain value	117.57	159.66	154.31	172.35
Net return over variable cost	89.32	118.00	138.98	142.51

Analysis excludes labor cost, as well as grazing time and gain of cows. Assumed values of \$2.50 bu^{-1} grain and \$0.75 lb^{-1} calf gain. DT is disk tillage and NT is no tillage.

Grazing of cover crops had both positive and negative effects on crop responses. When rye was grazed as a winter cover crop, summer grain yield and stover production were reduced compared to ungrazed rye under no tillage (Table 2). However, there was no effect of grazing of rye cover crop when the tillage system was disk tillage. Wheat grain yield was unaffected whether pearl millet cover crop was grazed or not, either under disk tillage or under no tillage. Wheat stover production was greater when pearl millet cover crops were grazed than not grazed under both tillage systems. Cattle gain was greater under no tillage than under disk tillage under both winter and summer cropping systems. Allowing cattle to graze cover crops appears to make good economic sense and is causing slight variations in agronomic response up to this point in this research.

Soil organic C and N contents following termination of pasture declined with disk tillage, but remained stable and similar to continuation of perennial pasture when crops were managed with no tillage (Fig. 1). More active fractions of organic matter followed similar trends as those of total organic C and N. These data suggest that longer term evaluation of these cropping systems will be needed to define a new steady-state level in soil organic matter. Allowing cattle to graze winter and summer cover crops has not led to any consistent negative effects on soil organic C and N fractions, and therefore, can be recommended as a viable conservation approach to intensify agricultural land use, especially when practiced in combination with no tillage. To preserve high surface-soil organic C and N fractions and total plow-layer contents, no-tillage cropping following termination of perennial pasture is highly recommended.

Table 2. Crop yields and animal production from four production systems across a 4-year period from 2002 to 2005 (Franzluebbers and Stuedemann, 2007).

	Sorghum (corn) / rye		Wheat / pearl millet	
Cover crop	DT	NT	DT	NT
Grain crop yield (bu acre^{-1})				
Ungrazed	49	61	40	38
Grazed	53	47	41	39
Stover yield of grain crop (ton acre^{-1})				
Ungrazed	1.9	3.3	0.5	0.6
Grazed	1.8	2.5	0.6	0.7
Cover crop yield (ton acre^{-1})				
Ungrazed	2.7	3.1	3.4	4.5
Grazed	0.1	0.2	0.2	0.4
Cattle gain on cover crop (lb acre^{-1})				
Grazed	182	312	247	289

DT is disk tillage and NT is no tillage.

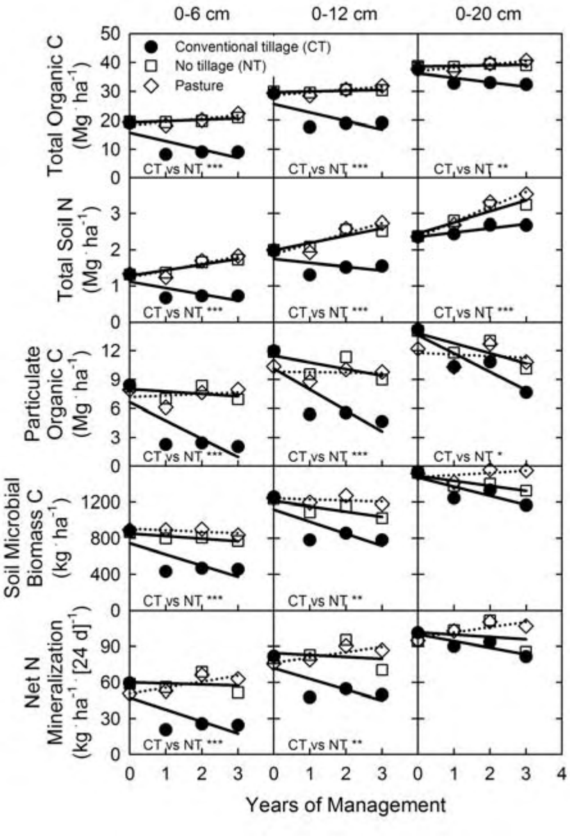

Fig. 1. Temporal change in total, particulate, microbial biomass, and mineralizable C and N fractions as affected by disk- and no-tillage management at three different depth intervals (Franzluebbers and Stuedemann, 2008a).

