Southern Conservation Agricultural Systems Conference

June 25-27, 2007

North Florida Research & Education Center

Quincy, Florida

Sponsored by :
Conservation Technology Information Center
University of Florida, North Florida Research & Education Center
Cotton Inc.
National Soil Dynamic Laboratory (Auburn, AL)

UF | UNIVERSITY of FLORIDA
IFAS

Dear Conference Participant,

Welcome to the 30th year of the Southern Conservation Agricultural Systems Conference. The theme for this year's conference is "Sod based rotation-the next step after conservation tillage". For those involved in the Southern Extension/Research Activities (SERA) Information Exchange Groups (IEG) meetings for some time, you have seen the innovations in conservation tillage over the years in equipment and management techniques along with what genetic technology has done to advance the movement to more conservation tillage.

This conference and field tour will focus on the benefits of the sod based rotation to the economics, risk management, and environmental impacts to the farm. This is the first year that heads of other conservation groups from around the country have joined with our group to develop a more national united front for conservation tillage efforts with leadership from the Conservation Technology Information Center.

A goal of this conference is to bring people together that have taken on the task of making conservation tillage work and conserving and enhancing natural resources while making the system economically attractive to growers. It is my hope that the conference will expose others to the value of perennial grasses in row crops systems and stimulate them to look at these systems with livestock. As farming becomes more complex and expensive, land and other resources will need to be utilized for longer periods throughout the year and the sod/livestock cropping system does intensify both labor and land utilization.

For those of you attending from outside Florida, I hope that you experience a small piece of the beauty of North Florida including such places as Wakulla Springs where some of the Tarzan movies were made about 30 miles SE of Quincy. This is an excellent place to see alligators in the wild and have a jungle cruise (at a cheap price) to see other wildlife. I hope you will enjoy your time here and we are open to working with others in our systems research.

Sincerely,

David Wright
Chair of the 2007 SCASC

ALTERNATING THE SHANK LOCATION ON A PARATILL EVERY OTHER YEAR PROVIDES SOME BENEFITS

Francisco J. Arriaga*, Kipling S. Balkcom, Randy L. Raper, and Ted S. Kornecki
USDA-Agricultural Research Service, National Soil Dynamics Laboratory
411 S. Donahue Drive, Auburn, AL 36832.
*farriaga@ars.usda.gov

ABSTRACT

Paratill operations are usually conducted with the shanks placed in the same location year after year, disrupting the same volume of soil. Moving the location of the shanks on the toolbar so they alternate from the previous year's location can potentially increase the volume of soil disrupted below ground. A corn-cotton rotation study was initiated in 2004 at the Field Crops Unit of the E.V. Smith Agricultural Research Center, near Shorter, AL. Data were not available until 2005 because of the timing of the alternating shank location tillage treatment. There were no differences in corn yield the first two years of the study. Total rainfall for the May to August period in 2006 was low (13.0). Differences in soil moisture between treatments during both growing seasons were small. However, there were significant differences in cotton yield. The alternating shank location produced greater cotton yield both years, 203 lb/ac greater (3,012 vs. 2,809 lb/ac) in 2005, and 475 lb/ac greater (1,978 vs. 1,503 lb/ac) in 2006. Soil penetration resistance data collected at the end of both seasons suggest that the alternating shank location treatment loosens a greater volume of soil. The alternating shank location could show some benefits to corn in future years.

INTRODUCTION

Paratill™ (Bigham Brothers Inc., Lubbock, TX)[1] operations are usually conducted with the shanks placed in the same location each year, disrupting the same volume of soil. Changing the orientation of the shanks on the toolbar on alternating years (Fig. 1) can potentially increase the volume of disrupted soil below ground. This can potentially improve conditions for root development and soil water redistribution in the root zone, while increasing soil rooting volume. The objective of this work is to determine if alternating the shank orientation each year on a paratill improves below ground disruption, and therefore improves root growth and crop yield.

MATERIALS AND METHODS

An experiment was established at the Field Crops Unit of the E.V. Smith Agricultural Research Center, near Shorter, AL, on a Compass loamy sand (coarse-loamy, siliceous, subactive, thermic plinthic Paleudults). Two tillage treatments were established, 1) Paratill™ with shanks oriented in the same manner each year (fig. 1A), and 2) Paratill™ with the shanks inverted on toolbar each alternating year (fig. 1A and 1B). Because of the nature of the tillage treatments, the experiment was started in spring 2004, but data collection did not begin until 2005. Cotton (*Gossypium hirsutum* L.) and corn (*Zea mays* L.) were grown simultaneously as a rotation. Total number of plots was 16 (4 replicates). Plots were 4-rows wide (36" spacing) and 50 ft long.

---

[1] -Mention of a company name or trademark does not constitute endorsement by the USDA to the exclusion of others.

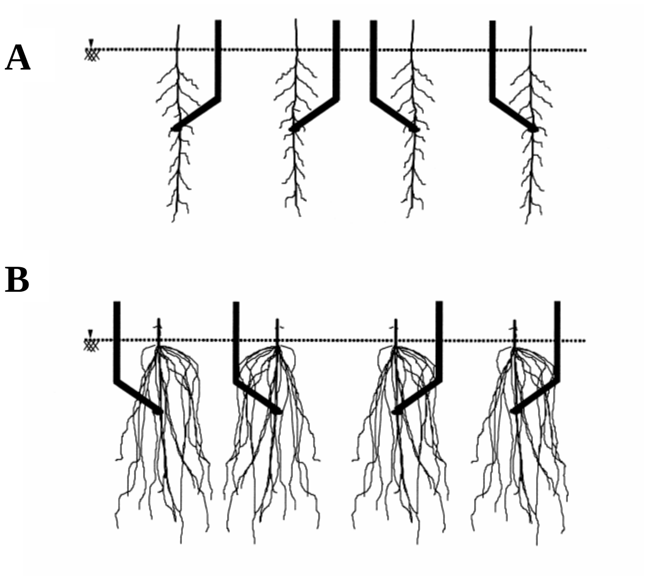


Figure 1. Shank orientation on the toolbar of a Paratill™. The treatment with the shanks on the same orientation each year is shown on top (A). Orientation of the shanks will alternate each year (between A and B) for the other treatment.

Soil moisture sensors were used to monitor soil water content during the growing season, but data is not presented here. Soil penetration resistance was measured at the end of the growing season in 2005 and 2006 (Raper et al., 1999). Corn and cotton yield were measured from the two center rows of each plot.

Statistical analysis was performed using the MIXED model in SAS (SAS Institute Inc., Cary, NC). Tillage treatment was considered as a fixed effect.

RESULTS AND DISCUSSION

No statistically significant differences in corn grain yield were observed between tillage treatments in 2005 and 2006 (Table 1). Rainfall during the May to August period in 2005 was adequate (14.5”) (Table 2), which could have diminished any positive effects of alternating the Paratill™ shank orientation. Additionally, there were small differences in soil moisture between tillage treatments during the growing season, but slightly greater soil moisture values were observed with the alternating shank orientation (data not shown). Total rainfall for the May to August period in 2006 was 11.4”, which resulted in overall low corn yields. Also, air temperature during the 2006 growing season was slightly greater than in 2005 (Table 2). Average corn yields for the test in 2006 were 17.6 bu/ac.

Table 1. Corn and seed cotton yield for the 2005 and 2006 growing seasons as affected by paratill shank orientation.

Shank location	Crop			
	2005	2006	2005	2006
	Corn		Seed cotton	
	----- bu/ac -----		----- lb/ac -----	
Same	127.2	19.9	2,809	1,503
Alternating	126.9	15.4	3,012	1,978
P-value	0.970	0.217	0.021	0.063

Table 2. Monthly rainfall amounts and average air temperature at the E.V. Smith research location from May until June.

	Rainfall		Average Temperature	
Month	2005	2006	2005	2006
	---------- in ----------		---------- °F ----------	
May	1.04	3.09	68.9	71.3
June	1.54	0.72	78.3	79.0
July	8.48	3.67	81.5	83.2
August	3.41	3.91	81.1	83.2
Total	14.47	11.39	---	---

Seed cotton yields were significantly greater for the alternating shank treatment in 2005 and 2006 (Table 1). Alternating the shank location every other year increased cotton yield by 7.2 and 31.6% during the 2005 and 2006 seasons, respectively. This increase in yield can be attributed to looser subsoil conditions created by alternating the shank location. Soil penetration resistance, as measured by cone index, was significantly lower in the alternating shank treatment during 2006 (Fig. 2). There were no significant differences in cone index between treatments in 2005. Cotton is more sensitive to soil compaction than corn and might benefit most by alternating shank orientation.

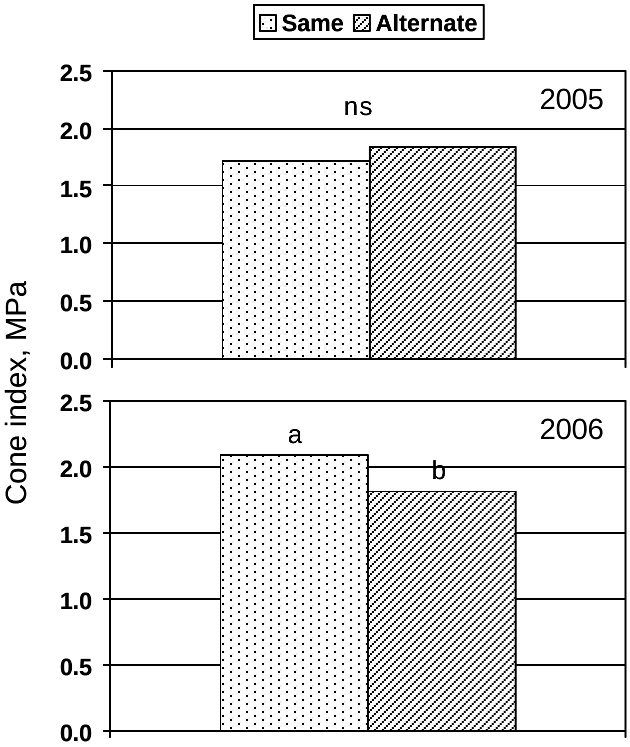


Figure 2. Cone index values after cotton harvest during the 2005 and 2006 cropping seasons. Different letter denote statistical significance between tillage treatments within the same year.

CONCLUSIONS

Data from first two years showed minimal differences in corn yield between tillage treatments. Rainfall was sufficient during the 2005 season, but it was unusually lower in 2006. This lack of rainfall reduced total corn grain yields dramatically.

Cotton benefited most from alternating the Paratill™ shank location every other year. Alternating the shank location increased cotton yields significantly both years. Cotton roots are more susceptible to soil compaction than corn, and thus, cotton might benefit more from alternating the Paratill™ shank orientation each year.

REFERENCES

Raper, R.L., B.H. Washington, and J.D. Jerrell. 1999. A Tractor mounted multiple-probe soil cone penetrometer. Appl. Eng. Agric. 15(4):287–290.

TILLAGE REQUIREMENTS FOR VEGETABLES FOLLOWING WINTER ANNUAL GRAZING

K.S. Balkcom[1], D.W Reeves[2], J.M. Kemble[3], and R.A. Dawkins[4]
[1]USDA-ARS, National Soil Dynamics Laboratory, Auburn, AL 36832.
[2]USDA-ARS, Natural Resource Conservation Center, Watkinsville, GA 30677.
[3]Department of Horticulture, Auburn University, AL 36849.
[4]Alabama Agricultural Experiment Station, Crossville, AL 35962.
Corresponding author's email: balkcks@auburn.edu

ABSTRACT

In Alabama, over 400,000 ac of winter annuals are grazed prior to planting summer row crops. Previous research indicates that cattle grazed on ryegrass (*Lolium multiflorum* L.) pastures over the winter months in Alabama can be profitable, but winter grazing creates excessive compaction, which can adversely affects yields of subsequent summer crops. We initiated a study to determine the optimal tillage system for sweet corn (*Zea mays*, L.), southern field pea (*Vigna unguiculata* L.), and watermelon (*Citrullus lanatus* L.) production on a Wynnville fine sandy loam (Fine-loamy, siliceous, subactive, thermic Glossic Fragiudults), in north central Alabama from 2001 to 2003. Three surface tillage treatments (chisel/disk/level, disk/level, no surface tillage) and three deep tillage treatments (no deep tillage, in-row subsoiling, paratill) were arranged in a factorial randomized complete block design with four replications. Each fall, all plots were planted to ryegrass and stocked with 3 cattle ac^{-1}. Southern field pea yields responded to surface tillage following winter annual grazing with disking comparable to chisel and disking. Sweet corn yields responded to a combination of surface and deep tillage, although deep tillage produced similar yields to surface tillage during one growing season. Watermelon yields were maximized following winter annual grazing with only deep tillage alone without any surface tillage.

INTRODUCTION

Growers who concentrate on vegetable production typically receive higher returns per land unit area than growers who produce only traditional summer field crops. Although the farm operations are much smaller, vegetables prices received are typically much higher. For example, Alabama's 2005 cotton crop was valued at $198 million across 550,000 acres ($360 ac^{-1}), but all vegetable crops were valued at over $12.5 million across only 6,300 acres (~$2000 ac^{-1}) during the same year (NASS, 2005). Despite the higher value that vegetable growers receive for their crops, the ability to diversify into other systems may further enhance potential economical benefits. One option involves the contract grazing of stocker cattle during the winter and early spring months.

In Alabama, Ball (1988) reported over 400,000 ac. of winter annuals are grazed prior to planting summer row crops. Bransby et al. (1999) reported profits of $70 to $224 ac^{-1} for cattle grazed on ryegrass pastures over the winter months in Alabama, while Siri-Prieto et al. (2007) reported profits of approximately $80 ac^{-1} for cattle winter grazed on ryegrass or oats (*Avena sativa* L.). These profits illustrate the potential that exists for vegetable growers to increase their income over the winter months following the summer growing season.

Unfortunately, winter grazing contributes to soil compaction problems, which negatively affects yields of subsequent summer crops (Touchton et al., 1989; Miller et al., 1997; Mullins and Burmester, 1997). Although vegetable growers can supplement their income and reduce economic risk by incorporating winter grazing into their operation, this increase in profitability over the winter months should not be at the expense of vegetable yields the following year. Therefore, the objective of this study was to compare vegetable yields in a sweet corn-watermelon-field pea rotation among various surface and deep tillage combinations following winter annual grazing of stocker cattle.

MATERIALS AND METHODS

This experiment was established at the Sand Mountain Research and Extension Center in Crossville, AL on a Wynnville fine sandy loam. Treatments were a factorial arrangement of three surface tillage treatments (chisel/disk/level, disk/level, no surface tillage) and three deep tillage treatments (no deep tillage, in-row subsoiling, paratill) in a randomized complete block design with four replications, established for each of three crops (sweet corn, southern pea, and watermelon) grown simultaneously. The crops were rotated each year in a southern pea-sweet corn-watermelon sequence for 3 yr. Plot dimensions were 11 ft. wide and 45 ft. long, allowing for a 1 ft. buffer between plots. Each replication of each crop phase was sampled separately for pH, P, and K to a depth of 8 inches by collecting 20 soil cores with a probe diameter of 0.75 inches. Initial soil pH, measured in a 1:1 soil/water extract, was 6.3, 6.2, and 6.2 for the watermelon, southern pea, and sweet corn phases. Phosphorus levels were 'high' and K levels were 'medium' for each phase based on the Mehlich I extractant (Mehlich, 1953) and the Auburn University Soil Testing Laboratory (Adams et al., 1994).

Ryegrass cv. 'Marshall' was planted at 25-30 lb ac^{-1} with a no-till drill that had row spacings of 7.5 inches on 14 Sept. 2000, 10 Sept. 2001, and 23 Sept. 2002. At planting, all plots received an average rate of 100 lb N ac^{-1}, 100 lb P_2O_5 ac^{-1}, and 100 lb K_2O ac^{-1}. In late February, ryegrass plots were fertilized with 62 lb N ac^{-1} in 2001, 60 lb N ac^{-1} in 2002, and 102 lb N ac^{-1} in 2003 to promote maximum vegetative growth for grazing. Sweet corn and watermelon received approximately 130 lb N ac^{-1} and 60 lb N ac^{-1} soon after planting, respectively.

Plots were grazed, beginning in late November to early December, at a stocking rate of 2.7 cattle ac^{-1} and removed by early to mid-April to facilitate vegetable planting. Cattle performance was determined each year by weighing each animal prior to grazing and again at the time of removal from grazing. Biomass samples were collected after cattle removal and prior to tillage operations. Ryegrass was chemically terminated and tillage treatments were administered to corresponding plots. Typical cultural practices recommended for each crop by the Alabama Cooperative Extension System for fertilizer and to control weeds and insects were utilized throughout the season to maximize yields. Agronomic practices related to specific cultivars, planting dates, seeding rates and harvest dates for each crop are presented in Table 1. Yields of each crop were measured by hand-harvesting mature vegetables from the two center rows of each plot and summing the weights from each harvest date.

Yields were analyzed using the MIXED procedure (Littell et al., 1996) and the LSMEANS PDIFF option to distinguish between treatment means (release 9.1; SAS Institute Inc.; Cary, NC). Data were analyzed with year as a fixed effect in the model, and there were significant year X treatment interactions for yield. Therefore, yields were analyzed within each year, with yield and discussion presented by year. Surface and deep tillage treatments were considered fixed effects, while rep was considered random. Treatment differences were considered significant if $P \leq 0.05$.

Table 1. Planting dates, cultivar, seeding rate, and harvest dates for sweet corn, southern field pea, and watermelon grown at the Sand Mountain Substation near Crossville, AL during 2001-2003.

Crop	Planting dates†	Cultivar	Seeding rate	Harvest dates		
				2001	2002	2003
			--plants ac^{-1}--			
	4-26-2001	Silver	26,000	7-19	7-12	7-25
Sweet corn	4-18-2002	Queen		7-26	7-19	7-28
	4-15-2003			8-6	7-24	7-31
				7-24	7-26	8-1
	5-16-2001	Pinkeye	2600	7-29	7-30	8-4
Southern field pea	5-15-2002	Purplehull		8-2	8-2	8-6
	5-29-2003			8-7	8-7	
	5-16-2001	AU	870	8-24	8-16	8-29
Watermelon	5-15-2002	Producer		8-30	8-23	9-5
	5-29-2003					

† Planting dates represent original planting dates. In 2001, a portion of the sweet corn plots (new plant date; 5-8-2001) and all the southern field pea and watermelon plots (new plant date; 5-25-2001) had to be re-planted due to dry weather. In 2003, sweet corn plots had to be re-planted (new plant date; 5-2-2003) due to poor seed germination.

RESULTS AND DISCUSSION

Cattle performance measured over three grazing periods indicated that the average gain was 925 lb ac^{-1}, which generated an average net return of \$169 ac^{-1} (Table 2). After cattle were removed, surface residue was minimal. Ryegrass biomass production was low due to intensive grazing by the cattle. In 2001, ryegrass was heavily grazed, so no biomass measurements were collected; however, prior to the initiation of tillage treatments, ryegrass biomass averaged 360 lb ac^{-1} in 2002 and 870 lb ac^{-1} in 2003.

Table 2. Cattle performance measured during three grazing periods at the Sand Mountain Research Station in Crossville, AL.

	2000-2001	2001-2002	2002-2003	Mean
Grazing period, days	129	129	138	132
Average daily gain, lb day^{-1}	2.5	2.9	2.4	2.6
Total gain, lb ac^{-1}†	871	1010	894	925
Gross income, \$ ac^{-1}‡	314	364	322	333
Net returns, \$ ac^{-1}§	150	200	158	169
Cost per gain. \$ lb^{-1}	0.19	0.16	0.18	0.18

† Stocking rate of 2.7 cattle ac^{-1}.
‡ Contract price of \$0.36 lb^{-1}
§ Average variable cost of \$164 ac^{-1}, excluding fences, water facilities, and rent.

In 2001, both surface tillage treatments produced superior sweet corn yields when compared to no surface tillage (Table 3). Sweet corn yields following deep tillage were not different in 2001, but numerically higher yields were measured following either deep tillage operation (Table 3). A significant interaction was observed between surface tillage and deep tillage in 2002 and 2003. In 2002, both deep tillage operations required some form of surface tillage to maximize sweet corn yields (Fig. 1). However, the surface tillage operation was not consistent for each deep tillage operation. In-row subsoiling produced higher yields when the disk/level treatment was applied, while the paratill treatment produced higher yields in combination with the chisel/disk/level treatment. Sweet corn yields across all treatments were lower in 2003 due to wind damage from a tropical storm (Table 3). Surface tillage was required to maximize sweet corn yields when no deep tillage was performed, however there was no yield increase by including either form of surface tillage following in-row subsoiling or the paratill treatment (Fig. 1).

Southern field pea yields only responded to surface tillage treatments 2 out of 3 years compared to no surface tillage, while deep tillage had no effect on yields following winter annual grazing (Table 3). A single disking operation was equivalent to a chisel and disking operation, however, numerical field pea yields were greater in 2001 following the chisel and disking operation.