Conclusions

Preservation of high surface-soil organic matter with no-tillage management following termination of perennial pasture was a critical condition that allowed cattle grazing of cover crops to (1) improve soil microbial biomass C, (2) have little negative effect on surface soil compaction (i.e., bulk density), and (3) limited the degeneration of the soil pore network that influences water infiltration (results presented in Franzluebbers and Stuedemann, 2006). Grazing cover crops with cattle had (1) a positive effect on wheat stover production irrespective of tillage system, (2) no effect on winter grain and summer grain and stover production under disk tillage, and (3) a negative effect on summer grain and stover production under no tillage. Both rye and pearl millet cover crops provided an abundant and high quality diet for cattle for 26 to 77 days each season. Calf performance on cover crops was 4.7 ± 0.4 lb head^{-1} day^{-1} under no tillage, which was an average of 11% greater than under disk tillage (Franzluebbers and Stuedemann, 2007). These data indicate that integrated crop–livestock production may not necessarily suppress crop yields, but could even enhance yields and net economic return, especially if managed with conservation tillage. Despite current social challenges with integrated crop–livestock production systems, significant agronomic and economic benefits could be expected with their adoption.

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Using Cover Crop Residues as a Biofuel Feedstock: Willingness of Farmers to Trade Improved Soil Conservation for Profit

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Summary: Harvesting crop residues biomass and/or cover crop biomass for bioenergy production could provide an additional source of income to farmers to offset higher input prices and reduced crop prices in the market. The purpose of this study is to assess farmers' willingness to produce cover crops as a bio-energy feedstock in the Southeast. A survey was administered to Alabama farmers in the fall of 2007 assessing cover crop usage and willingness to produce. Analysis of survey data indicates that at the "right" price farmers may be willing to trade the soil conserving benefits of cover crops for biofuel production.

Crop Rotations, Reduced Tillage and N Fertilization Effects on Corn Yields And Aflatoxin Levels

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Introduction

The physical and biological environments of soils (Barber and Matocha. 1994; Matocha, et al. 2002; Wright, et al. 2005) can be influenced by tillage and crop rotations. The change in these environments may be associated with the quantity and distribution of organic matter, an important constituent of soils (Matocha, et al. 1999). Response to N fertilization and crop productivity can be a function of some of these biotic and abiotic changes. The purpose of this study is to determine the influence of tillage intensity and crop rotation on grain productivity and aflatoxin level in corn at varying levels of N fertilization.

Materials and Methods

The experimental site was a Victoria clay (montmorillonitic Udic Pellusterts), a vertisol with at least 30 inches of dark gray surface soil. Predominate clay in this soil is a swelling and shrinking montmorillonite. The site was located at the Texas AgriLife Research and Extension Center at Corpus Christi, and had been cropped to grain sorghum and cotton on alternate two-year cycles and low N rates for the previous three years. Initially, the soil tested low to medium in available N and P and high in available K. Four crop rotation schemes using the two basic row crops (corn and cotton) grown in the region and soybean as the main blocks while two tillage systems (minimum, MT, and conventional tillage, CT) were compared in split-plot within each main block. Minimum tillage involved four tillage operations with less than 3-inch plow depth while CT had eight operations with plow depth at 6-inches. Each tillage treatment within each cropping system was split into three sub-plots which received 0, 30, and 60 lb N/ac. Nitrogen rates for the soybean crop were 0, 15, and 30 lb/ac. Phosphorus was blanketed to all plots at 20 lb P_2O_5/ac. All 24 treatments were compared in four replications. A medium maturity corn hybrid and an early maturing cotton cultivar were used in the study. Soybean variety RA 452 (Group IV) was seeded in alternate years to complete the rotation scheme.

Results

In the first year, a devastating drought stressed the corn and cotton resulting in negligible grain yields, therefore yields are not reported for year one of the study. Results for the second year when normal rainfall was received are presented in Figures 1 and 2. The rotation effects from cotton or soybean on grain yields were considerably greater than in Year 1. Without N fertilization, corn yields under MT increased approximately 1422 lb/ac (74%) when corn followed cotton as compared to monoculture corn which produced a total yield of only 1913 lb/ac. With CT, the rotation increased yields approximately 1324 lb/ac or 65% compared to continuous corn. As N rate was increased to 60 lb/ac, the net contribution from the rotation decreased to 37 and 20%, respectively, for MT and CT systems.

The rotation effect from soybean under both tillage systems was generally less than with cotton (Fig. 2). Without N fertilization, the soybean contribution ranged a disappointing 47% to 38% for the MT and CT systems, respectively. With N fertilization, the rotation effect decreased to 13 and 0% for MT and CT, respectively. The lesser contribution from soybean than cotton to the rotation effect in Year 2 may be partly attributed to the drought stressed soybean crop having restricted N fixation capabilities in the Year 1 season. The effect from crop rotation was slightly accentuated when corn was grown with MT compared to CT.

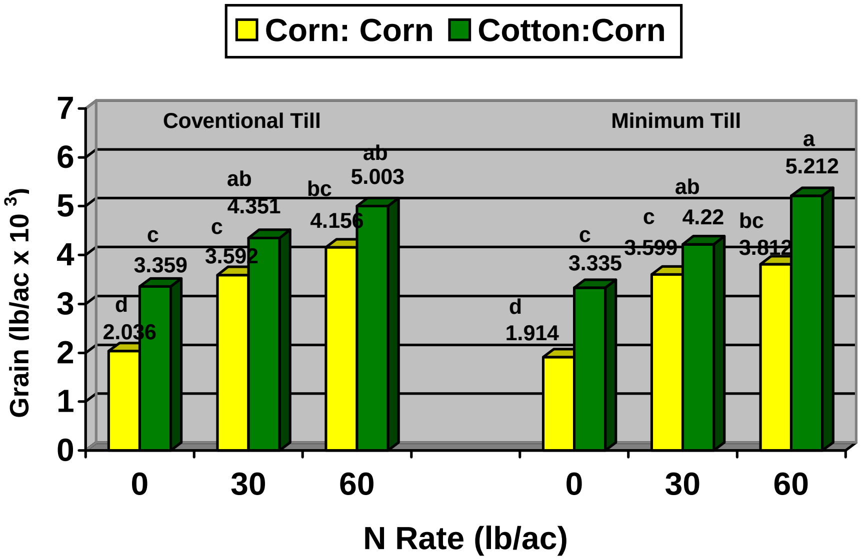

Fig. 1. Corn grain yields as influenced by cotton rotation, N rate and tillage in Year 2. Bars highlighted with the same letter are not significantly different across tillage systems, Fischer's LSD $_{0.005}$.

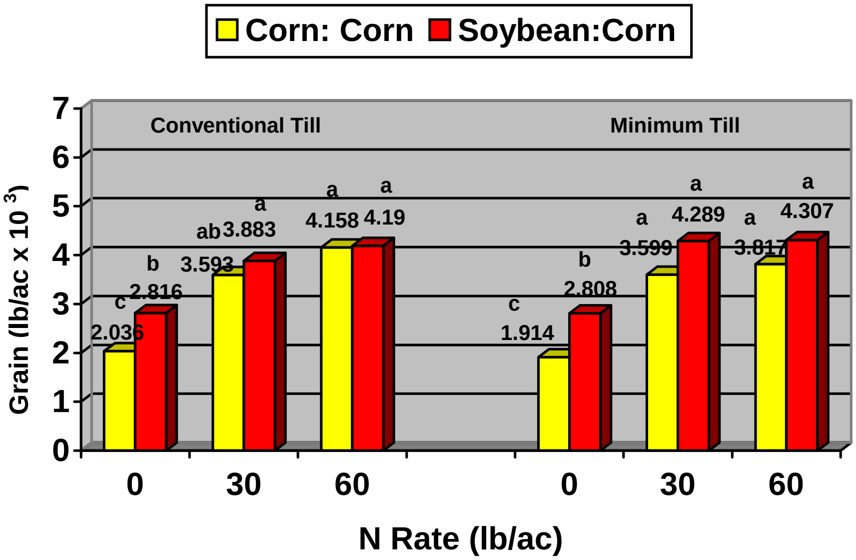

Fig. 2. Corn grain yields as influenced by soybean rotation, N rate and tillage in Year 2. (Soybean received 0,15,30lbsN/ac)

Soil moisture was above average starting the growing season in Year 3 but negligible rainfall throughout the growing season caused severe plant stress for moisture and final grain yields were approximately 50-60% of Year 2 yields. In Year 3, corn was grown under 12 separate treatments, six of which were in a monoculture of continuous corn cropping system and six in a cotton-corn rotation. The rotation scheme for this year did not include soybean.

In the third season, very small differences in treatment response were measured due to drought related abnormally low yields. In general, corn grain yields ranged from a high 2391 with 60 lb/ac to a low 1351 lb/ac with CT (Fig. 3). Averages over fertilizer treatments within cropping systems show little or no yield difference due to tillage. However, under CT response to N fertilizer was significant for continuous corn and the cotton-corn systems, response to N was recorded only up to 30 lb/ac for both cropping systems. The slight decrease in yields from the cotton-corn rotation compared to continuous corn was possibly due to lower residual soil moisture in the soil profile at season start when cotton preceded corn. These data show that under identical fertilization regimes and CT, corn following cotton in a droughty season will produce a slight increase in grain compared to continuous corn. No benefit from rotation was evident under MT.