Watermelon yields responded to a combination of surface and deep tillage treatments during the 2001 and 2002 growing seasons (Table 3). Although not significant, there was a trend ($P<0.12$) the last year of the experiment that also indicated a combination of surface and deep tillage treatments were required to maximize yields. In 2001 and 2002, watermelon yields responded to surface tillage in the absence of deep tillage, which were equivalent to yields obtained when surface tillage was combined with deep tillage (Fig. 2). The difference was not significant, but watermelon yields responded greater to in-row subsoiling compared to the paratill operation, either alone or combined with surface tillage (Fig. 2).

CONCLUSIONS

Sweet corn yields responded to a combination of surface and deep tillage, although deep tillage produced similar yields to surface tillage during one growing season. Southern field pea yields only responded to surface tillage following winter annual grazing with disking comparable to chisel and disking. Watermelon yields following winter annual grazing with only deep tillage alone were maximized without any additional surface tillage. The results of this study confirm that vegetable growers who complement their operations with winter annual grazing should be aware of potential soil compaction problems, but the tillage system required to correct the problem varies with the vegetable grown.

Table 3. Sweet corn, southern field pea, and watermelon yields measured following winter annual grazing of stocker cattle and combinations of surface and deep tillage for the 2001, 2002, and 2003 growing seasons at the Sand Mountain Research Station in Crossville, AL.

	Sweet corn			Southern field pea			Watermelon		
Tillage system	2001	2002	2003	2001	2002	2003	2001	2002	2003
					---cwt ac^{-1}†---				
Surface tillage									
Chisel/disk/level	195.5	175.9	97.3	60.7	36.6	52.7	631.3	384.8	357.1
Disk/level	185.7	166.1	93.8	57.1	36.6	55.4	621.4	393.8	407.1
None	92.9	127.7	74.1	48.2	39.3	44.6	520.5	350.9	326.8
$LSD_{0.05}$	25.0	16.1	15.2	6.3	NS‡	7.1	NS	NS	NS
Deep tillage									
In-row subsoil	175.0	152.7	93.8	55.4	39.3	51.8	655.4	480.4	360.7
None	144.6	153.6	75.9	53.6	36.6	51.8	470.5	304.5	364.3
Paratill	154.5	163.4	96.4	58.0	36.6	49.1	647.3	343.8	365.2
$LSD_{0.05}$	25.0	NS	15.2	NS	NS	NS	100.9	108.0	NS
					Analysis of variance (P > F)				
Surface tillage	<0.0001	<0.0001	0.0090	0.0011	0.5597	0.0145	0.0626	0.6905	0.1702
Deep tillage	0.0564	0.3024	0.0241	0.4154	0.6530	0.7230	0.0010	0.0068	0.9922
Surface X Deep	0.3843	0.0135	0.0152	0.1208	0.9858	0.5202	0.0002	0.0172	0.1252

† Yields are the totals of all the harvest dates within each year.

‡ Not significant at the 0.05 level of probability.

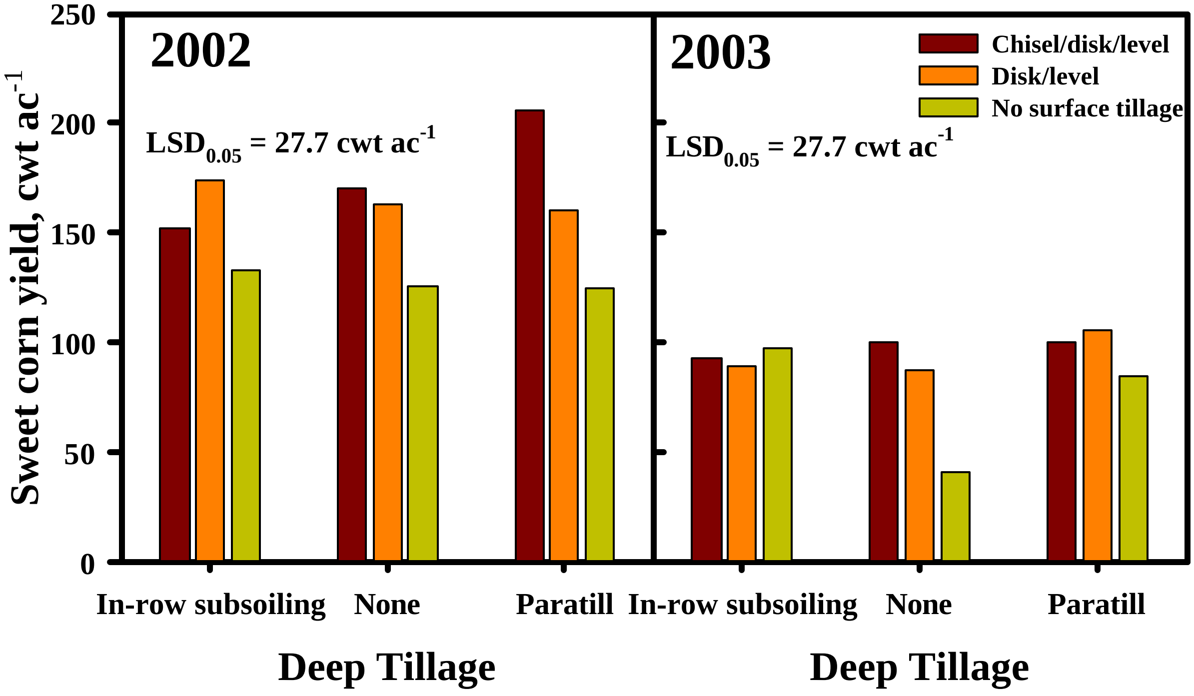


Figure 1. Sweet corn yields measured following winter annual grazing of stocker cattle and combinations of surface tillage and deep tillage treatments during the 2002 and 2003 growing seasons at the Sand Mountain Research and Extension Center in Crossville, AL

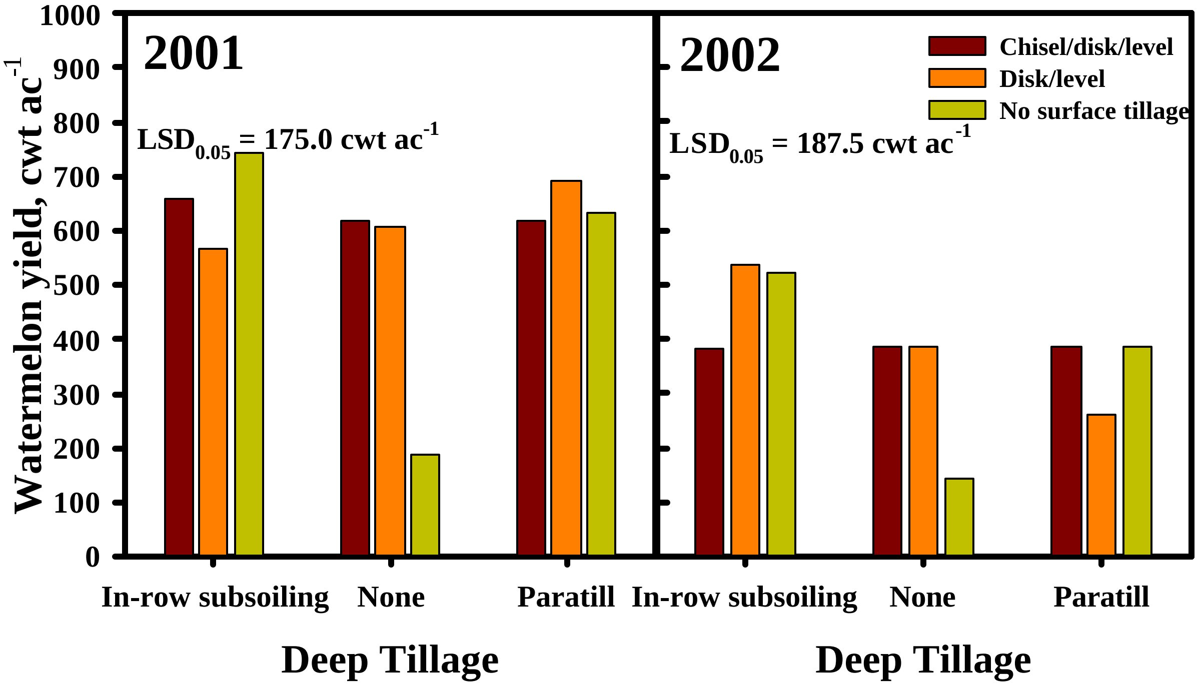


Figure 2. Watermelon yields measured following winter annual grazing of stocker cattle and combinations of surface tillage and deep tillage treatments during the 2001 and 2002 growing seasons at the Sand Mountain Research and Extension Center in Crossville, AL

REFERENCES

Adams, J.F., C.C. Mitchell, and H.H. Bryant. 1994. Soil test fertilizer recommendations for Alabama crops. Alabama Agric. Exp. Stn., Agronomy and Soils Dept. Series. No. 178.

Ball, D.M. 1988. Acreages of forage crops in Alabama. Agronomy Series, Agriculture & Natural Resources Timely Information No. PF-I-88. Alabama Cooperative Extension Service, Auburn University, AL.

Bransby, D., B.E. Gamble, B. Gregory, M. Pegues, and R. Rawls. 1999. Feedlot gains on forages: Alabama's stocker cattle can make significant gains on ryegrass pastures. Alabama Agricultural Experiment Station. Highlight of Agricultural Research Vol. 46, No. 2. Summer 1999.

Mehlich, A. 1953. Determinations of P, Ca, Mg, K, Na, and NH_4. NC Soil Test Div. Mimeo. NC Dept. Agric., Raleigh, NC.

Miller, M.S., D.W. Reeves, B.E. Gamble, and R. Rodriguez-Kabana. 1997. Soil compaction in cotton double-cropped with grazed and ungrazed winter covers. Proc. Beltwide Cotton Conf. January 6-10. New Orleans, LA. Vol. 1, pp. 647-648. National Cotton Council.

Mullins, G.L., and C.H. Burmester. 1997. Starter fertilizers and the method and rate of potassium fertilizer effects on cotton grown on soils with and without winter grazing by cattle. Commun. Soil Sci. Plant Anal. 28:739-746.

National Agricultural Statistics Service. 2005. Quick Stats (Agricultural Statistics Database) U.S. and State Data – Vegetables. Available online at http://www.nass.usda.gov/ NASS, Washington, DC. (verified on 4-27-07).

SAS Institute. 2001. The SAS system for Windows. Release 8.02. SAS Inst., Cary, NC.

Siri-Prieto, G., D.W. Reeves, and R.L. Raper. 2007. Tillage requirements for integrating winter-annual grazing in cotton production: Plant water status and productivity. Soil Sci Soc. Am. J. 71:197-205.

Touchton, J.T., D.W. Reeves, and D.P. Delaney. 1989. Tillage systems for summer crops following winter grazing. *In* I.D. Teare (ed.) Proc. South. Regional Conserv. Tillage Conf., p. 72-75, 12-13 July, Tallahassee, FL.

Joint Adoption of Conservation Agricultural Practices by Row Crop Producers in Alabama

Jason S. Bergtold, Agricultural Economist, USDA-ARS-NSDL, Auburn, AL
Manik Anand, Graduate Student, Auburn University, Auburn, AL
Joseph M. Molnar, Professor, Auburn University, Auburn, AL

Presenter: Jason Bergtold, USDA-ARS-NSDL, 411 S. Donahue Dr., Auburn, AL 36832. Phone: (334) 844-4741, Email: jbergtold@ars.usda.gov.

Abstract

Conservation agricultural production systems for row crops are usually comprised of a number of integrated conservation practices including conservation tillage, cover crops, soil testing, crop rotations, buffers, precision agriculture and integrated pest management. Current incentive structures for promoting the adoption of conservation programs rely on a piece meal approach for adopting conservation systems. That is, the adoption of practices is done one step at a time, which can lengthen the adoption process and potential for adverse economic and environmental consequences. The purpose of this paper is to examine the joint adoption of conservation practices by farmers in Alabama and factors that might impact this type of adoption. A survey of farmers in three watersheds was conducted in 2005 examining the adoption of conservation practices by producers. The survey was used to collect data about the adoption of farming practices, incentives for adopting conservation practices, farm characteristics and demographics of Alabama farmers. Survey data were statistically modeled to derive conditional measures of correlation to examine the impact of different socio-economic factors on the joint adoption of conservation practices. This information can be used to help develop outreach and incentive programs for promoting the adoption of conservation practices and systems by farmers. For example, if farmers have a higher likelihood of using winter cover crops in rotation with conservation tillage practices, then incentives might be developed that promote both practices jointly.

Introduction

A significant change in agri-environmental policy occurred in 2004, with the initial sign-up for the Conservation Security Program (CSP). The CSP is a voluntary conservation program that pays farmers who have met prescribed guidelines established by the USDA Natural Resource Conservation Service (NRCS) concerning the quality of soil, water, air, energy, plant and animal life to maintain and enhance conservation practices on their land. A factor that may limit participation is the eligibility requirements for the CSP. A base conservation management system that includes soil testing, crop rotations, crop nutrient management, integrated pest management, prescribed or rotational grazing and conservation tillage must be in place on-farm for a minimum of two years to qualify. Financial incentives are provided for environmental stewardship on-farm at the time of sign-up and for intensification of the on-farm conservation management system (NRCS 2004a, 2004b).

Conservation programs have historically focused on the adoption of conservation practices (components) instead of systems. That is, while a conservation systems approach is advocated by many conservation programs, most incentives are for individual practices, thereby resulting in a piece-meal approach for the adoption of conservation management systems. The result is a potential delay in economic and environmental benefits for the farmer and society, due to a lengthened adoption process.

The purpose of this paper is to examine the joint adoption of conservation practices by row crop producers in Alabama. Specifically, the joint adoption of conservation tillage, crop rotations and cover crops is examined using a multinomial logistic regression model. Survey data of farmers in three Alabama watersheds conducted in 2005 is used to estimate the model. Conditional measures of association (dependence) and conditional probabilities between conservation practices are examined to provide additional insight into socio-economic factors affecting the adoption of conservation practices and systems.

Materials and Methods

Data

The survey data used in the paper were collected in 2005 in a survey examining the adoption of conservation practices by farmers in three regions of Alabama. A random sample of farm operators included those operations with more than $10,000 gross value of sales and row crop and/or livestock control data. The sampling design for the survey was structured to obtain 300 responses from each of three regions in Alabama, the Wheeler Lake watershed (northern AL), the Upper Alabama watershed (central, AL), and the combined area of the Upper Choctawhatchee \Pea watersheds (southern, AL).

Producers were contacted by mail using a self-administered survey instrument. A second request questionnaire was used to increase the mail response, and a telephone contact was initiated if needed to boost response rate in areas with low response. In total 5935 surveys were mailed to respondents, of which 23 percent responded back. Of those, 1081 responses were usable for data analysis. Given the sample included row crop and livestock producers, the total sample size for this study was 247, the number of row crop producers.

The survey data included variables concerning the adoption of conservation tillage, cover crops, crop rotations, rotational grazing, crop nutrient management and integrated pest management practices for each respondent, as well as demographic, farm, financial and conservation program participation data. Definitions and summary statistics of the explanatory variables used in the empirical model are presented in Table 1.

The three conservation practices (dependent variables) jointly examined in this study are conservation tillage, crop rotation, and use of cover crops. All three variables are binary, taking a value of ‘1’ if the conservation practice was used by the farmer being surveyed, and ‘0’ otherwise. Of the respondents, 72 percent used conservation tillage, 54 percent use crop rotations at least every two years, and 51 percent used cover crops on same portion of their land. Given that we are examining these practices jointly, seven different conservation management systems could be devised, each used to represent the probability of adopting different combinations of the conservation practices being examined. Each of these potential management systems is presented in Table 1, along with the number of respondents who adopted each system.

Table 1: Variables and Descriptive Statistics

Variable	Mean	Standard Deviation[a]	Definition
Explanatory Variables			
Wheeler Lake[a]	0.55	---	Reside in Wheeler Lake Watershed. (1 = yes, 0 = no)
Upper Choctawhatchee[a]	0.38	---	Reside in Upper Choctawhatchee/Pea Waterhsed. (1 = yes, 0 = no)
Conservation Plan	0.77	0.42	Have a conservation plan on farm. (1 = yes, 0 = no)
EQIP	0.31	0.46	Participate in EQIP. (1 = yes, 0 = no)
CRP	0.26	0.44	Participate in CRP. (1 = yes, 0 = no)
NRCS Contact	0.61	0.49	Contact with NRCS in last 12 months (1 = yes, 0 = no)
Cotton	0.43	0.49	Grow cotton. (1 = yes, 0 = no)
Corn	0.77	0.42	Grow corn. (1 = yes, 0 = no)
Peanut	0.37	0.48	Grow peanuts. (1 = yes, 0 = no)
Farm Size	618	829	Size of farm in acres.
Row Crop Land	0.43	0.52	Percent of land used for row crop production.
Row Crop Sales	0.42	0.34	Percent of gross farm sales from row crop production.
Low Income	0.55	0.50	Gross farm sales less than $50,000. (1 = yes, 0 = no)
Debt	0.38	0.49	Have medium to high amount of debt. (1 = yes, 0 = no)
Farm Age	29	15	Number of years of farm experience.
Education	0.57	0.49	College education. (1 = yes, 0 = no)

Dependent Variables

Management System[b]	Conservation Practices			Percent Adoption by Respondents
	Conservation Tillage	Crop Rotation	Cover Crop	
None	---	---	---	0.09
T	X	---	---	0.14
R	---	X	---	0.09
C	---	---	X	0.10
TR	X	X	---	0.17
TC	X	---	X	0.13
RC	---	X	X	0.08
TRC	X	X	X	0.20

[a] The standard deviation of all binary variables is calculated as: $\sqrt{p(1-p)}$, where p is the mean of the binary variable. Wheeler Lake and Upper Choctawhatchee Pea Watershed Variables are included in the model as fixed effects.

[b] T = Conservation Tillage, R = Crop Rotation, C = Cover Crops

The Model

Suppose a farmer has the option of adopting J different management practices. These practices can be combined to form a set of $M = 2^J$ conservation management systems, representing different combinations of conservation practices from those available. Denote a specific management system as d_m, $m = 1,\dots,M$, where d is a $(J \times 1)$ vector of indicator variables equal to 1 if the j^{th} practice is part of plan m, making the set of conservation plans $C = \{d_m, m = 1,\dots,M\}$. A farmer will adopt d_m, if:

$$u^E_{i,m} = h_m(\mathbf{z}_i; g_m) + v_{i,m} = \max(u^E_{i,1},\dots,u^E_{i,M}), \tag{1}$$

where $u^E_{i,m}$ is the expected utility of choosing d_m, $h_m(.,.)$ is the systematic component of the farmer's expected utility function, $\mathbf{z}_i$ is a $(K \times 1)$ vector of explanatory variables (i.e. a set of physical and socioeconomic characteristics of the farmer and operation), g_m is a vector of parameters, and $v_{i,m}$ is the non-systematic (or random) component of expected utility. If the residuals, $v_{i,m}$, $m = 1,\dots,M$ are independently distributed with extreme value distribution, then the probability of a farmer choosing d_m can be represented as:

$$\mathbf{P}(I = m) = \frac{\exp(h_m(\mathbf{z}_i; g_m))}{\sum_{s=1}^{M} \exp(h_s(\mathbf{z}_i; g_s))}, \text{ for } m = 1,\dots,M \tag{2}$$

where I is a polychotomous index denoting the choice of conservation management system by the farmer. Equation (2) gives rise to a traditional multinomial logistic regression model (Train, 2003; Wu and Babcock, 1998). It is assumed that, $h_m(\mathbf{z}_i, g_m) = g'_m \mathbf{z}_i$ for $m = 1,\dots,M$ (i.e. linear). The model given by equation (2) is estimated with the conservation management systems and explanatory variables (socio-economic factors) indicated in Table 1. The Wheeler Lake and Upper Choctawhatchee variables represent fixed effects in the model to take account of heterogeneity across watersheds.[1]

Marginal Effects, Conditional Probabilities and Measures of Association

The marginal effects of each explanatory variable (e.g. $z_{i,k}$, $k = 1,\dots,K$) on the probability of adopting a particular management plan can be determined by differentiating equation (2) with respect to the $z_{i,k}$ of interest (Greene, 2000).

Measures of association provide a way to assess the dependence between adopting alternative conservation practices that make up a system. A type of conditional correlation (or

---

[1] The Upper Alabama Watershed is represented by the intercept term.

concentration) coefficient between two (binary) nominal variables $Y_{i,j}$ and $Y_{i,r}$ given $\mathbf{Z}_i = \mathbf{z}_i$ can be derived using Goodman and Kruskal's tau, as:

$$t_{j,r} = \frac{\sum_{p_j=0,1}\sum_{p_r=0,1} \frac{\left(\sum_{m\in\{d_m:Y_{i,j}=p_j \text{ and } Y_{i,r}=p_r\}} g_m(\mathbf{z}_i;g)\right)^2}{\sum_{m\in\{d_m:Y_{i,r}=p_r\}} g_m(\mathbf{z}_i;a)} - \sum_{p_j=0,1}\left(\sum_{m\in\{d_m:Y_j=p_j\}} g_m(\mathbf{z}_i;g)\right)^2}{1-\sum_{p_j=0,1}\left(\sum_{m\in\{d_m:Y_{i,j}=p_j\}} g_m(\mathbf{z}_i;g)\right)^2}, \qquad (3)$$

where $t_{j,r} \in [0,1]$ and $g_m(\mathbf{z}_i;g)$ is given by equation (2) and $g = (g_1,\ldots,g_M)'$ (Spanos, 1999). When $t_{j,r} = 0$ the j^{th} and r^{th} practices are statistically independent. This measure can be used to generate a type of conditional correlation matrix between the adoption of conservation practices being examined (Bergtold, 2005; Spanos, 1999).

The conditional probability of adopting a particular management plan can be determined using Bayes Theorem. Of interest here is the conditional probability that cover crops are adopted given conservation tillage has been adopted. To consider this, let C, T and R represent binary variables for the adoption of cover crops, conservation tillage and crop rotations respectfully. Then the conditional probability is given by:

$$P(C=1\,|\,T=1) = \frac{P(T=1,C=1)}{P(T=1)} = \frac{P(I=TC)+P(I=TRC)}{P(I=T)+P(I=TR)+P(I=TC)+P(I=TRC)}, \qquad (4)$$

where the probabilities in the last equality are given by equation (2). Marginal effects for the conditional probability given by equation (4) can be obtained by differentiating it with respect to each $z_{i,k}$.

Standard errors for marginal effects, conditional probabilities and measures of association were obtained using a Monte Carlo method. The estimated parameters, g_m, $m = 1,\ldots,M$, are assumed to be asymptotically multivariate normal with the mean being the estimated parameters and covariance matrix being the estimated covariance matrix of the parameters from the multinomial model. Based on these assumptions, 10,000 sets of parameters are randomly generated and used to compute each statistic and stored. The standard errors represent the sample standard error of the 10,000 stored values for the statistic of interest.

Results and Discussion

The multinomial model given by equation (2) and specified in the previous section was estimated using MATLAB (2007). Estimation results are provided in Table 2. The fixed effects tell us there exists significant differences in adoption rates among the three Alabama watershed areas examined in the survey. The remainder of the coefficients in Table 2 are not readily interpretable, given all coefficients appear in equation (2) for all the conservation management plans. Thus, the m^{th} coefficient on the k^{th} explanatory variable cannot be directly related to the m^{th} outcome. An alternative is to examine the marginal effects of the explanatory variables on the probability of adopting a particular conservation management system.

The estimated marginal effects for the estimated multinomial joint adoption model are provided in Table 3. The marginal effects provide the change in probability of adopting one of the conservation management systems given a one unit change of an explanatory

Table 2: Estimation Results and Fit Statistics for the Joint Adoption Model

Variable	**Conservation Management System[a]**						
	T	**R**	**C**	**TR**	**TC**	**RC**	**TRC**
Intercept	-4.20**	-2.63	-2.57	-2.97*	-7.62**	0.23	-4.49**
	(1.91)	(2.13)	(2.01)	(1.77)	(2.35)	(2.10)	(1.78)
Wheeler Lake[b]	0.61	-0.22	-0.80	2.12**	1.51	-0.58	2.06**
	(0.86)	(1.00)	(1.33)	(0.87)	(1.22)	(1.43)	(0.96)
Upper Choctawhatchee[b]	-1.02	0.29	0.88	0.03	2.86**	-0.11	1.64*
	(0.96)	(0.96)	(0.90)	(0.92)	(1.28)	(1.15)	(0.94)
Conservation Plan	1.74**	-0.96	-0.06	0.32	2.33**	0.69	1.34*
	(0.74)	(0.76)	(0.72)	(0.67)	(1.05)	(0.86)	(0.71)
EQIP	-0.67	1.35	0.99	-0.11	1.65*	-0.40	0.77
	(0.99)	(1.06)	(0.93)	(0.90)	(0.92)	(1.04)	(0.86)
CRP	-0.63	-0.83	-1.16	-0.28	-2.17**	-1.54*	-0.83
	(0.70)	(0.86)	(0.80)	(0.68)	(0.85)	(0.91)	(0.67)
NRCS Contact	-0.14	-0.97	0.95	0.39	0.61	0.69	0.69
	(0.72)	(0.84)	(0.77)	(0.69)	(0.83)	(0.83)	(0.69)
Cotton	0.22	-1.59	-0.24	-0.38	-0.85	-1.38	0.04
	(0.91)	(1.10)	(1.06)	(0.88)	(1.01)	(1.05)	(0.88)
Corn	1.75**	2.23**	2.31**	2.46**	0.64	1.34	1.95**
	(0.81)	(0.98)	(0.96)	(0.80)	(0.85)	(0.93)	(0.76)
Peanut	0.95	1.60	1.99*	2.25**	0.53	3.12**	2.00**
	(1.14)	(1.16)	(1.09)	(1.05)	(1.20)	(1.17)	(1.00)
Farm Size	0.001	-0.001	-0.002	0.000	0.001	-0.002	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Row Crop Land	-0.67	0.68	-1.85	-0.61	0.61	0.23	-3.63**
	(1.03)	(0.94)	(1.54)	(1.03)	(0.93)	(1.09)	(1.25)
Row Crop Sales	1.94	2.21	0.93	1.83	2.09	-0.45	3.48**
	(1.45)	(1.52)	(1.68)	(1.39)	(1.63)	(1.66)	(1.44)
Low Income	0.85	-0.27	-0.40	-0.47	-0.66	-2.90**	-0.31
	(1.00)	(1.12)	(1.04)	(0.94)	(1.01)	(1.10)	(0.91)
Debt	1.61**	2.17**	1.26	0.89	2.18**	0.77	1.30*
	(0.83)	(0.90)	(0.87)	(0.81)	(0.89)	(0.92)	(0.80)
Farm Age	0.02	0.02	0.01	-0.01	0.05*	-0.01	0.01
	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.02)
Education	-0.04	0.28	0.28	0.05	-0.09	0.33	0.03
	(0.65)	(0.73)	(0.70)	(0.63)	(0.70)	(0.77)	(0.62)
Predicted Probabilities	0.14	0.09	0.10	0.17	0.13	0.08	0.20
Other Statistics							
Likelihood Ratio							-370.67
McFadden Pseudo R^2							0.26

Percent Correct Predictions	43.72

Note: T = Conservation Tillage, R = Crop Rotation, C = Cover Crops. Standard errors are in parentheses. * and ** indicate statistical significance at the 10% and 5% level, respectively.

variable. For example, the presence of a conservation management plan increases the probability of adopting a conservation management system with conservation tillage, crop rotations and cover crops by 10 percent. The results in Table 3 are mixed. The marginal effects are not consistent across management plans for a given explanatory variable. For example, participation in the Environmental Quality Incentives Program (EQIP) decreases the probability of only adopting conservation tillage by 10 percent, but increases the probability of adopting both conservation tillage and cover crops by 12 percent. This phenomenon is likely due to the fact that we are looking at management systems and not individual practices. The probability of adopting conservation tillage is not the same as the probability of adopting the management system with only conservation tillage (see equation (4)). When considering the adoption of all three conservation practices being examined, the presence of a conservation plan, growing cotton and

Table 3: Estimated Marginal Effects for Conservation Management Plans

Variable	**Conservation Management System**							
	None	**T**	**R**	**C**	**TR**	**TC**	**RC**	**TRC**
Conservation Plan	-0.06*	0.12**	-0.14**	-0.06*	-0.07*	0.11**	0.01	0.10**
	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)
EQIP	-0.03	-0.10**	0.07*	0.04	-0.07*	0.12**	-0.06**	0.04
	(0.05)	(0.04)	(0.06)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)
CRP	0.07*	0.00	-0.00	-0.02	0.08*	-0.10**	-0.04	0.01
	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)
NRCS Contact	-0.02	-0.05	-0.10**	0.05*	0.02	0.02	0.02	0.05
	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)
Cotton	0.03	0.06	-0.07**	0.01	-0.01	-0.04	-0.06*	0.07*
	(0.06)	(0.05)	(0.04)	(0.06)	(0.05)	(0.05)	(0.04)	(0.06)
Corn	-0.18**	0.02	0.05	0.06*	0.11**	-0.10**	-0.01	0.06
	(0.06)	(0.05)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)
Peanut	-0.10**	-0.07	-0.01	0.02	0.10*	-0.10**	0.10**	0.06
	(0.04)	(0.06)	(0.05)	(0.05)	(0.07)	(0.06)	(0.06)	(0.07)
Farm Size	0.00	0.00**	-0.00	-0.00**	0.00**	0.00**	-0.00*	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Row Crop Land	0.07	0.02	0.11**	-0.07	0.06	0.16**	0.08**	-0.44**
	(0.06)	(0.07)	(0.04)	(0.10)	(0.08)	(0.05)	(0.05)	(0.11)
Row Crop Sales	-0.14*	0.02	0.05	-0.07	-0.00	0.01	-0.15**	0.28**
	(0.09)	(0.08)	(0.07)	(0.09)	(0.09)	(0.08)	(0.07)	(0.10)
Low Income	0.04	0.13**	0.02	0.02	-0.02	-0.02	-0.20**	0.03
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)	(0.06)	(0.05)
Debt	-0.09**	0.04	0.07**	-0.00	-0.06*	0.08**	-0.04	-0.01
	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)
Farm Age	-0.00	0.00	0.00	-0.00	-0.00**	0.00**	-0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Education	-0.01 (0.04)	-0.01 (0.04)	0.01 (0.04)	0.01 (0.04)	-0.00 (0.04)	-0.02 (0.04)	0.01 (0.04)	-0.01 (0.05)

Note: T = Conservation Tillage, R = Crop Rotation, C = Cover Crops. Standard errors are in parentheses. * and ** indicate statistical significance at the 10% and 5% level, respectively.

having higher row crop gross sales increases the probability of adopting all three practices simultaneously by 10, 7 and 28 percent respectively. In contrast, a farmer with the majority of their land under row crop production decreases this probability by 44 percent, possibly due to a perceived increase in production risk from adopting these practices.

Table 4 provides estimates of a conditional form of Goodman and Kruskal’s tau to examine the association between adopting the different conservation practices being examined. Although all the statistics in table 3 are significantly different from zero, these results indicate there is not a strong association between adopting any of the conservation practices. That is, knowing a farmer has adopted one conservation practice, such as conservation tillage, does not allow us to strongly predict that he/she will adopt another, such as cover crops. The lack of association may be due to the historical component rather than systems focus of outreach and research efforts toward farmers, and the monetary incentives for conservation practices provided by federal and state level conservation programs.

To assess what could be done to move toward a systems focus (i.e. increase these measures of association), the conditional probability of adopting a conservation practice, given the adoption of another conservation practice is examined. Specifically, the adoption of cover crops given the adoption of conservation tillage is examined in detail (i.e. equation (4)). Estimated conditional probabilities and marginal effects are provided in Table 5. The estimated probability of adopting cover crops once conservation tillage has been adopted is 51 percent. Findings suggest that the presence of a conservation plan, participation in EQIP, higher row crop gross sales, and each year of on-farm experience significantly increases the probability of adopting cover crops if a farmer is already doing conservation tillage by 12, 26, 21 and 0.5 percent. All these factors potentially decrease the risk of adopting cover crops by reducing uncertainty with experience and a conservation plan, as well as, helping to cover potential production costs with financial incentives and higher revenues. In contrast, participation in CRP, growing of corn, and having a high percentage of your land under row crop production significantly decreases the probability of adopting cover crops even though conservation tillage has already been adopted by 13, 15 and 27 percent, respectively. Participation in CRP pays to take land out of production providing a potential disincentive to adopting working land conservation practices. Farmers may perceive corn residue as being sufficient to meeting the conservation tillage requirement of 30% surface cover and therefore have obtained their perceived maximum benefit. A higher percentage of land under row crop production may increase the perceived risk faced by a farmer, potentially due to less diversification in the farming operation, limiting income streams.

Table 4: Goodman and Kruskal’s Tau Coefficients for Conservation Practices

	Conservation Tillage	Crop Rotation	Cover Crops
Conservation Tillage	---	0.1049**	0.0574**

		(0.0274)	(0.0226)
Crop Rotation	---	---	0.0858**
			(0.0239)
Cover Crops	---	---	---

Note: Standard errors are in parentheses. * and ** indicate statistical significance at the 10% and 5% level, respectively.

Table 5: Conditional Probability of Adopting Cover Crops Given Adoption of Conservation Tillage and Associated Marginal Effects.

Estimated Conditional Probability	0.51**
	(0.03)

Variable	**Marginal Effect**
Conservation Plan	0.12*
	(0.08)
EQIP	0.26**
	(0.08)
CRP	-0.13**
	(0.08)
NRCS Contact	0.08
	(0.08)
Cotton	-0.02
	(0.09)
Corn	-0.15**
	(0.08)
Peanut	-0.05
	(0.11)
Farm Size	0.00
	(0.00)
Row Crop Land	-0.27**
	(0.14)
Row Crop Sales	0.21*
	(0.15)
Low Income	-0.08
	(0.09)
Debt	0.07
	(0.08)
Farm Age	0.00**
	(0.00)
Education	-0.01
	(0.07)

Note: Standard errors are in parentheses. * and ** indicate statistical significance at the 10% and 5% level, respectively.

Conclusion

Historically, conservation policy has promoted the adoption of conservation practices rather than systems via its incentive mechanisms. While a systems approach is the desired result, the actual outcome is an outreach system that promotes conservation components and practices. This result is partially supported by the low dependence exhibited between the adoption of conservation tillage, crop rotations and cover crops by Alabama farmers. The likelihood of adopting cover crops once conservation tillage has been adopted is examined to assess what socio-economic factors might help to increase the association between adoptions of conservation practices, thereby moving toward a systems approach. Findings suggest if a farmer: (i) has a well developed conservation plan established, (ii) receives financial incentives from conservation programs such as EQIP (that are coupled with other conservation practices, such as conservation tillage and cover crops), (iii) possess information showing the potential profitability of conservation system components (in a system context), (iv) and has access to mentors (other farmers) that can help guide integration of conservation components, then likelihood of cover crops being adopted once the initial decision to adopt conservation tillage has been made. Such an approach may increase the success of conservation programs like the CSP, which are based upon a systems focus, by increasing eligibility and focusing incentive structures on conservation system intensification.

References

1. Bergtold, J., J. Molnar and G. Brant. "Limited Access to Conservation: Limited Resource Farmer Participation in the Conservation Security Program in the Southeast." Submitted for review to the *Journal of Agricultural and Resource Economics* in December, 2005.
2. Greene, W.H. *Econometric Analysis*. 4th Edition. Upper Saddle River, NJ: Prentice Hall, Inc., 2000.
3. MATLAB. 2007. *MATLAB Programming*. Ver. 7. Natick, Mass.: The Mathworks.
4. Natural Resource Conservation Service (NRCS), USDA. "Conservation Security Program: Interim Final Rule with Request for Comments." *Federal Register*. 7 CFR Part 1469. 69(June 12, 2004a): 34502 – 34532
5. Natural Resource Conservation Service (NRCS), USDA. *Conservation Security Program: Self-Assessment Workbook*. PA-1770. June 2004b.
6. Spanos, A. *Probability Theory and Statistical Inference: Econometric Modeling with Observational Data.* Cambridge, UK: Cambridge University Press, 1999.
7. Train, K. *Discrete Choice Methods with Simulation*. Cambridge, UK: Cambridge University Press, 2003.
8. Wu, J.J. and B.A. Babcock. "The Choice of Tillage, Rotation, and Soil Testing Practices: Economic and Environmental Implications." *American Journal of Agricultural Economics*. 80(August 1998): 494 – 511.

ENHANCING COTTON PRODUCTION BY INCORPORATING SOD INTO TRADITIONAL ROW CROPPING SEQUENCES IN VIRGINIA: ANOMALY OR REALITY?

J.C. Faircloth[1], J.M. Weeks[1], Jr., M.A. Alley[1], Chris Teutsch[1], and P.M. Phipps[2],.
[1]Department of Crop and Soils Environmental Science, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060; [2]Department of Plant Pathology and Weed Science, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060

6321 Holland Rd., Suffolk, VA 23437
jfaircloth@vt.edu

INTRODUCTION

In southeastern Virginia, production of cotton and Virginia-type peanuts has been important to the economic base throughout the past century. Peanut and cotton complement each other well in rotation because they host relatively few common pests. For this reason many peanut producers throughout the U.S. peanut producing region are also cotton producers.

Following the loss of the quota program (2001), peanut acreage in southeastern Virginia has declined from 75,000 acres (30,300 ha) in 2001 to 15,000 acres (6000 ha) in 2006 (NASS, 2006a). Disease control comprises a large portion of the input costs associated with peanut production in southeastern Virginia due to the high incidence of soilborne disease associated with past short rotation intervals, i.e. one or 2 years between peanut crops. Sclerotinia blight (*Sclerotinia minor)* occurs frequently in the Mid-Atlantic States and is an expensive disease to control.

Cotton acreage in Virginia has ranged from 110,000 acres (44,500 ha) and 90,000 (40,400 ha) acres between 2000 and 2006 (NASS, 2006b). The cotton industry is characterized by volatile prices, uncertain government support programs, and increasing input costs including fuel, machinery and fertilizers. In the past several years, producers have had to utilize government price supports due to low cotton prices. Without government price supports, cotton production with current land and input costs would have produced negative economic results during recent years. These price supports are currently being scrutinized by the World Trade Organization, and many economists believe may be reduced in the 2008 farm bill (personal communication, Roberts 2007).

Development and adoption of a more environmentally and economically sustainable cotton and peanut production system is needed for Southeastern Virginia. Such systems will reduce dependency on government support payments and enable farmers in this region to be more economically competitive. Farming systems with lower economic risks, higher yield potential and more environmentally favorable practices need to be developed and their benefits demonstrated to gain widespread acceptance.

The Natural Resources and Conservation Service (NRCS) and the Farm Service Agency have initiated the Conservation Reserve Program (CRP) which offers incentives to producers adopting systems that offer environmental benefits such as soil stabilization (Farm Service Agency, 2005, Lawrence Personal Communication, 2007) and provide an opportunity for growers to transition to new cropping systems. The integration of perennial grass crops into the peanut/cotton rotation in Florida and Alabama has demonstrated potential to improve soil quality, decrease overall pesticide inputs, reduce nitrate leaching, and reduce financial risks without sacrificing profitability (Katsvairo et al., 2006). The potential benefits and feasibility of integrating perennial grass crop production into row crop systems in southeastern Virginia needs to be examined for enhancing the sustainability of cotton and peanut production.

University and USDA researchers in other states (Florida, South Carolina, Alabama, and Georgia) have similar projects underway and have demonstrated significant yield, economic, and environmental benefits of incorporating perennial grass crops into a traditional peanut/cotton rotation (Wright et al., 2002). Most recent efforts in the southeastern US have utilized bahiagrass as the grass crop in the rotation to be baled and sold, or for cattle grazing. Producers in South American countries such as Brazil, Argentina, and Uruguay have made extensive use of perennial grass based rotations for row crop production for many years. In the absence of a government price support program, 52% of farms in Uruguay utilize such systems (Prechac et al., 2002).

This project was initiated to examine the impact of incorporating perennial grasses into traditional row crop rotations in southeastern Virginia. This presentation reports cotton growth development, yield, and quality when produced following traditional row crops, tall fescue, and orchardgrass. Additionally, it reports the results from producer survey conducted to assess the potential for incorporating perennial grasses into traditional row crop sequences in Virginia.

MATERIALS AND METHODS

The study is being conducted at the Tidewater Agricultural Research and Extension Center. Eight crop rotations (see below) were selected for study and are shown in Table 1. The rotations are arranged in a Randomized Complete Block Design with four replications. Plots are 8-rows (7.38 m, 24 ft) wide by 12.3 m (40 ft) long. Thirty foot alleyways will be established between blocks for maneuvering equipment. The experiment is located on a Nansemond fine loamy sand soil series (Coarse-Loamy, Siliceous, Subactive, Thermic Aquic Hapludults).

Table 1. Eight crop rotations selected for study and the sequence of crops in each rotation for the years 2003-2007.

Rotation	2003	2004	2005	2006	2007
1	Peanut	Cotton	Cotton	Cotton	Cotton
2	Peanut	Cotton	Corn	Cotton	Peanut
3	Peanut	Cotton	Peanut	Cotton	Peanut
4	Peanut	Tall fescue	Tall fescue	Cotton	Peanut
5	Peanut	Orchardgrass	Orchardgrass	Cotton	Peanut
6	Peanut	Tall fescue	Tall fescue	Tall fescue	Peanut
7	Peanut	Orchardgrass	Orchardgrass	Orchardgrass	Peanut
8	Peanut	soybean	Cotton	Cotton	Peanut

*follow all row crops after 2005 with wheat cover after row crop harvest and until spring planting

Grass plots were all established in the early spring of 2004 and row crops were planted according to recommendations. In each row crop planting, extension recommendations were followed with respect to fertility, seed rate, variety, disease, and pest control.