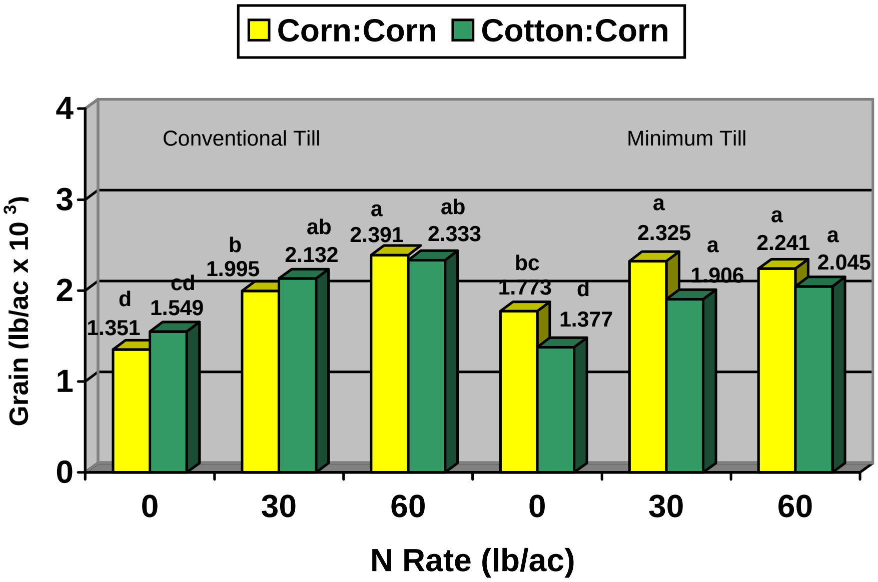

Fig. 3. Corn grain yields as influenced by cotton rotation, N rate and tillage in Year 3.

Grain yields during the fourth year of the study increased substantially over those for Year 3 and were about 90% of those yields for Year 2 (Fig. 4). The rotation benefit from cotton was considerably below that measured in Year 2 and ranged from 5% for MT without N fertilization to 11% for the CT system. Unlike the findings during Year 2, the rotation effect in Year 4 appeared to increase slightly with N fertilization in both tillage systems, however the yield effect was nonsignificant. Highest yields were measured when corn was grown with the MT system at the high N rate.

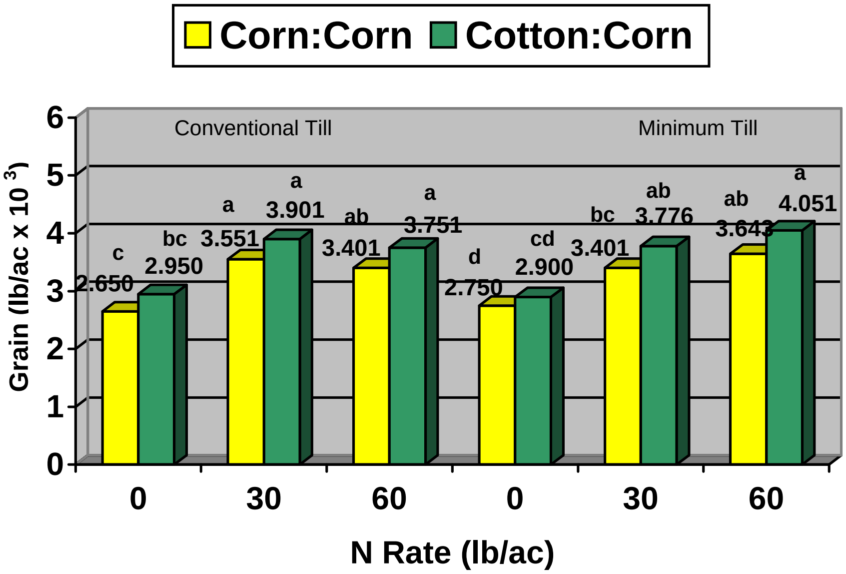

Fig.4. Corn grain yields as influenced by cotton rotation, N rate and tillage in Year 4.

Substituting soybean for cotton in the Year 4 rotation improved corn grain yields considerably over continuous corn when N fertilization was withheld (Fig. 5). The approximate 1050 lb/ac increase (38%) in grain due to soybean for the MT system decreased to 752 lb/ac (28% increase) for corn grown with CT, but still equaled or exceeded the soybean benefit measured earlier in the Year 2 season.