Weeds in row crop plots, including those following perennial grass, are burnt down with a standard herbicide application approximately 1 month prior to planting. Cotton, corn, and soybean are strip-till planted and peanut plots are moldboard plowed in the spring followed by land conditioning. Plots will be kept weed free to eliminate competition effects and non-uniform plant response.

Sod plots were be fertilized three times annually a Gandy broadcast spreader and granular fertilizer (15-5-20) at a rate of 666 1b/acre with applications typically made three times annually. Applications were made prior to seeding and following each harvest if grass was still growing vigorously. If cutting was made in late fall no fertilizer was applied. This particular fertilizer analysis is recommended for top hay and pasture production by Virginia Cooperative Extension. The cotton, peanut, soybean, and corn crops will receive lime and fertilizer applications based on soil tests taken prior to planting in April.

In 2006, cotton will be harvested and subsamples of seedcotton from each plot ginned for lint percentage and high volume instrumentation (HVI) quality determinations. Various measurements of plant growth and maturity including nodes above cracked boll, nodes above white flower, and plant height will be monitored in cotton plots. Nutrient status of cotton plants will be monitored via tissue sampling of leaves and petioles.

At three Virginia Cooperative Extension producer meetings in 2006, surveys were completed by producers in attendance. These surveys requested information on acres planted to peanut and cotton in 2006, accessibility to forage harvesting equipment and markets, and interest in implementing rotations that incorporate perennial grasses if economically viable.

RESULTS AND DISCUSSION

All cotton had emerged by 1 week after planting (18 May). Emergence was non-uniform due to difficulties achieving uniform planting depth as well as a lack of moisture following planting. Therefore, two rows from all plots with similar plant populations were used for in-season measurements, yield, and quality. Adjacent rows were manually reseeded where necessary two weeks after planting to provide uniform competition.

Height (Table 1)

First measurements of plant height occurred on 13 June, 2006 with 10 plants from the harvest rows chosen at random. On this date, cotton plants in rotations fescue-fescue-cotton (f-f-ct) and orchardgrass-orchardgrass-cotton (o-o-ct) were significantly taller than all other treatments except continuous cotton. Continuous cotton (ct-ct-ct) was not significantly different from cotton-corn-cotton (ct-c-ct) or soybean-cotton-cotton (s-ct-ct). Rotations ct-c-ct and s-ct-ct were not significantly different from the cotton-peanut-cotton (ct-p-ct) rotation.

On 28 June, the trend of taller plants in the f-f-ct and o-o-ct rotations continued with plant height being significantly greater than any conventional rotation (ct-ct-ct, ct-p-ct, ct-c-ct, and s-ct-ct) but with no significance between the two perennial grass rotations. There were no significant differences in plant height in any of the conventional rotations.

On the 20 July, the f-f-ct continued to be significantly taller than all other plots except o-o-ct, however the latter was statistically similar to ct-ct-ct. Continuous cotton was not statistically different from any other conventional rotations.

Measurements on 27 July once again showed statistically greater heights in the f-f-ct rotation. Fescue-

fescue-cotton was not statistically different from o-o-ct, and o-o-ct was not statistically greater than either continuous cotton or ct-p-ct. Soybean-cotton-cotton and ct-c-ct were the shortest and statistically the same but not significant from ct-ct-ct or ct-p-ct.

The final measurement of plant height taken the 9 August again showed the greatest height from f-f-ct but not statistically different than that of o-o-ct or ct-p-ct. Orchardgrass-orchardgrass-cotton and ct-p-ct were also statistically the same as continuous cotton. The four conventional rotations were statistically the same.

Nodes and NAWF (Table 2)
Counts of nodes above the cotyledon were begun on the 28 June. On this date the f-f-ct rotation was statistically greater in number of nodes compared to any other rotation averaging around 1 full node more. No other plots were statistically different. The second count of total nodes was conducted one month later on the 27 July. On this date rotations f-f-ct and o-o-ct had the greatest total nodes averaged across ten plants. Continuous cotton was statistically the same as both of the rotations containing perennial grass but also statistically the same as all other conventional rotations. Nodes above white flower (NAWF) were taken in late July and early August to assess possible differences in time to reach physiological cutout. On the 27 July all plots had statistically the same NAWF with means ranging between 6.1 and 6.5 nodes, indicating similar progression to maturity among treatments. On the 9 August NAWF again was statistically the same among treatments with means ranging between 2.8 and 3.4 nodes indicating that plants had reached physiological cutout (NAWF=5) just prior to the sampling date.

Leaf and petiole sampling for nutrient status (Tables 3 & 4 respectively)
On August 9, 2006 20 leaves and petioles were sampled and separated from each plot to be analyzed for nutrient concentrations. Nutrients measured include nitrogen (N), sulfur (S), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na). Among all rotations N, Mg, Ca, and Na concentrations in the leaf and petiole samples were statistically the same.

Leaf S concentration was statistically greatest in rotations ct-p-ct, f-f-ct, and o-o-ct. Continuous cotton was statistically equal to both the latter three rotations as well as the s-ct-ct rotation. Soybean-cotton-cotton was also statistically the same as c-ct-ct which had the lowest leaf concentrations. Petiole samples reflected similar S concentrations as the leaf samples. Continuous cotton, ct-p-ct, f-f-ct, and o-o-ct were statistically the same and had the highest concentrations of S. Cotton-corn-cotton and s-ct-ct were statistically the same with the lowest concentrations.

Phosphorous was found to be the in the highest concentration in leaf samples in the f-f-ct rotation. Orchardgrass-orchardgrass-cotton, ct-ct-ct, and ct-c-ct were statistically the same with slightly lower leaf phosphorous concentrations than f-f-ct rotation. Cotton-peanut-cotton and s-ct-ct were lowest and statistically the same for leaf phosphorous. The latter two rotations were also statistically the same as ct-ct-ct and ct-c-ct. Fescue-cotton-cotton also had the highest mean petiole P concentration and was statistically equal to o-o-ct. Orchardgrass-orchardgrass-cotton was statistically the same as continuous cotton and ct-c-ct which had the next highest petiole P concentrations. The lowest petiole P concentrations were again found in ct-p-ct and s-ct-ct which were statistically equal to each other as well as continuous cotton and ct-c-ct.

Leaf potassium concentrations showed an opposite trend compared to all other nutrients which had shown differences between treatments. The highest concentrations of K were found in continuous cotton, ct-c-ct, ct-p-ct, and s-ct-ct which were all statistically equal. Cotton-peanut-cotton was statistically the same as o-o-ct which had the next highest concentrations of leaf K. Fescue-cotton-cotton had the lowest leaf K concentration and was statistically the same as o-o-ct. Petiole potassium concentrations on the other hand showed no statistical difference between the rotations.

Leaf area index (Table 5)

Measurement of Leaf Area Index (LAI) was collected on the 18th of August, 2006. Measurements were made in two locations of each treatment between the two rows designated for harvesting. Treatments ct-p-ct, f-ct-ct, and o-o-ct were statistically similar. Treatments o-o-ct and ct-p-ct were statistically similar as treatments ct-ct-ct and s-ct-ct. Treatments ct-ct-ct, ct-c-ct, ct-p-ct, and s-ct-ct were also statistically similar. Data from leaf area index is shown in table 4.

Lint yield (Table 6) and fiber properties

Cotton following the two year perennial grass treatments (f-f-ct or o-o-ct) yielded significantly greater lint than any other rotation. The yields of cotton in treatments following two years of either perennial grass were insignificant between the grasses. Yields of the remaining four treatments (ct-ct-ct, ct-c-ct, ct-p-ct, and s-ct-ct) were insignificant between these treatments. Data for yield and % lint can be found in table 5 and figure 2.

There were no differences in the micronaire, fiber length, strength, and uniformity of lint.

Producer Survey

The producer survey represented 31 producers. Sixty five percent of the producers planted cotton in 2006, 90% planted peanut, and 61% planted both peanut and cotton. The percentage of total acres in Virginia represented for cotton and peanut were 10 and 18 percent respectively. The percentage of producers that had livestock was 49 and the percentage of producers that produced hay crops was 39. Of the producers surveyed, 68% indicated they would have an interest in incorporating perennial grasses into their current rotations if it is feasible.

CONCLUSION

Based on the producer survey, there appears to be an interest in incorporating perennial grasses into current crop rotations in Virginia. This may be due to the number of producers (49%) that are currently involved in livestock and/or forage production in addition to producing row crops. The economic feasibility of incorporating fescue and orchardgrass into rotations has not been determined and is certain to vary with each producer. Government incentives for conservation efforts, labor and producer time constraints, access to hay markets on and off producer farms, and availability of hay/pasture equipment are just a few of numerous factors that will influence the feasibility.

As measured by plant height and LAI, cotton growth following perennial grasses was enhanced relative to following other row crops utilized in this study. Earlier canopy closure, as measured by LAI, reduces the sunlight reaching the ground in row middles, reducing the window of time when many weeds will germinate and thus reducing the need for late season herbicide applications and/or plant competition. The economics of cotton production following perennial grasses was enhanced in 2006 due to increased cotton lint yields. This study does not conclude that this yield enhancement will occur every year and the underlying factors supporting it are currently being investigated. Also, the question remains of whether the increase in lint yield in one season will offset possible income reductions while the land is planted to perennial grasses. As previously mentioned, the inherent challenge in determining the economics is accounting for the variability in government programs, commodity prices, land rental vs. ownership, and individual farming enterprises.

REFERENCES CITED

Farm Service Agency. 2005 fiscal year report on Conservation Reserve Program. www.fsa.usda.gov/Internet/FSA_File/jy2005.pdf. Accessed January 26, 2007.

Katsvairo, T.W., D. L. Wright, J. J. Marois, D. L. Hartzog, J. R. Rich, and P. J. Wiatrak. 2006. Sod-Livestock Integration into the Peanut-Cotton Rotation: A Systems Farming Approach. Agron. J. 98:1156-1171.

Lawrence, C. Agronomist, USDA-NRCS. Personal Communication February 1, 2007.

National Agricultural Statistics Service (NASS). 2006a. Peanut acreage years 2001 through 2006 by state. www.nass.usda.gov:8080/Quickstats/PullData_US.jsp. Accessed May 23, 2006.

National Agricultural Statistics Service (NASS). 2006b. Cotton acreage years 2001 through 2006 by state. www.nass.usda.gov:8080/Quickstats/index2.jsp. Accessed May 23, 2006.

Prechac, F.G., O. Ernst, G. Siri, and J.A. Terra. 2002. Integrating No-Till Into Livestock Pastures and Crops Rotation in Uruguay. Proc. Of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. 74-80.

Roberts, M.T. Extension Agent, Commodity Marketing. Virginia Cooperative Extension. Personal Communication February 9, 2007.

Wright, D.L., J.J. Marois, and P.J. Wiatrak. 2002. Perennial Forage in Rotation with Row Crops in the Southeast. Proc. Of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. 87-92.

	Plant Height (inches)				
Treatment	**13-Jun-06**	**28-Jun-06**	**20-Jul-06**	**27-Jul-06**	**9-Aug-06**
Ct-Ct-Ct-Ct	**5.9 ab**	**7.8 b**	**19.1 bc**	**22.1 bc**	**25.3 bc**
Ct-C-Ct-P	**5.5 bc**	**7.7 b**	**17.7 c**	**20.3 c**	**21.6 c**
Ct-P-Ct-P	**5.2 c**	**7.6 b**	**18.7 c**	**21.9 bc**	**26 abc**
F-F-Ct-P	**6.3 a**	**9.7 a**	**22.7 a**	**26.7 a**	**30.3 a**
O-O-Ct-P	**6.1 a**	**9.1 a**	**21.3 ab**	**25 ab**	**29.6 ab**
S-Ct-Ct-P	**5.5 bc**	**7.9 b**	**18.6 c**	**20.7 c**	**23.4 c**

Table 1: Cotton heights in inches
Means followed by the same letter do not significantly differ (P=0.05, LSD)

	Avg. Nodes per 10 plants			Nodes Above White Flower	
Treatment	**28-Jun-06**	**27-Jul-06**	**9-Aug-06**	**27-Jul-06**	**9-Aug-06**
Ct-Ct-Ct-Ct	**7.1 b**	**13.7 ab**	**14.2 b**	**6.5 a**	**3.8 a**
Ct-C-Ct-P	**7.2 b**	**13.2 b**	**13.2 c**	**6.1a**	**3.4 a**
Ct-P-Ct-P	**7.3 b**	**13.1 b**	**14.3 ab**	**6.4 a**	**4.0 a**
F-F-Ct-P	**8.1 a**	**14.3 a**	**15.3 a**	**6.4 a**	**4.8 a**
O-O-Ct-P	**7.4 b**	**14 a**	**14.7 ab**	**6.5 a**	**4.1 a**
S-Ct-Ct-P	**7.1 b**	**13.1 b**	**13.8 bc**	**6.1 a**	**3.5 a**

Table 2: Mean nodes per 10 plants and mean NAWF
Means followed by the same letter do not significantly differ (P=0.05, LSD)

	Leaf Tissue Analysis by %						
Treatment	**Nitrogen**	**Sulfur**	**Phosphorous**	**Potassium**	**Magnesium**	**Calcium**	**Sodium**
Ct-Ct-Ct-Ct	**4.395 a**	**0.608 ab**	**0.325 bc**	**2.175 a**	**0.548 a**	**2.638 a**	**0.038 a**
Ct-C-Ct-P	**4.665 a**	**0.378 c**	**0.353 bc**	**2.035 a**	**0.58 a**	**2.718 a**	**0.038 a**
Ct-P-Ct-P	**4.379 a**	**0.73 a**	**0.318 c**	**1.893 ab**	**0.555 a**	**2.68 a**	**0.043 a**
F-F-Ct-P	**4.367 a**	**0.67 a**	**0.44 a**	**1.54 c**	**0.535 a**	**2.333 a**	**0.035 a**
O-O-Ct-P	**4.360 a**	**0.655 a**	**0.378 b**	**1.713 bc**	**0.555 a**	**2.550 a**	**0.035 a**
S-Ct-Ct-P	**4.524 a**	**0.468 bc**	**0.3 c**	**2.035 a**	**0.555 a**	**2.623 a**	**0.035 a**

Table 3. Analysis of leaf tissue for nutrient content. 20 leaves analyzed per plot..
Means followed by the same letter do not significantly differ (P=0.05, LSD)

	Petiole Tissue Analysis by %						
Treatment	**Nitrogen**	**Sulfur**	**Phosphorous**	**Pottasium**	**Magnesium**	**Calcium**	**Sodium**
Ct-Ct-Ct-Ct	**2.053 a**	**0.24 a**	**0.275 bc**	**6.663 a**	**0.705 a**	**1.980 a**	**0.033 a**
Ct-C-Ct-P	**1.928 a**	**0.125 b**	**0.263 bc**	**5.003 a**	**0.725 a**	**1.883 a**	**0.028 a**
Ct-P-Ct-P	**2.057 a**	**0.240 a**	**0.243 c**	**6.045 a**	**0.753 a**	**2.153 a**	**0.028 a**
F-F-Ct-P	**1.853 a**	**0.260 a**	**0.390 a**	**5.985 a**	**0.708 a**	**1.993 a**	**0.030 a**
O-O-Ct-P	**2.108 a**	**0.235 a**	**0.323 ab**	**6.705 a**	**0.725 a**	**2.070 a**	**0.030 a**
S-Ct-Ct-P	**1.809 a**	**0.158 b**	**0.210 c**	**5.875 a**	**0.705 a**	**1.853 a**	**0.030 a**

Table 4: Analysis of petiole tissue for nutrient content. 20 petioles analyzed per plot.
Means followed by the same letter do not significantly differ (P=0.05, LSD)

Leaf Area Index	
Treatment	**LAI**
Ct-Ct-Ct	**1.56 bc**

Ct-C-Ct	**1.20 c**
Ct-P-Ct	**1.84 abc**
F-F-Ct	**2.20 a**
O-O-Ct	**1.97 ab**
S-Ct-C	**1.35 bc**

Table 5: Leaf Area Index measured August 18th, 2006.
Means followed by the same letter do not significantly differ (P=0.05, LSD).

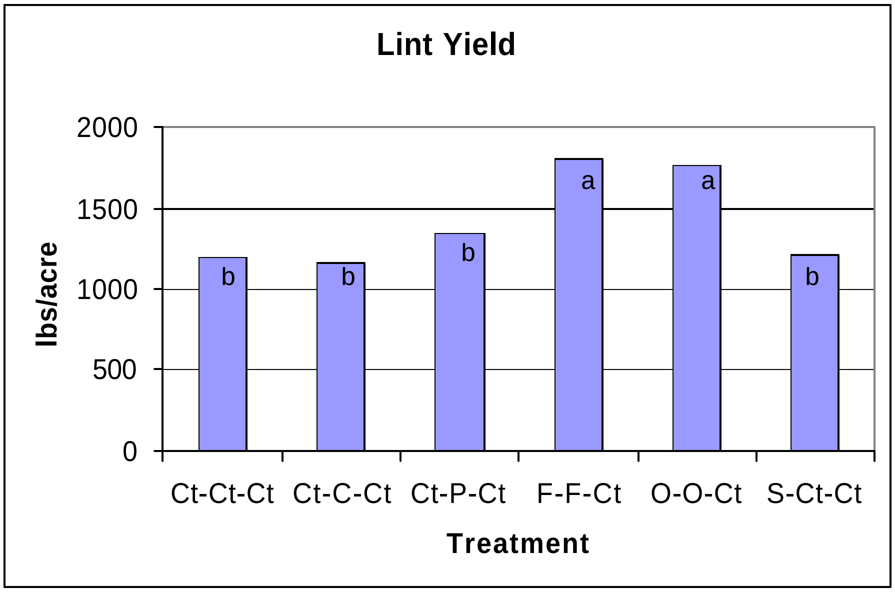


Figure 1: Lint yield of treatments in lbs/acre.
Bars labeled with the same letter do not significantly differ. (P=0.05, LSD)

AGCLIMATE: CROP YIELD RISK DECISION SUPPORT SYSTEM FOR THE SOUTHEASTERN USA

C. W. Fraisse

Agricultural & Biological Engineering Department

University of Florida

Introduction

Seasonal climate variability is a major source of production risks. The majority of crop failures in the U.S. are associated with either a lack or excess of rainfall (Ibarra and Hewitt, 1999). Climate variability is also associated with other sources of production risks such as pest and disease incidence. Weather patterns, including high temperature and humidity, and the potential for daily rainfall, can favor the outbreak of fungal diseases. They can also impact the reproductive cycle of other pests and insects that function as disease vectors (Fraisse et al., 2006). Crop yield variability differs geographically and depends on soil type and quality, climate, and management practices such as irrigation and fertilization. In the U.S., yield variability tends to be the lowest in irrigated areas and in the central Corn Belt, where soils are deep and rainfall dependable (Hardwood et al., 1999). In the Southeast, in spite of annual average precipitation around 60 inches in certain areas such as the Florida panhandle, yield variability can be substantial due to low water holding capacity soils and the potential for the lack of rainfall during critical phases of crop development.

The El Niño Southern Oscillation (ENSO) phenomenon is the strongest driver of interannual climate variability around the world (Ropelewski and Halpert, 1996) and affects crop production in many regions. ENSO phases are characterized by sea surface temperature anomalies in the eastern equatorial Pacific Ocean. When sea surface temperature (SST) is higher than normal the phenomenon is referred as El Niño. Associated with the warmer surface temperatures is an increase in convective activity, and at a certain stage, a persistent reduction of the normally westward flowing winds (Cane, 2001). When the sea-surface temperature is lower than normal, the phenomenon is referred to as La Niña. During La Niña events, the equatorial trade winds strengthen, resulting in colder water being brought up from the ocean's floor. Neutral is the term for when neither El Niño nor La Niña are present in the Pacific. Under Neutral conditions, trade winds blow from east to west near the Equator in the Pacific Ocean.

Previous research has demonstrated that ENSO exerts a substantial influence on the climate of the Southeastern U.S. El Niño years tend to be cool and La Niña years tend to be warm between October and April (Kiladis and Diaz, 1989; Sittel, 1994, Mearns et al., 2003). Although the influence on rainfall is spatially less consistent, El Niño years tend to be wet and La Niña years dry during these months. The ENSO signal in the region is strongest in the fall and winter months; some evidence exists that La Niña summers tend to be slightly wetter than normal (Sittel, 1994). The impact of climate variability on crop yields in the southeastern U.S. has been well documented. Hansen et al. (1998) analyzed the historical (1960-1995) response of total production value and its components (yield, area harvested and price) to ENSO phases and quarterly SST for six crops (peanut, tomato, cotton, tobacco, corn and soybean) in four southeastern states (Alabama, Florida, Georgia and South Carolina). ENSO phase significantly influenced corn and tobacco yields, the areas of soybean and cotton harvested, and the values of corn, soybean, peanut and tobacco. ENSO phases explained an average shift of $212 million, or 25.9%, of the value of corn. They also identified significant responses of corn, soybean and cotton yields, and peanut value to SST across the region. Additionally peanut and tobacco yields, and tomato and soybean values in particular states were significant effected.

Based on the strong evidence that climate variability plays an important role on crop yields in the southeastern USA, a crop yield risk analysis component was developed under the framework of a web-based climate decision support system (http://www.agclimate.org) designed to help producers analyze and mitigate risks associated with climate variability.

AgClimate.org

AgClimate is a web-based climate forecast and decision support system developed by the Southeast Climate Consortium (SECC) in partnership with the Cooperative State Extension Service. The SECC is a coalition of six universities - Florida State University, University of Florida, University of Miami, University of Georgia, Auburn University, and University of Alabama-Huntsville. AgClimate and the other programs of the SECC are designed around broad themes of product assessment and evaluation, program evaluation, and economic analysis and highlight research done into the fields of climate, forestry, agricultural risk, extension, and natural resources and the environment. Information available in *AgClimate* includes climate forecasts combined with risk management tools and information for selected crops, forestry, pasture, and livestock.

Crop Yield Risk Tools in AgClimate

Production or yield risk comes from the unpredictable nature of the weather and uncertainty about the performance of crops under the pressure of diseases and pests or other unpredictable factors. Production and price risks, together with other forms of risk such as institutional and financial risks are significant factors affecting the profitability and long term sustainability of the farm enterprise. Several strategies can be adopted by producers to help minimize the impacts of adverse climate on crop yield. Changing crops or varieties, planting dates, and investing in irrigation equipment are a few examples of the decisions that a producer can contemplate. Nevertheless, the process to minimize yield risk must include an understanding or quantification of the risk involved; the ability to simulate what-if scenarios for evaluating potential adaptation strategies, and real time information and weather monitoring.

Figure 1 illustrates the various components of the yield risk analysis component available in *AgClimate.* Past yield records can be analyzed in conjunction with historical weather information to help producers understand the effects of ENSO phases on crop yield. Crop models can be used in conjunction with climate forecasts for evaluating alternative management practices such as planting dates, crops and varieties. Yield potential (future) at a given location under different climate scenarios and management practices can be simulated to help producers in their decision making process. Once a season starts and the crop is planted (present) risks associated with climate variability can be minimized by monitoring real time weather and taking the necessary actions when possible. Information provided by *AgClimate* does not include real time weather monitoring capabilities but it links to agricultural weather networks in the States of Florida (Florida Automated Weather Network, FAWN) and Georgia (Georgia Automated Environmental Monitoring Network). In addition to links to real time weather monitoring networks, climate outlooks and agricultural outlooks released throughout the year provide producers with an update on current conditions and a summary interpretation of the latest climate forecast. In the case of agricultural outlooks, potential impacts are listed and adaptation strategies are discussed. Agricultural outlooks are produced by climate extension specialists in partnership with commodity specialists.

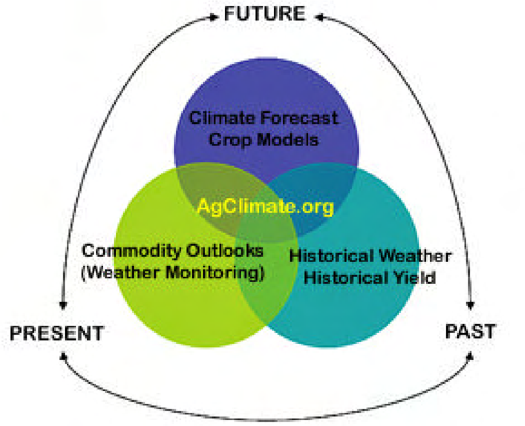


Figure 1. Framework for crop yield risk analysis in AgClimate.

Historical Yield Tools

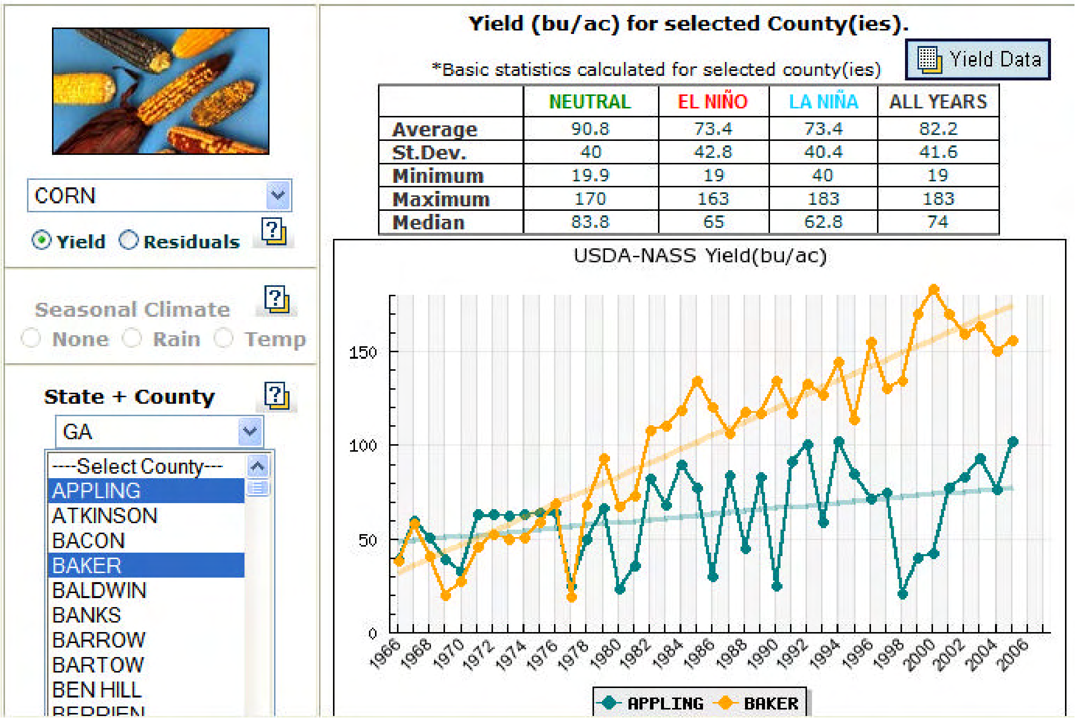
Historical yield records at the county level can provide a valuable perspective of the possible influence of ENSO on crop yield. However, in addition to climate variability, historical crop yield data integrates a number of factors such as technological advances (improved varieties or management, shifts from rainfed to irrigated production) and price cycles. The data needs to be processed to separate the effects of seasonal climate variability from other factors that tend to change more slowly. Long term trends need to be removed from the dataset to allow the analysis of more frequent shifts related to climate variability.

Historical yield trends can be analyzed in *AgClimate* using two different approaches. First, users can plot county level time series based on records from the USDA-National Agriculture Statistics Service (NASS). This dynamic tool (Figure 2) allows users to plot county historical yield for several crops including corn, cotton, peanut, soybean, potato, and others. The user can plot crop yield time series for one or more counties allowing yield comparison among counties. The tool calculates summary statistics based on the records for the selected counties for each ENSO phase and also for all years in the database. The user has also the option to review yield values by year in a table format by clicking on "Yield Report" or to plot seasonal total rainfall or average temperature by selecting the appropriate radio button in the left side menu. This last option is only available when only one county is selected. A linear trend line is fitted to represent yield trends of each individual county and residuals (the deviations from the fitted line to the observed values) can be visualized to allow a better evaluation of climate variability impacts on yield (Figure 3). The plot of residuals also includes a small bar graph on the top right corner of the page displaying average residuals for each ENSO phase. In the case of the example shown in Figure 3, it can be observed that corn yields are, on average, lower during El Niño years (-8.9%). It can also be noticed that yield variability in Appling County was more intense during the last 10 to 15 years than the observed for Baker County. This could be potentially explained by a shift to irrigated production in Baker County, which would also help explain the more significant upward trend in actual yields (Figure 2).

Average residuals can be visualized in a map format by selecting the regional yield trend maps tool. Maps showing average crop yield residuals for each ENSO phase can be displayed providing a regional overview of potential production risks for each ENSO phase. It is important to recognize that regional averages are a good first piece of information but do not include any probabilistic information that must be taken into consideration when dealing with effects of climate variability on crop yield. Figure 4 shows the average soybean yield residuals observed during El Niño years in the states of Alabama, Florida, and Georgia. It can be noticed that, on average, soybean yields tend to be below average in the northern regions of Alabama and Georgia during El Niño years. This information by itself can trigger producers in those regions to consider better crop insurance coverage during years when an El Niño is taking place.

Crop Model-Based Yield Tools

A crop modeling effort was undertaken for selected commodities with the objective of providing base lines for evaluating crop production risk under alternative climate forecasts. The crops that were initially selected are peanut, tomato, and potato. The Decision Support System for Agrotechnology Transfer – Cropping System Model (DSSAT-CSM) suite of crop models (Jones et al., 2003) was used for this effort. The DSSAT-CSM Version 4.0 (Hoogenboom et al., 2004) crop models are process based models that simulate crop growth and development, soil water processes, and nitrogen balances. Long-term historical weather compiled from the National Weather Service was used for the simulations. A solar radiation generator, WGENR, with adjustment factors obtained for the Southeastern USA (Garcia and Hoogenboom, 2005) was used to generate daily solar radiation data. Soil profile characteristics for the main agricultural soil types in each county were obtained from the soil characterization database of the USDA National Resource Conservation Service.



CORN

● Yield ○ Residuals

○ None ○ Rain ○ Temp

State + County

GA

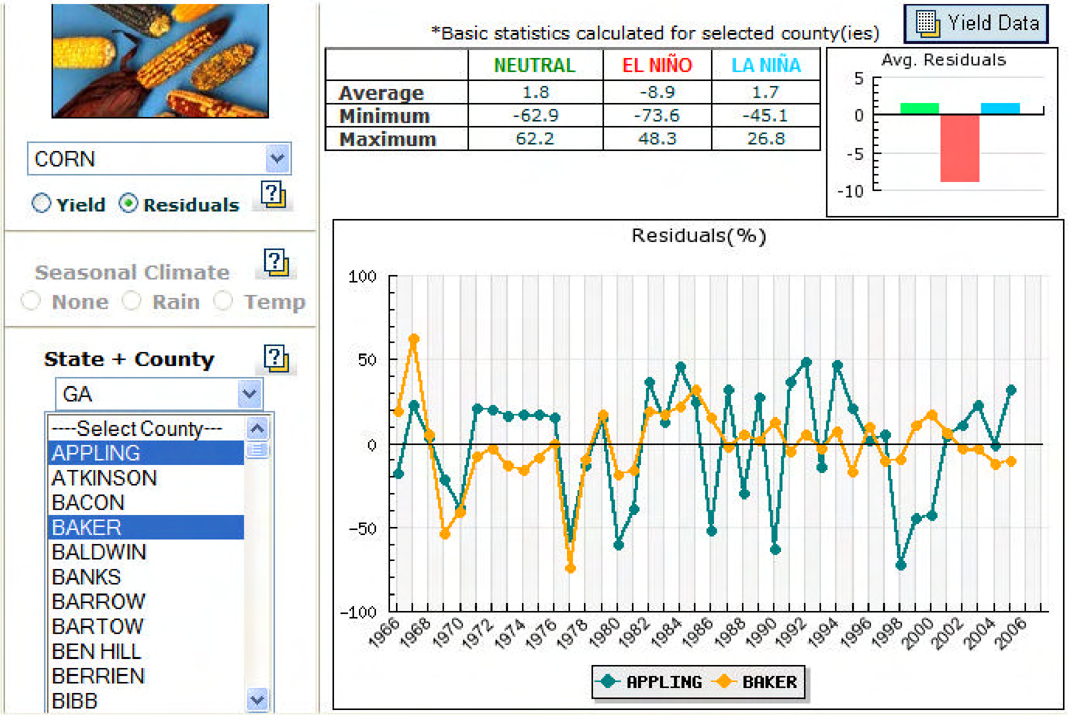
----Select County---
APPLING
ATKINSON
BACON
BAKER
BALDWIN
BANKS
BARROW
BARTOW
BEN HILL

Yield (bu/ac) for selected County(ies).

*Basic statistics calculated for selected county(ies)

	NEUTRAL	EL NIÑO	LA NIÑA	ALL YEARS
Average	90.8	73.4	73.4	82.2
St.Dev.	40	42.8	40.4	41.6
Minimum	19.9	19	40	19
Maximum	170	163	183	183
Median	83.8	65	62.8	74

Figure 2. Corn historical yield time series for Appling and Baker counties, GA.



CORN

○ Yield ● Residuals

○ None ○ Rain ○ Temp

State + County

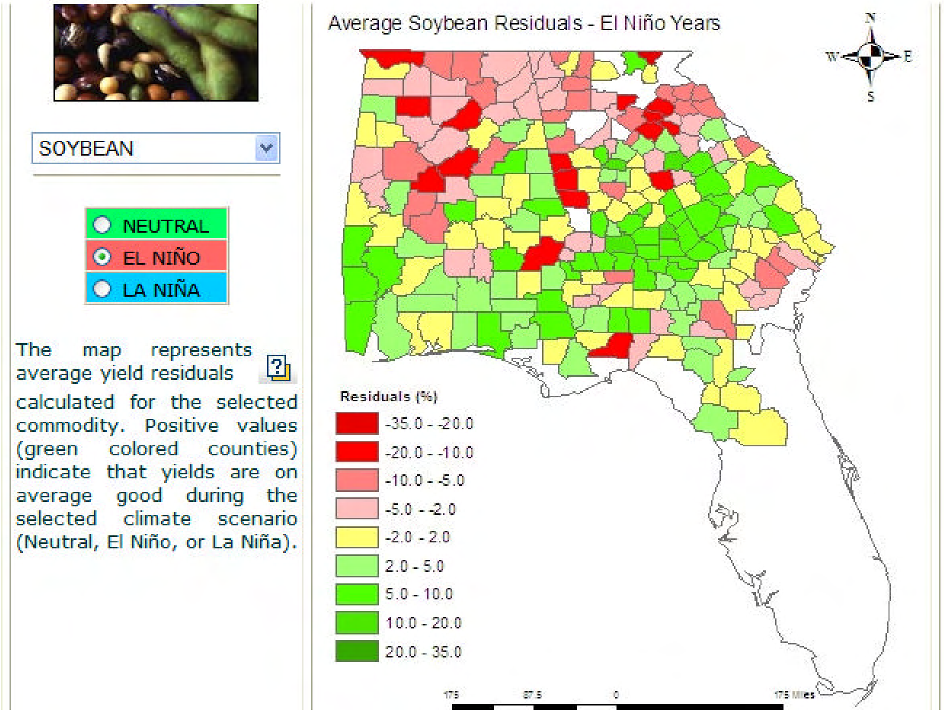
GA

----Select County---
APPLING
ATKINSON
BACON
BAKER
BALDWIN
BANKS
BARROW
BARTOW
BEN HILL
BERRIEN
BIBB

*Basic statistics calculated for selected county(ies)

	NEUTRAL	EL NIÑO	LA NIÑA
Average	1.8	-8.9	1.7
Minimum	-62.9	-73.6	-45.1
Maximum	62.2	48.3	26.8

Figure 3. Corn yield residuals (%).



The map represents average yield residuals calculated for the selected commodity. Positive values (green colored counties) indicate that yields are on average good during the selected climate scenario (Neutral, El Niño, or La Niña).

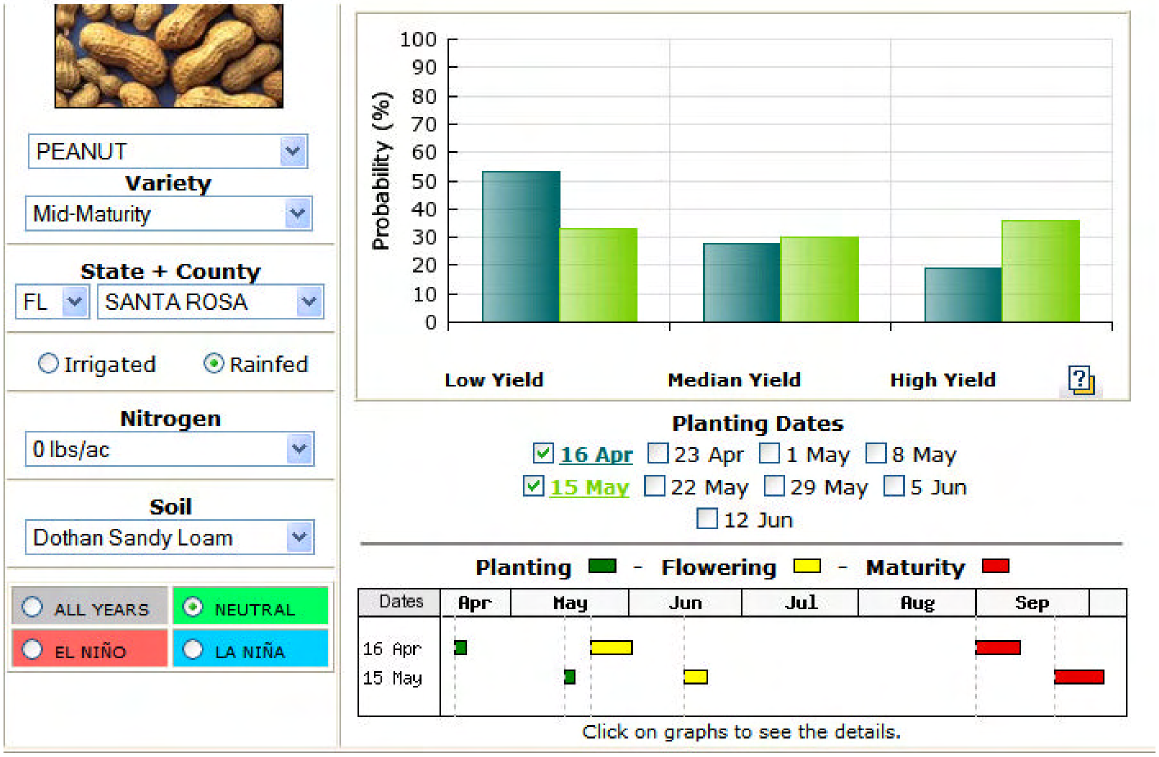
Figure 4. Regional map of average soybean yield residuals during El Niño years.

The CSM-CROPGRO-Peanut (Hoogenboom et al., 1992; Boote et al. 1998; Jones et al., 2003), CROPGRO-Tomato (Scholberg et al., 1997), and SUBSTOR-Potato (Ritchie, 1995) crop models were used to simulate crop yield under different management scenarios using weather data from 1950-2004 for several counties in Georgia, Florida and Alabama. In the case of peanut, the Georgia Green peanut cultivar, a medium maturing runner-type peanut variety, was selected as the representative variety for the main peanut producing counties in each state. The typical planting window for peanuts is between mid-April and mid-June. Peanut responses were simulated with and without irrigation. Potatoes are grown commercially in Florida in the winter and spring months when the days are warm and the nights are cool. Potato simulations were performed for the variety Atlantic which is a standard variety for processing with high yield potential. Tomato simulations focused initially on the fresh market tomato crop produced in Fall-Winter-Spring in south Florida. A common tomato cultivar, Sunny, was selected to represent the range of cultivars grown in South Florida.

The crop model-based dynamic tool available in *AgClimate* allows users to analyze yield probability distributions for various planting dates under alternative climate scenarios or ENSO phases. Figure 5 shows yield probabilities for peanut planted on April 16 and May 15 in Santa Rosa County, Florida, during neutral years. The user can select one or more planting dates to explore potential yield effects. In the example shown in Figure 5, it can be noticed that peanut planted on May 15th carries a higher chance of yielding in the top one third of all potential outcomes. A phenology table underneath the probability graph shows the period of time when flowering and maturity are expected for peanut planted in the selected dates. Crop model results are currently available for a limited number of counties and soil types. Additional crops including cotton and corn are currently under implementation and should soon be available.

Climate and Agricultural Outlooks

AgClimate releases climate outlooks four times during the year. The main purpose of the outlooks is to summarize current conditions and expected climate conditions during the next two or three months. Climate outlooks are released in order to match producers' decision calendar such as early spring before planting, mid-summer during crop development stages, and mid to late fall, when citrus and winter vegetable producers are concerned about freeze forecasts. Agricultural outlooks have been recently added to the suite of products in *AgClimate*. The main purpose of these outlooks is to translate climate outlooks into practical actions for the various crops.