Using soybean in the rotation rather than cotton produced significantly higher corn yields as compared to the cotton rotation only when N fertilizer was excluded (Figs. 4-5). The benefits of the soybean rotation were greatest in the MT system at zero N.

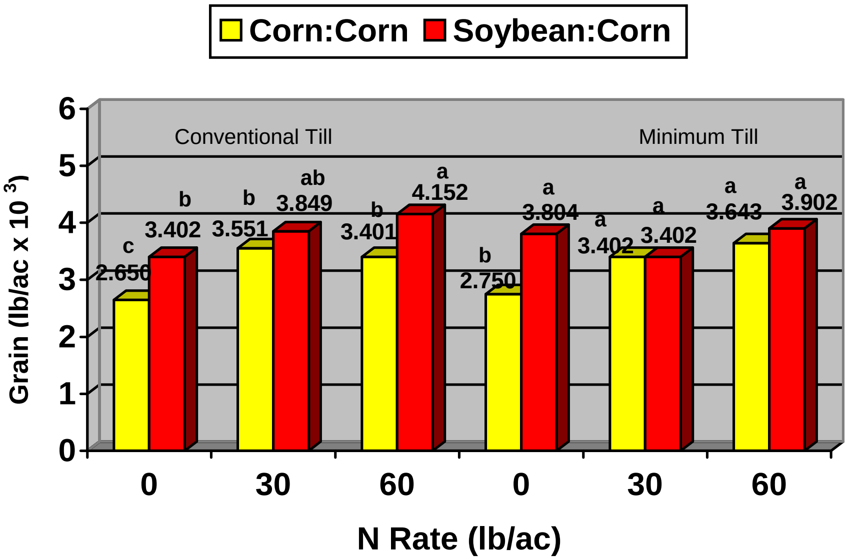

Fig.5. Corn grain yields as influenced by soybean rotation, N rate and tillage in Year 4. (Soybean received 0,15,30lbN/ac)

Aflatoxin levels in corn grain varied widely with seasons. When precipitation was average and above (Years 2 and 4), disease levels were generally below or slightly above the critical 20 ppb with an average of 16 and 22 ppb for Years 2 and 4, respectively. In these two seasons, treatment differences were relatively small but trended lower for the MT system when corn followed cotton. Corn stressed for moisture (Year 3) contained approximately a 10 fold increase in aflatoxin compared to non-stressed corn with an average of 204 ppb as compared to 21 in seasons when soil moisture was adequate. Corn following cotton produced higher disease levels as compared to monoculture corn in both tillage systems. Reduced tillage appeared to slightly lower grain aflatoxin.

Table 1. Influence of crop rotation/tillage and fertilizer N rate on aflatoxin levels in corn grain

Cropping System	1)Tillage	Fertilizer N	Aflatoxin (ppb)		
		Lb/Ac	Year 2	Year 3	Year 4
Continuous corn	CT	0	13	313	6
Continuous corn	CT	30	19	198	5
Continuous corn	CT	60	8	214	8
		$\bar{X}$	13	242	6
Continuous corn	MT	0	6	165	33
Continuous corn	MT	30	27	150	9
Continuous corn	MT	60	3	88	16
		$\bar{X}$	12	134	19
Cotton:corn	CT	0	15	182	25
Cotton:corn	CT	30	26	308	24
Cotton:corn	CT	60	24	159	36
		$\bar{X}$	22	216	28
Cotton:corn	MT	0	24	278	33
Cotton:corn	MT	30	16	184	15
Cotton:corn	MT	60	11	213	15
		$\bar{X}$	17	225	21

1) CT = conventional tillage; MT = minimum tillage

Summary and Conclusion

Results showed that precipitation and available soil moisture will greatly influence response of corn to crop rotation and tillage treatments. With adequate precipitation and no N fertilization in the second study year corn following cotton produced 74% higher yields while corn following soybeans produced a 47% yield increase. However, in the fourth year of the study, the contribution from soybean rotation was considerably greater than from the cotton rotation, especially at 0 N rates. These data suggest the beneficial effects from a soybean rotation with corn on soil quality and yields may have greater temporal dependency than with the cotton rotation. Although the tillage intensity effect appeared smaller than in the case of the rotation effect on corn yields, the positive effects from both cotton and soybean rotations were usually best expressed in the MT system. Corn following cotton produced higher grain aflatoxin compared to monoculture corn while reducing tillage somewhat suppressed disease levels. More research is needed to study the possible interactive effects.

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