PEANUT

Variety: Mid-Maturity

State + County: FL SANTA ROSA

○ Irrigated ● Rainfed

Nitrogen: 0 lbs/ac

Soil: Dothan Sandy Loam

○ ALL YEARS ● NEUTRAL
○ EL NIÑO ○ LA NIÑA

Planting Dates
☑ 16 Apr ☐ 23 Apr ☐ 1 May ☐ 8 May
☑ 15 May ☐ 22 May ☐ 29 May ☐ 5 Jun
☐ 12 Jun

Click on graphs to see the details.

Figure 5. Yield risk tool showing yield probabilities for peanut planted on April 16 and May 15 in Santa Rosa County, Florida, during neutral years.

Summary and Conclusions

A web-based set of dynamic tools for analyzing crop yield risk associated with climate variability has been developed under *AgClimate.org*. Crop yield risk can be analyzed by means of historical yield records or by evaluating potential yield levels using crop models in conjunction with ENSO-based climate forecasts. The main purpose of this study was to provide extension agents and producers in the southeastern U.S. with a set of tools to quantify yield risk and define adaptation strategies in light of climate forecasts. Adaptation strategies must take into account a number of factors in addition to climate forecasting, such as commodity prices and availability of equipment and labor. The goal is not to provide a recommendation but information and ways to explore options for adaptation. Historical yield can be analyzed in conjunction with climate using different approaches, plotting county level yield time series based on records from the USDA-NASS database or mapping average crop yield residuals for each ENSO phase. Historical yield can be analyzed for several crops including corn, cotton, peanut, soybean, potato, sugarcane and winter wheat. Yield risk can also be quantified by analyzing simulated yields obtained by using crop models in conjunction with climate forecasts. Crop model-based analysis is available for a limited number of crops (peanut, potato, and tomato) and geographic locations. This tool allows users to estimate yield potential for alternative management practices such as planting dates and irrigation. In addition to dynamic tools, agricultural outlooks are produced by climate extension specialists in partnership with crop specialists to help producers identify adaptation strategies.

References

Boote, K. J., Jones, J. W., Hoogenboom, G., 1998: Simulation of crop growth: CROPGRO Model. Agricultural Systems Modeling and Simulation, R. M. Peart and R. B. Curry, Eds., Marcel Dekker, New York, 113-133.

Cane, M. A., 2001. Understanding and predicting the world’s climate system. In: Impacts of El Niño and climate variability on agriculture. American Society of Agronomy (ASA) Special Publication 63.

Fraisse, C. W., N. Breuer, J. G. Bellow, V. Cabrera, U. Hatch, G. Hoogenboom, K. Ingram, J. W. Jones, J. O’Brien, J. Paz, and D. Zierden. 2006. AgClimate: A climate forecast information system for agricultural risk management in the southeastern USA. *Computers & Electronics in Agriculture* 53(1):13-27.

Garcia y Garcia, A., and G. Hoogenboom. 2005. Evaluation of an improved daily solar radiation generator for the southeastern USA. Climate Research 29:91-102.

Hansen, J. W., Hodges, A. W., Jones, J. W., 1998. ENSO influences on agriculture in the Southeastern US. *J. of Climate* 11(3):404-411.

Harwood, J., Heifner, R., Coble, K., Perry, J., Somwaru, A., 1999. Managing Risk in Farming: Concepts, Research, and Analysis. United States Dept. of Agriculture, Economic Research Service (AER-774).

Hoogenboom G., Jones, J. W., Boote, K. J., 1992: Modeling growth, development, and yield of grain legumes using SOYGRO, PNUTGRO, and BEANGRO: a review. *Transactions of the ASAE*, 35: 2043-2056.

Hoogenboom, G., J.W. Jones, P.W. Wilkens, C.H. Porter, W.D. Batchelor, L.A. Hunt, K.J. Boote, U. Singh, O. Uryasev, W.T. Bowen, A.J. Gijsman, A. du Toit, J.W. White, and G.Y. Tsuji., 2004. Decision Support System for Agrotechnology Transfer Version 4.0 [CD-ROM]. University of Hawaii, Honolulu, HI.

Ibarra, R., Hewitt, T., 1999: Utilizing crop insurance to reduce production risk, Institute of Food and Agricultural Sciences (IFAS Publication FE-198), Florida Cooperative Extension Service, Gainesville, Florida.

Jones, J. W., Hoogenboom, G., Porter, C. H., Boote, K. J., Batchelor, W. D., Hunt, L. A., Wilkens, P. W., Singh, U., Gijsman, A. J., Ritchie, J. T., 2003: DSSAT Cropping System Model. *European Journal of Agronomy* 18:235-265.

Kiladis, G. N., Diaz, H. F., 1989. Global climatic anomalies associated with extremes in the Southern Oscillation. J. of Climate 2:1069-1090.

Mearns, L. O., Giorgi, F., McDaniel, L., Shields, C., 2003. Climate Scenarios for the Southeastern U.S. based on Regional Model Simulations. *Climatic Change* 60: 7-35.

Ritchie, J. T., Griffin, T. S., Johnson, B. S., 1995. SUBSTOR: Functional model of potato growth, development, and yield. In Modelling and Parameterization of the Soil–Plant–Atmosphere System: A Comparison of Potato Growth Models, 401–434. P. Kabat, B. Marshall, B. J. van den Broek, J. Vos, and H. van Keulen, eds. Wageningen, The Netherlands: Wageningen Press.

Ropelewski, C. F., Halpert, M. S., 1996. Quantifying southern oscillation: precipitation relationships. *J. Climate* 9:1043-1059.

Scholberg, J. M. S., Boote, K. J., Jones, J. W., McNeal, B. L., 1997. Adaptation of the CROPGRO model to simulate the growth of field-grown tomato. In: Kropff, M. J. et al. (Ed.), Systems approaches for sustainable agricultural development: Applications of systems approaches at the field level. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 133-151.

Sittel, M. C., 1994. Marginal probabilities of the extremes of ENSO events for temperature and precipitation in the Southeastern United States. Tech. Rep. 94-1, Center for Ocean-Atmospheric Studies. The Florida State University, Tallahassee, FL.

SITE-SPECIFIC MANAGEMENT OF COTTON PRODUCTION USING REMOTE SENSED THERMAL IMAGERY WITHIN A CONSERVATION TILLAGE SYSTEM

John Fulton, Dana Sullivan, Joey Shaw, Mark Dougherty, and Geoff Bland
Auburn University, 200 Corley Bldg, Auburn, AL 36849
fultojp@auburn.edu

Abstract

Thermal infrared (TIR) imagery has shown promise for early detection of crop stress while conservation tillage practices have provided benefits to cotton production. The objective of this investigation was to evaluate cotton production on rolling terrain irrigated with subsurface-drip irrigation (SDI) while using TIR for in-season detection of cotton response to irrigation and management in Northern Alabama. A 15-acre field located at the Tennessee Valley Research and Extension Center (TVREC) was used for this study and is managed as a no-tillage, continuous cotton system. Treatments consisted of irrigation (SDI vs. non-irrigated) and crop residue cover (cover vs. no-cover). TIR imagery was acquired in-season using an unmanned aerial system equipped with a TIR sensor. Results indicated that TIR emittance correlated well with canopy cover ($r = -0.44$, $\alpha < 0.05$) and stomatal conductance ($r= -0.48$, $\alpha < 0.05$). Differences between irrigated and non-irrigated plots existed with irrigated yields over 50% higher. Cover treatments yielded higher than no cover. Results from this investigation showed promise that TIR imagery could be used for site-specific management of cotton.

Introduction

The production of cotton plays an important role in the row crop agricultural economy in Alabama. Production systems using conservation tillage have been successfully adopted showing benefits for both soil and water conservation. However, drought continues to negatively affect yields while generating considerable yield variability within and between years depending on the timing and adequacy of rainfall. New technologies offer the opportunity to integrate precision agriculture techniques with precision irrigation technology to maximize yield each year while optimizing the use of production inputs such as fertilizer, agricultural chemicals, and seed. These technologies include pressure compensated subsurface drip irrigation (SDI) and the use of unmanned aerial vehicles (UAV's) to collect remote sensed imagery cost effectively.

Pressure compensated SDI offers a method to apply subsurface water uniformly on rolling terrain by maintaining uniform emitter flow over a range of operating pressure differences. Traditional or non-pressure compensating SDI is impacted when installed on rolling terrain because gravity causes more water to be distributed down slope. System design and management is a major factor in determining application uniformity. Due to the nature of the system, emitter clogs, crimped lines or other subsurface issues are not visible. Once crop stress is observed, oftentimes the effects are identified too late and result in yield loss. Better methods for determining issues is needed so they can be corrected in a timely fashion to minimize potential impacts on yield.

Past research has reported that reflectance and emittance spectra data can be used to evaluate in situ crop stress (Colwell, 1956; Jackson et al., 1983; Penuelas et al., 1993; Shanahan, 2001). Recent development of high spatial and spectral resolution sensors, collection of remote sensed data applications for site-specific and irrigation management, soil sampling and potential problem areas are being investigated. However, the expense and timeliness of obtaining high resolution remotely sensed imagery has limited the adoption of it by crop producers. The use of low-altitude UAVs for acquiring imagery on crop fields is a technique that has not been well-investigated. Simpson et al. (2003) acquired VIS and NIR imagery via a UAV to differentiate between variable nitrogen rates and water treatments in a corn canopy. Herwitz et al. (2002) used an UAV to assess field equipped with a multispectral camera and found reflectance patterns from the coffee tree canopy were positively related to yield.

The use of thermal infrared (TIR) sensors has been limited to date due to timeliness of data acquisition, data delivery and spatial resolution constraints. Barnes et al. (2000) found a linear relationship existed between the crop water stress index (CWSI) and soil water depletion when they evaluated a prototype sensor (VIS, NIR and TIR) mounted to an irrigation system to assess nitrogen and water stress within a cotton field. However, while TIR shows promise for use in in-season evaluation of crop stress, additional research is needed to fully establish its potential. Therefore, the objective of this investigation was to evaluate cotton production on rolling terrain irrigated with subsurface-drip irrigation (SDI) while using TIR for in-season detection of cotton response to irrigation and management in Northern Alabama.

Materials and Methods

A 15-acre field located at the Tennessee Valley Research and Extension Center (TVREC) in Belle Mina, Alabama was selected for this investigation. The field consists of Decatur silt loam and Decatur silt clay soils with slopes ranging from 1% up to 6%. The site is managed as a no-till, continuous cotton system with Soil fertility management was conducted according to Alabama Cooperative Extension System guidelines. The experimental design is a randomized block design with two irrigations treatments (Irr – irrigated; No Irr – non-irrigated) and two cover crop treatments (C – Cover; NC – No Cover) with four replications. Plot measure 27 ft by 1250 ft. The two cover crop treatments consist of a no cover and a winter wheat (*Triticum aestivum* L.) cover crop. Irrigation treatments include dryland versus pressure compensated sub-surface drip irrigation (SDI). SDI tape was installed on 80-in spacing between every other plant row at a nominal depth of 13 inches. In 2006, cotton was planted on April 18 using a 40-in. row spacing while irrigation was initiated on May 26. Irrigation was scheduled based on pan evaporation and adjusted for canopy closure, triggering an irrigation event at 60 % pan evaporation. This level was selected based on 6 years of prior SDI research on cotton at the same research facility (Fulton et al., 2005). Figure 1 presents the accumulated precipitation, pan evaporation, and irrigation on a monthly basis for the 2006 growing season at TVREC.

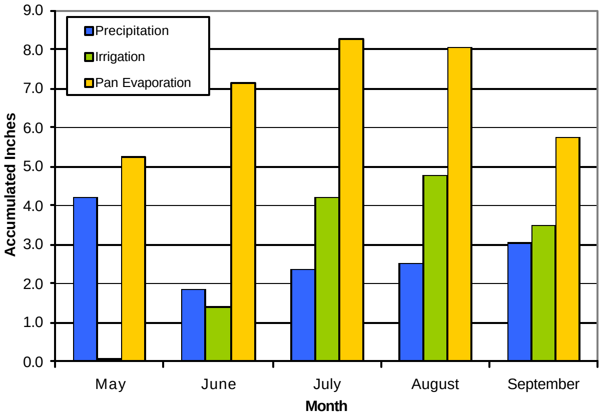


Figure 1. Accumulated irrigation, precipitation and pan evaporation on a monthly basis during the 2006 growing season.

An AgLeader PF3000 cotton yield monitoring system was used to determine cotton performance. The accumulated amount harvested from each plot was also weighed. A quality analysis was conducted by harvesting 50 cotton bolls collected at three locations within each plot (48 total samples; 3 locations X 16 plots). Quality factors considered were micronaire, strength, leaf grade, uniformity, and length. Differences existed between all quality features except for Leaf Grade. Yield and quality data were analyzed using LSD T-tests to determine if any significant differences existed between treatments.

TIR collected included collecting ground truth data coincident with remotely sensed TIR data acquisition to quantify differences in plant, soil, and residue attributes contributing to measured emittance, as well as, to directly verify the relationship between canopy response and emittance. Six sample locations along the length of each plot were identified and marked using a RTK survey grade GPS unit. Ground truth consisted of soil water content, stomatal conductance, and digital photographs. Thermal infrared data were collected using an unmanned aerial vehicle (UAV) equipped with a TIR sensor (L3 Communications Infrared Products, Dallas, TX). The TIR system consisted of a lightweight (145 g) camera with a thermal sensitivity of =100mK. The focal plane array (160 x 120 pixels) for the camera consisted of an uncooled, amorphous silicon microbolometer. The system records emittance (7–14 µm) as a digital value ranging from 0-255, with increasing emittance represented by increasing digital value. TIR infrared data was acquired on 18 July 2006, at 10:13 AM central standard time, under clear conditions. The cotton was between 1st and peak flower with a percent canopy ranging from 15% to 72%. Collected data was saved in a TIFF file format and imported into ERDAS Image 8.7 for clipping, geo-registration and data extraction. Statistical Analysis System (SAS Inst., NC) was to determine the relationship between TIR emittance, stomatal conductance, soil water content or plant available water, crop residue management, and vegetative fraction (canopy closure).

Results and Discussion

Yield results from the four treatments had significant differences (Table 1). There were, as was expected, significant differences between irrigated and non-irrigated plots yields. Yields on irrigated plots were as high as 61% higher than the yields measured on non-irrigated plots. There were also differences for the cover crop vs. no cover crop comparison, with those of the irrigated cotton having significantly higher yields. Yields for the plots receiving a cover crop treatment were as much as 16% higher than the plots without a cover crop. The trend appears to be that cover crops are providing yield benefits. This yield response could be a result of increased organic matter (OM) for the cover crop plots over the past 3 years potentially providing increased soil water holding capacity and reduce surface water evaporation.

Table 1. 2006 cotton yield averages for each treatment.

Treatment	**Yield - Seed Cotton (lbs/ac)**[*]
Irrigated / Cover	2853 [a]
Irrigated / No Cover	2396 [b]
Non-Irrigated / Cover	1098 [c]
Non-Irrigated / No Cover	941 [c]

* Mean yields with similar letters indicate they are not statistically different at the 90% confidence level.

The cotton quality analyses indicated that for Micronaire, the irrigation-cover crop treatments were significantly higher than the other treatments. Irrigated plots had significantly higher lint strengths than on the non-irrigated plots. The non-irrigated plot with cover also had significantly higher lint strength than the non-irrigated plot without a cover crop. Lint uniformity was significantly higher on irrigated plots with a cover crop. Uniformity was also significantly higher for the plots with irrigation and no cover crop compared to both non-irrigated treatments. The lint length was significantly longer on all irrigated treatments than on the non-irrigated treatments.

Table 2. Cotton quality averages per treatment.

Treatment	**Micronaire** *[1]	**Strength (g/Tex)***	**Uniformity (%)***	**Length (in)***
Irrigated / Cover	4.4 [a]	28.5 [a]	83.5 [a]	1.1 [a]
Irrigated / No Cover	3.9 [b]	28.0 [a]	82.8 [b]	1.1 [a]
Non-Irrigated / Cover	4.1 [b]	26.1 [b]	81.8 [c]	1.0 [b]
Non-Irrigated / No Cover	4.1 [b]	25.2 [c]	81.2 [c]	1.0 [b]

* Mean yields with similar letters indicate they are not statistically different at the 90% confidence level.

[1] Values between 3.5 and 4.9 are not discounted at the gin.

Another result discovered during 2006 for this project was that using 60% of calculated pan evaporation (adjusted for % canopy closure) for scheduling irrigation was not sufficient during drought conditions. Visual assessment of the cotton during the growing season showed less vegetation and boll development when compared to other ongoing irrigation studies at TVREC. Final yields between this project and the other studies also supported these in-season observations. Therefore, 60% pan did not supply sufficient water during irrigation events to maximize cotton yields for the dry growing conditions experiences in 2006. Based on these results, 90% has been selected for future use to schedule irrigation for this project.

Due to the integrated effect of surface characteristics (canopy closure, % actively transpiring vegetation, crop residue cover and bare soil) impacts observed emittance (digital values), variability in surface characteristics at the time of TIR acquisition were evaluated (Table 1). It was necessary to log transform stomatal conductance and canopy cover to normalize the dataset prior to analysis of variance (ANOVA). No differences in soil water content were observed between treatments. However, significant differences in canopy closure were noted across irrigation as well as cover treatments. No significant interaction between treatments was observed. The impact of irrigation management on canopy closure was most significant having 40% canopy closure on irrigated treatments and 26% canopy closure on non-irrigated treatments. Differences in canopy closure between covered and no-covered treatments were less significant, but showed greater canopy closure on cover treatments compared to no-cover treatments.

Table 1. Soil water content, canopy closure, crop residue cover and stomatal conductance reported for significant treatment effects. Interactions between treatments are denoted by "x".

Treatment			Stomatal Conductance	Soil Water Content	Thermal Infrared	Canopy Closure	Crop Residue Cover
Irrigation	**x**	**Cover**	**mmols m^{-2} s^{-1}**	**cm^3 cm^{-3}**	**D.V.**	**%**	**%**
Irrigated			6.09 A	NS‡	94.6 B	3.65 A	
Dryland			5.36 B	NS	157.2 A	3.24 B	
LSD			**0.30**		24.1	0.11	
		Cover		NS	114.7 B	3.53 A	
		No Cover		NS	143.9 A	3.36 B	
		LSD			**23.9**	**0.1**	
Irrigated		Cover					24.4 A
Irrigated		No Cover					27.7 A
LSD							**3.8**
Dryland		Cover					32.7 A
Dryland		No Cover					27.5 B
LSD							**3.9**

Means followed by the same letter are not statistically different at alpha = 0.05.

† A significant interaction was observed between Irrigation and Cover treatments for estimates of residue cover only.

‡ No significant response is indicated by NS.

The relationships between observed TIR emittance and ground truth parameters were evaluated using Pearson Linear Correlation Coefficients. Of particular importance to the evaluation of the TIR system, a negative correlation between stomatal conductance and TIR emittance (r = -0.48, alpha = 0.05) provides evidence that the TIR system was related to plant transpiration. Additionally, a negative linear relationship was observed between TIR emittance and canopy closure (r = -0.44, alpha = 0.05), indicating cooler surface conditions as canopy closure increased. As transpiration rates increased, TIR emittance decreased. Although soil water content was highly correlated with stomatal conductance (r = 0.58, alpha = 0.05), no significant correlation was observed between TIR emittance and soil water content.

Collected TIR imagery was able to identify some SDI issues. One image acquired over the north-eastern quadrant of the field indicated the existence of two crimped SDI lines within irrigation plots and an area were distribution issues existed (Figure 2). The crimped lines are evident, spanning the length of the image as a very bright feature within two irrigated treatments. Comparing the area along either side of the crimped lines with adjacent rows of well-watered cotton, emittance was more than two times greater along the crimped lines. Based on the evaluation of the TIR system, this represents an area where cotton plants are not actively transpiring and exhibiting signs of water stress. The distribution issues are evident as an area of very bright surface features (canopy stress), bounded on either side by dark surface features (actively transpiring canopy). Yield monitor data indicated yield losses up to 35% due to the crimped SDI tape. However, results suggest that SDI problems can be rapidly and easily identified using the UAV and TIR imagery allowing such issues to be corrected in a timely fashion during the growing to minimize yield loss.

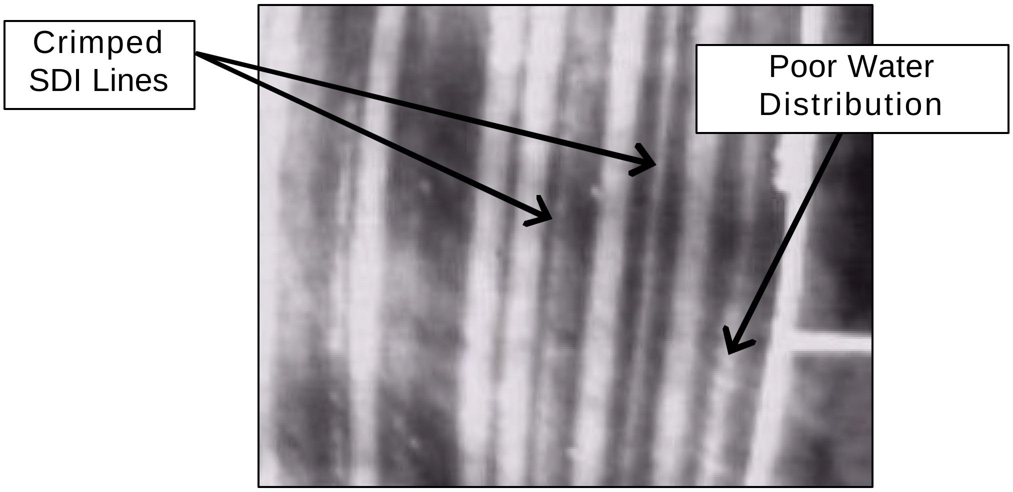


Figure 2. Thermal infrared image showing crimped SDI tape and an area of poor water distribution.

Conclusion

Irrigated treatments had significantly higher yields along with the cover crop treatments. Cover crop treatments tended to be higher yielding. For the quality data the difference that was noted repeatedly, and was significant, was that micronaire, lint strength, lint uniformity, and lint length are all significantly higher on irrigated plots than on non-irrigated plots. Remote-sensed thermal imagery was also collected during the 2006 growing season. Emittance spectra were also highly correlated with stomatal conductance (r = -0.48, alpha = 0.05), providing evidence that observed emittance was related to variability in canopy response to irrigation and cover treatments. More importantly, the UAV observations more accurately differentiated between relative differences in canopy response to irrigation and crop residue cover management compared to ground measurements of stomatal conductance, which were time and labor intensive. TIR was capable of identifying SDI tape issues. In conclusion, preliminary results indicated that high resolution thermal imagery may prove to be very useful in identifying in-season SDI issues and provide a management tool for SDI.

References

Barnes, E.M., T.R. Clarke, S.E. Richards, P.D. Colaizzi, J. Huberland, M. Kostrzewski, C. Choi, E. Riley, T. Thompson, R.J. Lascano, H. Li, and M.S. Moran. 2000. In Proc. 5th International Conference on Precision Agriculture. ASA-CSSA-SSSA, Madison, WI.

Campbell, G.S. 1977. An introduction to environmental biophysics. Springer Verlag, New York.

Cline, R.G. and G.S. Campbell. 1976. Seasonal and diurnal water relations of selected forest species. Ecology. 57:367-373.

Colwell, R.M. 1956. Determining the prevalence of certain cereal crop diseases by means of aerial photography. Hilgardia. 26:223-286.

Fulton, J.P., M. Dougherty, L.M. Curtis, H.D. Harkins, C.H. Burmester. 2005. Subsurface Drip Irrigation (SDI) Scheduling and Tape Placement for Cotton Production in Alabama. ASAE Paper No. 052244. Annual International Meeting, Tampa Convention Center, Tampa, Florida, July 17-20.

Herwitz, S.R., L.F. Johnson, J.C. Arvesen, R.G. Higgins, J.G. Leung, and S.E. Dunagen. 2002. Precision agriculture as a commercial application for solar-powered unmanned aerial vehicles. In Proc. AIAA's 1st Technical Conference and Workshop on Unmanned Aerial Vehicles, Portsmouth, VA. 20-23 May 2002.

Penuelas, J. I. Filella, C. Biel, L. Serrano, and R. Save. 1993. The reflectance at the 950-970 nm region as an indicator of plant water status. Int J. Remote Sens. 14:1887-1905.

Sadler, J.E., C.R. Camp, D.E. Evans, and J.A. Millen. 2002. Corn canopy temperatures measured with a moving infrared thermometer array. Trans. ASAE 45:581-591.

Shannahan, J.F., J.S. Schepers, D.D. Francis, G.E. Varvel, W.W. Wilhelm, J.M. Tringe, M.R. Schlemmer, and D.J. Major. 2001. Use of remote sensing imagery to estimate corn grain yield. Agron. J. 93: 583-589.

Simpson, A., T. Stombaugh, L. Wells, and J. Jacob. 2003. Imaging techniques and applications for UAV's in agriculture. In Proc. ASAE Annual International Meeting, Las Vegas, NV. 27-30 July 2003.

The Next Level of Conservation - No-Till and StabilizedNitrogen™ Technology

John A. Hassell
Manager, Research and Agronomic Development
Agrotain International
629 Rose Street
West Lafayette, IN 47906

Abstract

Throughout most of the Earth's history, soil formation exceeded soil erosion. Soil erosion in and of itself is not a problem unless the rate of soil erosion exceeds the rate of new soil formation through natural processes. Over the past 100 years, a combination of over plowing, overgrazing and deforestation has reversed that relationship. With soil erosion exceeding soil formation in many areas, parts of the Earth are slowly being drained of their inherent fertility (Brown, Flavin and French, 1998). Continued excessive erosion will affect the productivity of the land to where it is no longer economical to farm, forcing abandonment of the farm. Fewer farms could mean decreasing food, fiber and energy supplies for an ever-demanding and increasing world population.

The first agricultural crop production occurred in fertile river valleys, where new sediment were deposited annually during flooding conditions. Agricultural areas were close to water sources, which was a necessity for crop production and growth of civilization. As populations grew, more food was needed, so farming expanded farther and farther away from fertile river valleys. Lacking the knowledge of conservation and fertilization, early farmers abandoned lands that became unsuitable for crop production and moved their operations to new areas. Extreme pressure was exerted to farm more area, in order to feed more people. This was a continuous cycle – increased populations needed more food, which meant more land would be placed into crop production.

By the 1950s, the population of the world was approximately 2.5 billion. This level of population could easily be supported by today's technology, and food, energy and fiber production. However, today the world's population is at 6.2 billion and continuing to grow (US Census Bureau, International Data Base, September 2004). The world is faced with an unbridled population growth of 76 million people per year which is placing increased pressures on our agricultural croplands. Coupled with this population explosion, has been an increase in affluence and protein requirements, primarily in China and India.

With the increase in population there continues to be a decrease in the amount of arable cropland necessary to keep up with this ever increasing, consumptive population demanding safe food, fiber and energy. It has been estimated that within the last 50 years, the world has lost approximately 20 % of our topsoil resources. Satellite imagery documents these losses to delta areas of the Mississippi River, Amazon River and the Yangtze River. Recent dust storms over China, India and parts of Africa are reminiscent of the dust bowl days of the 1930's.

In developing countries, for every pound of food produced, 12 pounds of farmable soil are lost. Loss of topsoil and arable cropland has decreased the available cropland per capita. It has been determined that the available cropland acres per capita are currently at .64 acres, with this decreasing to .4 acre by the year 2050, when the worldwide population is expected to reach 9 billion (United Nations, Population Division, Department of Economic and Social Affairs).

Over the past 16 years, it has been documented that grain consumption is greater than grain production. In 1990, grain stores were at approximately 102 days, as compared to 54 days at the end of 2006 (USDA, Production, Supply and Distribution). The current grain stores are at their lowest in the last 30 years. With China and India having exhausted their grain stores, pressures will be put on other agricultural lands to be more efficient in food production. These challenges described above will continue to place more pressure on our cropland acres and will require an increased emphasis to be placed on conservation that protects the soils resources, while utilizing products that maximize the effectiveness of inputs such as fertilizers and crop chemicals.

This presentation will address enhancing the quality of our soil resources and the use of StabilizedNitrogen™ technology. No-till conservation is recommended to improve soil quality, while StabilizedNitrogen™ fertilizers provide nitrogen at the right place, at the right time, and in the most advantageous form when the crop needs it. StablilizedNitrogen™ keeps nitrogen in the ammonium form longer, which provides many agronomic benefits. These two conservation practices, when adopted, will aid in meeting future growing needs for food, fiber and energy. Utilizing these two conservation practices will provide economic benefits to growers, while at the same time providing environmental benefits. No-till addresses the soil loss and amendments that may attach to the soil, while StabilizedNitrogen™ will address nitrogen losses from volatilization, nitrification and denitrification. Research information and data will be presented during the course of this presentation.

AGROTAIN International is the world's largest producer of *S*tabilized*N*itrogen™ fertilizers. Marketed under the brands AGROTAIN®, AGROTAIN® PLUS, SuperU®, HYDREXX™, UMAXX® and UFLEXX™, *S*tabilized*N*itrogen™ fertilizers contain proprietary nitrogen stabilizer technology. This award winning technology has a proven track record, backed by worldwide research studies. AGROTAIN® International's *S*tabilized*N*itrogen™ fertilizers reduce nitrogen losses, and extend plant-available nitrogen for healthier plants and higher yields.

AGROTAIN® International's products are currently licensed or sold through Agricultural, Turf & Ornamental or Industrial partners in over 55 countries. AGROTAIN® International is headquartered in St. Louis, Missouri, USA.

PRECISION AGRICULTURE TO FURTHER ENHANCE LIVESTOCK AND PERRENIAL-BASED PEANUT/COTTON CROPPING SYSTEMS

Tawainga Katsvairo, David Wright, James Marois, and Jimmy Rich
University of Florida, Florida Research and Education Center
Quincy, FL 32351
E-mail: katsvair@ufl.edu

ABSTRACT

Site-specific management can be used in livestock/ peanut/cotton cropping systems to increase efficiency and economic returns. Spatial variability of plant height, leaf area index, soil organic matter, NPK and yield for cotton in a sod/livestock/peanut/cotton cropping system was evaluated in Florida in 2006. The parameters were evaluated for irrigated and non-irrigated conditions and under conservation tillage. Geostatisticals techniques were used to analyze the spatial distribution of soil fertility status, plant growth and yield, and maps were produced using ArcGIS. All variables showed spatial variation across the field. Plant height showed moderate to strong spatial dependence. Areas of the field with the tallest plants did not necessarily produce highest yield, and no yield differences were found between irrigated and non-irrigated areas. Site-specific management has potential to increase cotton management efficiency. It will, however, be necessary to create individual zone maps for some variables since the maps for different variables did not always overlap. There is also a need to test the spatial distribution of the variables over a number of years to determine if the management zones remain the same across different climatic conditions.

INTRODUCTION

Both site-specific (precision agriculture) and perennial grass - based peanut/cotton production systems are management systems developed to increase efficiency and ultimately increase income. The premise behind site specific management is that a precise amount of inputs is applied only where needed, based on spatial variation across the fields as opposed to the standard blanket application recommendations from extension services. Site specific management enables efficient use of agricultural resources to include fertilizers, pesticides and irrigation water. However, site-specific management has not been extensively researched in cotton. An Australian study reported no yield benefit with site specific fertilizer application but reported more efficient fertilizer use (Boydell et al., 2001). On the other hand a study from the southern US showed a slight yield increase with site specific fertilizer application. The same study also showed no fertilizer reductions overall, however, specific zone recommendations either decreased or increase by up to 57%, depending on yield potential (Watson et al., 2005) and this can potentially reduce nutrient leaching. With so much potential, site-specific management is often described as “The farming of the future”.

Integrated production of crops and livestock offers improved efficiencies, whether in early, primitive agriculture or modern production systems. Recently, economic and environmental concerns have resulted in increased interest in these systems. A growing body of literature reports on the many benefits of integrated cropping systems in several row- crop production systems (Katsvairo et al. 2006; Franzluebbers and Triplett, 2006). Perennial pastures including bahiagrass and Bermuda grass are ideal for production systems in the Southeast due to their extensive root systems that penetrate an underlying compaction layer prevalent in soils in the southeast (Elkins et al., 1977; Kashirad et al., 1967; Campbell et al., 1974). Channels created in the compaction layer can be utilized by crop roots in subsequent years to access water and nutrients that are available below this layer. The perennial grasses also increase soil moisture, organic matter, reduce soil compaction, earthworm numbers and activities (Katsvairo et al., 2007a; Franzluebbers and Triplett, 2006). Perennial grasses such as bahiagrass are also a non host of several important cotton diseases and nematodes (Katsvairo et al., 2006). A combination of enhanced resource-uptake by the plants grown in rotation with perennial grasses, accelerating crop growth and development plus the fact that perennial grasses are non-host to major cotton pests would be expected to be a major boast to cotton production. Vigorous growing plants are better able to tolerate pest pressure. In fact inclusion of perennial grasses in cotton and peanut cropping systems is often described as “the next step in crop production after conservation tillage”.

Unlike other major row crops such as corn and soybean, there is still substantial room for improvement in the use of precision agriculture principles in cotton production. Information on spatial variation for soil nutrients and plant growth characteristics such as leaf area index, height, nematode populations, nutrients, organic matter, and yield for in cotton fields is scarce. While many advantages have been observed with a sod/livestock/peanut/cotton cropping sequence, integrating this system with the use of precision agriculture tools has not been explored. We hypothesize that this integrated system would offer further benefits beyond those obtained from the cropping sequence alone. The objectives of this study were to evaluate spatial variability in soil nutrients, crop growth parameters and yield for cotton in a sod/livestock/peanut/cotton system under both irrigated and non-irrigated conditions using conservation tillage.

MATERIALS AND METHODS

An experiment was conducted in Marianna, Florida in 2003 to examine the influence of 2 years of bahiagrass rotation on the spatial variation of soil nutrients, moisture and plant phenotypical development of subsequent cotton crops in the rotation. This experiment is part of a long-term multi-disciplinary study which looks at integrated livestock/peanut/cotton/perennial grass cropping systems. The 50 ha experimental site encompassed two soil types, a Fuquay coarse sand, the dominant soil in the field, and an Orangeburg loamy sand. The northern section of the field was generally wetter and the north central area of the field was occasionally water logged. The field was planted to bahiagrass for 2003 and 2004, peanuts in 2005 and cotton in 2006. The southwest section of the field was not irrigated but the rest of the field was irrigated. Irrigation was based upon extension recommendations for Florida (Smajstrla et al., 2006). Standard crop management procedures were followed, and conservation tillage practices were utilized for cotton production.

A systematic unaligned sampling grid (Wollenhaupt et al., 1994) with a spacing of 88 x 88 m was superimposed over the experimental site to establish sampling locations. The location coordinates for each station were recorded with a global positioning system unit. Soil samples were taken to a depth of 20 cm from each sampling location at the end of the growing season to determine residual soil nutrients. All cores were a composite of 10 soil cores taken on a 4 m grid centered on the geo referenced sampling location. The soil samples were sealed in plastic bags, placed in a cooler in the field, transferred to cardboard cartons at the end of the day, and dried in a forced-air oven (55°C) to constant moisture. Samples were submitted to a lab for N, P, and K soil nutrient analysis and soil organic matter. Plant height was measured 3 times during the early, mid and late growing season by estimating the height of 12 representative plants a taken from a 3 m radius from each sampling location. Chlorophyll index was measured on the last fully expanded leaf of thirty plants per location with Minolta's SPAD meter and leaf area index (LAI) was determined with a Licor LAI 2000. Both chlorophyll and LAI were measured several times during the growing season. Cotton was manually harvested from two areas of 1 m^{-2} for each sampling station.

Geostatistics were used to analyze spatial variability and create maps of all variables including yield, LAI, plant height, chlorophyll, soil moisture and residual soil nutrient concentrations using the geostatistical software package, Arc GIS (ESRI, 2004). Sample variograms were fitted with spherical variogram models (best fit) using the following equation:

$$?(h) = c_o + c[1.5(h/a) - 0.5(h/a)^3]$$

where $\gamma(h)$ is the spatial structure of the variable, h is the distance between sampling locations, c_o is the nugget component of the variogram, c is the positive variance component, and a is the variogram range. The variogram range is the distance beyond which spatial correlation of the data no longer exists. The nugget value represents unsampled spatial variation or the random component of the variation. The ratio of the nugget (c_o) to sill ($c_o + c$) indicates the degree of randomness in the spatial variability of the data. Cambardella and Karlen (1999) suggested that a ratio of <0.25 indicates the measured variable is strongly spatially dependent. A ratio of 0.25 to 0.75 indicates moderate spatial dependence, whereas a ratio >0.75 indicates weak spatial dependence.

RESULTS AND DISCUSSION

Plant height differed across the field for all three sampling stages. The nugget/sill ratio of the variograms showed moderate spatial dependence during the first sampling date (0.45), and a strong spatial dependence during the second sampling date (0.23) (Table 1). In the early to mid season, plants were tallest in the north section of the field which was the wetter section of the field (Fig 1). Spatial height differences became pronounced as the season progressed. By maturity cotton plants were almost twice as tall in the east section of the field close to the edge compared to most of the field. Uneven irrigation distribution may have further influenced the differences in plant height. The center pivot irrigation stopped at the west end of the field where it would have applied more water as the irrigation rig slowed down. In general, the tallest plants were observed in the wetter regions of the soil and the shortest plants were observed in the non-irrigated area.

Table 1. Nugget value (c_o), nugget/sill fraction (c_o/c_o+c) for SOM, plant height, yield and NPK in Florida in 2006.

Variable	Nugget	sill	(c_o/c_o+c)	range
Height (early season)	0.54	0.76	0.41	330
Height (mid-season)	1.80	6.04	0.23	330
Height (late season)	0.00	61.06	0.00	330
Yield	0.00	179610	0.00	75
Soil organic matter	0.00	0.17	0.00	115
N	31.73	24.48	0.56	184
P	1177	1110	0.51	330
K	3008	448	0.87	330

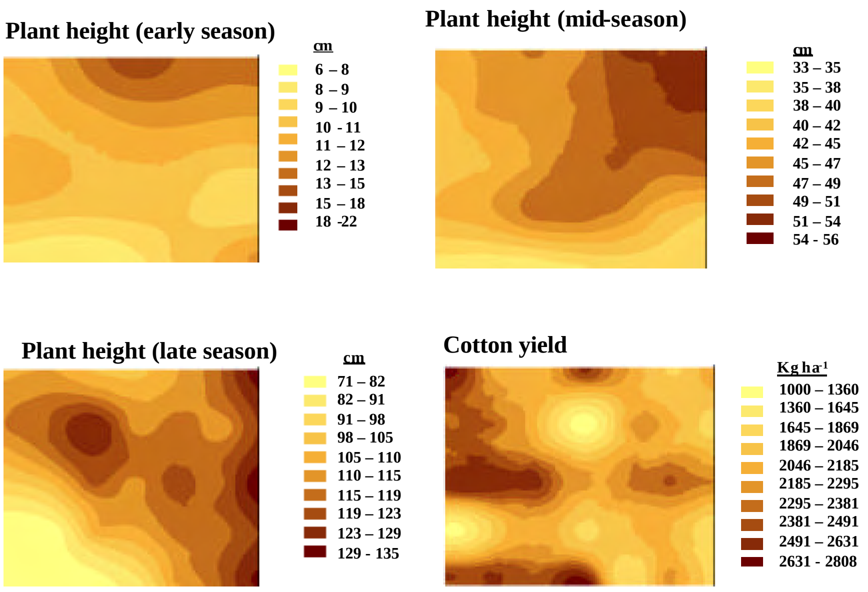


Fig 1. Krigged interpolations using ArcGIS of plant height at three stages of growth and yield in cotton in a bahiagrass rotation in Florida in 2006.

Cotton was hand harvested, collecting more fiber than machine harvesting and as a result, our yields are generally higher than normal average yields for the Mariana region. Like plant height, yield showed spatial variation across the field. The yield differences ranged between 1000 to 2808 kg ha^{-1}. The variogram range was 75 m. Yield was generally higher in the west side of the field and lowest in the north central part of the field which occasionally water logged (Fig. 1). Yield under non-irrigated conditions was equal to the best yield under irrigated conditions. Our other studies conducted over 5 years have not shown any advantages to irrigating cotton unless there is severe soil moisture deficit. Yield was greater in the regions with shorter cotton compared to the regions with the tallest cotton. Plot test studies showed no yield benefits to cotton with greater biomass (Katsvairo et al., 2007b). The greater biomass is produced at the expense of yield. If variable rate N management was practiced, the sections of the field with the excessively tall plants would be expected to receive less N. Yield was also greater across the entire Orangeburg loamy sand, soil type but it should be noted that the Orangeburg loamy sand, soil type covered only a small portion of the field.

.

All soil macronutrients showed spatial variation across the field. Residual soil NO_3–N was greatest in the non-irrigated section and lowest in the north end of the field. The north end was also the portion of the field which was wettest and had the tallest plants in the early to mid-season. It is possible that soil NO_3–N could have leached out of the soil since that portion of the field was wettest. N leaches more rapidly in sandy soil and moist soils, but mostly likely, partially due to more rapid denitrification under the wet soil conditions. An additional factor may have been greater assimilation of NO_3–N due to the taller plants in that section of the field. In another study, we also observed taller plants in cotton after bahiagrass than cotton in the conventional peanut/cotton rotation. The taller plants in the bahiagrass rotation could have been a result of more N from the decomposing sod. The nugget/sill ratio of the variograms showed moderate spatial dependence for N (Table 1).

P levels showed a definite pattern, with higher levels observed in the west section of the field. In general the west section of the field also had the greater yield (Fig. 2). Higher levels of K were distributed around the west and south edges of the field. The areas of the field which had the tallest plants tended to have lower K levels indicating more uptake (Fig. 2).

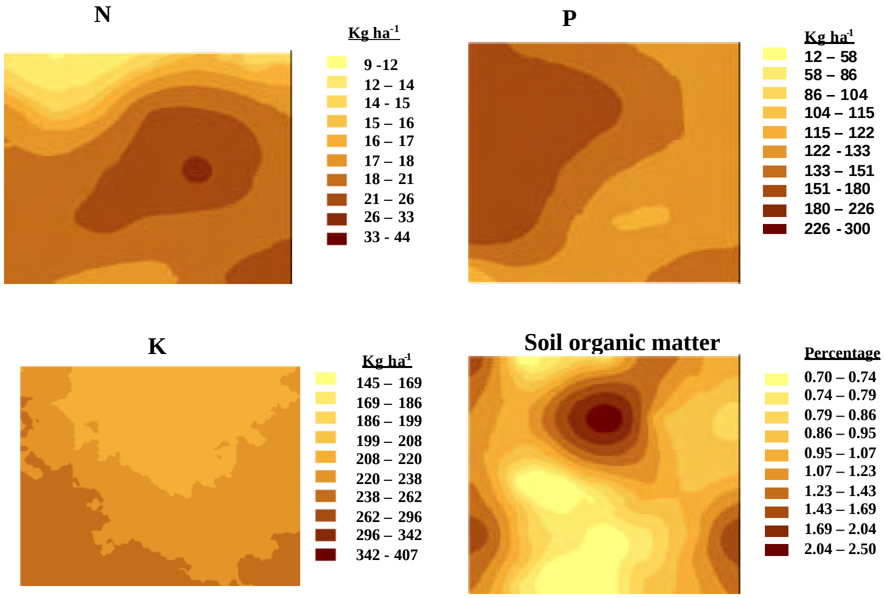


Fig 2. Krigged interpolations using ArcGIS of N, P,K and soil organic matter in cotton in a bahiagrass rotation at the end of the growing season in Florida in 2006.

The nugget/sill ratio of the variograms showed moderate spatial dependence for P and less spatial dependence for K (Table 1).Organic matter levels were greatest in the north central section of the field, which is also the section that tended to be water logged (Fig.2). This may have been a result of more decomposition of plant matter. The higher amount of organic matter in this section did not improve yield even though plants were larger. The west section of the field which had greater yield, partially overlapped with areas of higher organic matter.

CONCLUSION

Plant height, chlorophyll levels, soil macro nutrients, soil organic matter and yield all showed spatial variation across the field. Plants were generally tallest in wet sections of the field. However the taller plants did not necessarily result in greater yield. Plant height showed moderate to strong spatial dependence based on nugget/ (nugget + sill) ratios. P levels were greater in the west section of the field. K levels were highest in the outlying west and south section of the field, coinciding with regions of shorter plants and less K uptake. Yield was negatively affected by plant height and tended to be greater in areas with shorter plants. Non-irrigated areas had yields equal to the best irrigated areas. In this field, the spatial variation in plant height, macro nutrients, organic matter and yield would justify site-specific management of inputs. However, because the management zones for the different parameter (plant measurements and nutrients) did not always overlap, this may necessitate creating several management zones, making site-specific management more challenging to implement.

REFERENCES

Allen, V.G., C.P. Brown, R. Kellison, E. Segarra, T. Wheeler, P.A. Dotray, J.C. Conkwright, C.J. Green, and V. Acosta-Martinez. 2005. Integrating cotton and beef production to reduce water withdrawal from the Ogallala aquifer in the southern high plans. Agron. J. 97:556–567.

Boydell, B., C. Stewart, and A. McBratney. 2001. Precision agriculture in Australian cotton. Online available at: http://www.regional.org.au/au/gia/13/428boydell.htm

Cambardella, C.A., and D.L. Karlen. 1999. Spatial analysis of soil fertility parameters. Prec. Agric. 1:5–14.

Campbell, R.B., D.C. Reicosky, and C.W. Doty. 1974. Physical properties and tillage of Paleudults in the Southeastern Coastal Plains. J. Soil Water Conserv. 29:220-224

Elkins, C.B., Haaland, R.L. and Hoveland, C.S. 1977. Grass roots as a tool for penetrating soil hardpans and increasing crop yields. p. 21-26. *In* Proc. 34th Southern Pasture and Forage Crop Improvement Conference, Auburn Univ., Auburn, AL. 12-14 April 1977. USDA-ARS, New Orleans, LA.

Environmental Systems Research Institute. 2004. ArcGIS Spatial Analyst. ESRI, Redlands, CA.

Franzluebbers, A.J. and G.B. Triplet. 2006. Integrated crop-livestock systems to conserve water resources in the southeastern USA. *In* Southern Conservation Systems Conference Proceedings. Amarillo, TX. June 26 - 28. http://www.ag.auburn.edu/auxiliary/nsdl/sctcsa/proceedings.html

Kashirad, A. J., G.A. Fiskell, V.W. Carlisle, and C.E. Hutton. 1967. Tillage pan characterization of selected Coastal Plain soils. Soil Sci. Soc. Am. Proc. 31:534-541.

Katsvairo, T.W., D.L. Wright, J.J. Marois, D.L. Hartzog, J.R. Rich and P.J. Wiatrak. 2006. Sod/livestock integration in the peanut/cotton rotation: A systems farming approach. Agron. J. 98: 1156-1171.

Katsvairo, T.W., D.L. Wright, J.J. Marois, D.L. Hartzog, K.B. Balkcom, P. J. Wiatrak and J.R. Rich. 2007a. Cotton roots, earthworms and infiltration characteristics in peanut/cotton cropping systems. Agron. J. 99: 390-398.

Katsvairo, T.W., D.L. Wright, J.J. Marois, D.L. Hartzog, K.B. Balkcom, P. J. Wiatrak and J.R. Rich. 2007b. Peanut, cotton and bahiagrass yields in sod-based cropping systems (Agron. J. Vol. 99: September–October).

Karlen, D.K., M.D. Duffy, and T.S. Colvin. 1995. Nutrient, labor, energy, and economic evaluations of two farming systems in Iowa. J. Prod. Agric. 8:540–546.

Marois, J.J., T.W. Katsvairo, D.L. Wright and P. J. Wiatrak. 2004. Peanut and cotton plant development in sod based cropping systems. *In* International Annual Meetings Abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Smajstrla, A.G., B.J. Boman, D.Z. Haman, F.T. Izuno, D.J. Pitts and F.S. Zazueta. 2006. Basic irrigation scheduling in Florida. [Online] Available at http://edis.ifas.ufl.edu/AE111. (accessed 14 April. 2006; verified 2 May. 2006). University of Florida IFAS. Gainesville, FL.

Watson, S , E. Segarra , R. Lascano, K. Bronson, A. M. Schubert. 2005. Guidelines for Recommending Precision Agriculture in Southern Crops. Journal of Extension. Vol: 43 Number 2, Article Number 2RIB7

Wollenhaupt, N.C., R.P. Wolkowski, and M.K. Clayton. 1994. Mapping soil test phosphorous for variable rate fertilizer application. J. Prod. Agric. 7:441–448.

Assessment of Equipment Performance and Energy Requirements for the Development of Tillage Management Strategies

Corey Kichler
Auburn University
200 Tom Corley Building
Auburn, Alabama 36849
Phone: (334) 844-1337
Fax: (334) 844-3530

Abstract

Recently, increased fuel prices have made producers become more conscious of fuel usage leading to interests in possible fuel conservation strategies. Methods including equipment parameter monitoring and site-specific tillage can provide such cost saving techniques. Spatially monitoring and collecting tractor performance data during field operations can play an essential role in effective equipment management and increased operating efficiencies. The objective of this study is to evaluate tractor performance parameters during tillage to optimize in field-performance and quantify energy savings associated with site-specific tillage practices. A data acquisition system was developed to real-time monitor and archive fuel consumption, wheel slip, and draft load all tagged with GPS position information. Experiments are planned to collect these data under different conservation tillage practices. Results will be used to assess tractor performance and energy requirements for the development of site-specific management strategies while quantifying fuel savings.

SOD-BASED ROTATIONS AND GLOBAL WARMING

James J. Marois, David L. Wright, Cheryl L. Mackowiak, Duli Zhao
North Florida Research and Education Center, 155 Research Road, Quincy, FL 32351
jmarois@ufl.edu

INTRODUCTION

Global warming is the largest and most dangerous impact on the environment that humans have ever made. Some expected effects will be rising ocean levels and displacement of over ½ of the 150 million people in Bangladesh, exposure of over 500 million additional people to malaria, shortened growing seasons in Europe due to a collapse of the Gulf Stream, more intense droughts in the grain belt of the United States, and more intense storms originating in the Atlantic and Pacific. This is but another challenge to our survival. We have already effectively reduced acid rain, virtually eliminated small pox and polio, reduced lead poisoning in children to nearly insignificant levels, and greatly reduced air pollution in many of the major cities of the world.

The main cause of global warming is the increase in greenhouse gasses in the environment. The principal gas contributed by humans, on a mass basis, is carbon dioxide (CO_2) resulting from the burning of plant biomass and petroleum fuels. The carbon pools and fluxes have been estimated (Table 1). The major carbon (C) pool is carbonate rock at approximately 60,000,000 Gt (Gt = 1.1 billion tons) of C as compared to 750 Gt in the atmosphere (Flach et al 1997).

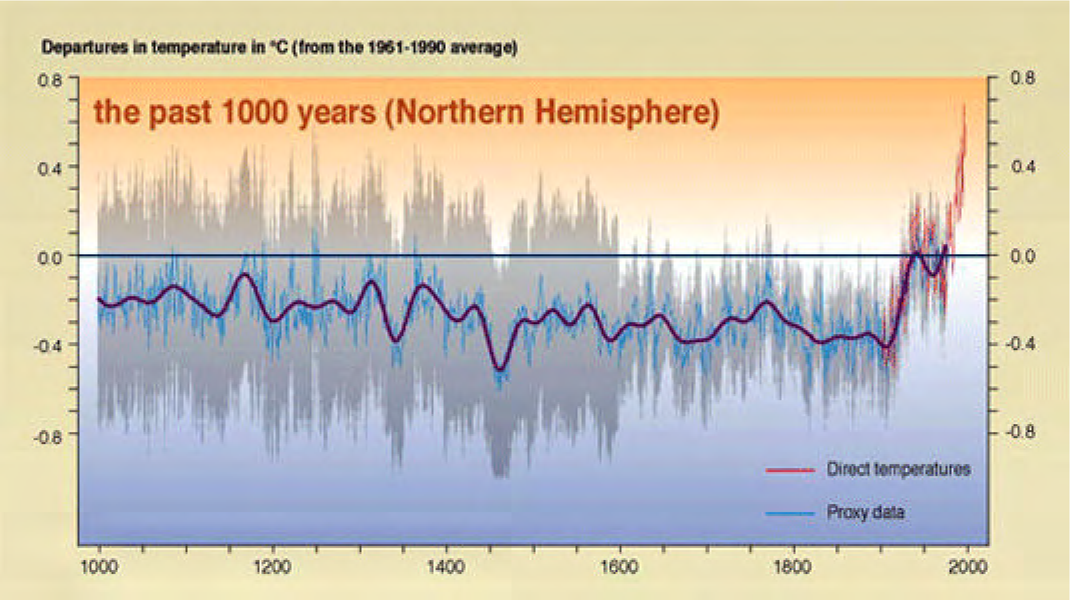
Table 1. The major carbon pools of the world (after Flach et. al. 1997)

Reservoir	Carbon (Gt) (Gt=1.1 billion tons)
Carbonates	60,000,000
Organic carbon	
Sedimentary rocks	10,300,000
Recoverable fossil fuels	4,000
Vegetation	760
Soil	1,400
Oceans	34,000
Atmosphere	750

Atmospheric C fluxes is well documented. It is estimated that the atmospheric C is increasing on average of 3 Gt per year (Table 2). As a result, the rate of temperature rise is greater than in any known historic or prehistoric time (Fig 1).

Table 2. Carbon fluxes to and from the atmosphere. (after Flach et. al. 1997)

Source	Carbon (Gt)
From Atmosphere to	
Vegetation (photosynthesis)	100-120
Ocean	100-115
Land (silicate weathering)	0.06
To Atmosphere from	
Ocean	100-115
Plant respiration	40-60
Decay of residues	50-60
Fossil fuels	4
Land use change	2



source: Intergovernmental Panel on Climate Change, www.ipcc.ch

Figure 1. The increase in average world temperature over time as compared to 1961-1990 average.

North America is currently a net source of CO_2 to the atmosphere, contributing to the global buildup of greenhouse gases in the atmosphere and associated changes in the earth's climate. In 2003, North America emitted nearly twp billion tons of C to the atmosphere as CO_2, mostly (80%) from the United States combustion of fossil fuels. The conversion of fossil fuels to energy (primarily electricity) is the single largest contributor, accounting for approximately 42% of North American fossil emissions in 2003. Transportation is the second largest, accounting for 31% of total emissions. There are additional globally important carbon sinks in North America. In 2003, vegetation in North America removed approximately 530 million tons of C per year (±

50%) from the atmosphere, storing it as plant material and soil organic matter. This land sink is equivalent to approximately 30% of the fossil fuel emissions from North America. The imbalance between the fossil fuel source and the sink on land is a net release to the atmosphere of 1468 million tons of C per year (± 25%) (Fig. 2). Approximately 50% of North America's terrestrial sink is in the re-growth of forests in the United States on former agricultural land that was last cultivated decades ago, and on timber land recovering from harvest. Other sinks are relatively small and not well quantified. The future of the North American terrestrial sink is also highly uncertain. The contribution of forest re-growth is expected to decline as the maturing forests grow more slowly and take up less carbon dioxide from the atmosphere. But, this expectation is surrounded by uncertainty because forests re-growth and other sinks responses to changes in climate and CO_2 is largely unknown (King et al, 2007).

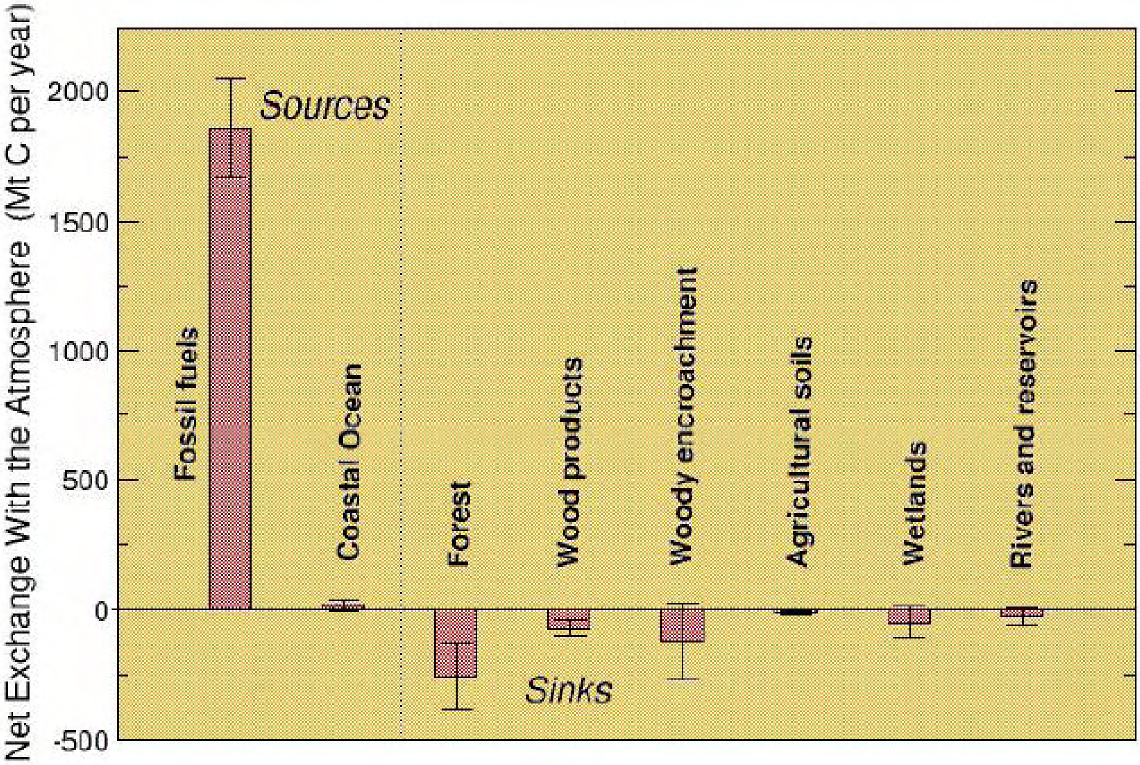


Fig. 2. North American carbon (C) sources and sinks (million tons of C per year) circa 2003. Height of a bar indicates a best estimate for net carbon exchange between the atmosphere and the indicated element of the North American carbon budget. Sources add carbon dioxide to the atmosphere; sinks remove it. Error bars indicate the uncertainty in that estimate, and define the range of values that include the mean value with 95% certainty. (From King et al, 2007).

One obvious solution to the rapidly increasing concentrations of atmospheric CO_2 is to sink the C in other areas. The terrestrial pool (Table 1) contains the vegetation pool (760 Gt of C) and the soil organic matter (SOM) pool (1400 Gt of C) and is about three times greater than the atmospheric pool of of 750 Gt of C. Since the flux between the terrestrial and atmospheric C pool is large, terrestrial systems can have a significant impact on the total amount of C in the atmosphere.

How can the ability of soil to accumulate C be manipulated such that atmospheric C is reduced and thus possibly reducing the current rate of global warming? It is known that changes in soil management can have a tremendous impact on soil organic carbon (SOC). In the classic Rothamsted experiments it was found that C storage in soil increased to 40 tons/acre when 15.6 tons/acre/year of farmyard manure were applied to the soil (Flach and Cline, 1954). The SOM continued to increase for over 140 years and is currently 3 times greater than the non-manure amended but fertilized soils. The non-manured and non-fertilized plots lost SOC over time.

In large part, the loss of soil organic matter can be attributed to one major event – the invention of the plow. The original wooden plow (an “ard”) developed in the fertile crescent evolved to the “Roman plow” with an iron plowshare. In the 8th century the inverting plow was developed. The moldboard plow was designed by Thomas Jefferson in 1784 and patented in 1796 by Charles Newfold. A cast iron version was marketed in the 1830’s by John Deere. Coupled with the “steam horse” the widespread plowing of the Midwest led to severe soil erosion and SOC loss, ultimately resulting in the dust bowl in the 1930’s. With the development of 2,4-D after World War II came no-till, which is presently practiced in 235 million acres globally (Lal et al, 2007).

The SOC is also impacted by crop species, especially when comparing annual row crops to perennial grasses. For example, in one study using warm season grasslands, the SOC in the surface 6 inches averaged 2.24 %, whereas croplands averaged 1.98 % (Omonode, et al 2006). They estimated that warm season grasses sequestered an average of 1 ton of C per acre per year. more than the corn-soybean rotation. Similar conclusions were made by Sainju et al (2006) for the humid southeastern United States. They concluded that cover crops and N fertilization can increase the SOC in tilled and no-tilled soils. They found that a biculture of legume and non legume crops (vetch and rye) in a notill situation sequestered nearly 300 lbs of C per acre per year.

The objective of this study was to examine a 4 year no-till, sod-based rotation (bahiagrass, bahiagrass, peanut, cotton) for its potential effect on SOC and its possible role in sequestering carbon using environmentally and economically sustainable farming practices.

MATERIALS AND METHODS

A 6-yr irrigation x rotation sod-based rotation study was initiated in the summer of 2000 on a Dothan sandy loam (fine, loamy siliceous, thermic Plinthic Kandiudult) at the University of Florida's North Florida Research and Education Center in Quincy, FL (84°33' W, 30°36' N). A two-year old bahiagrass sod was used to ensure good ground coverage and vigorous growth of the succeeding crop. An oat cover crop followed harvested peanut and cotton each fall. The percent soil organic matter (SOM) was determined from 2003-2006 in the cotton crop – which followed 2 years of bahiagrass then one year of peanuts. For the 2003 sample the plots were in bahiagrass, bahiagrass, peanut, then cotton. For 2004 the plots were in cotton, bahiagrass, bahiagrass, peanut, cotton. The 2005 plots were in peanut, cotton, bahiagrass, bahiagrass, peanut, cotton, and the 2006 plots were in bahiagrass, peanut, cotton, bahiagrass, bahiagrass, peanut, cotton. Crop management practices for the rotations, which included bahiagrass and peanut management, are described in more detail in Katsvairo et al., 2007.The percent SOM was converted to SOC by the relationship SOM = SOC X 1.727 (Stevenson, 1994) (conversion values typically range from 1.5-2).

RESULTS

The SOM in the cotton following bahiagrass was 1.29% in 2003 and increased to 1.60% in 2006 (Fig. 3).

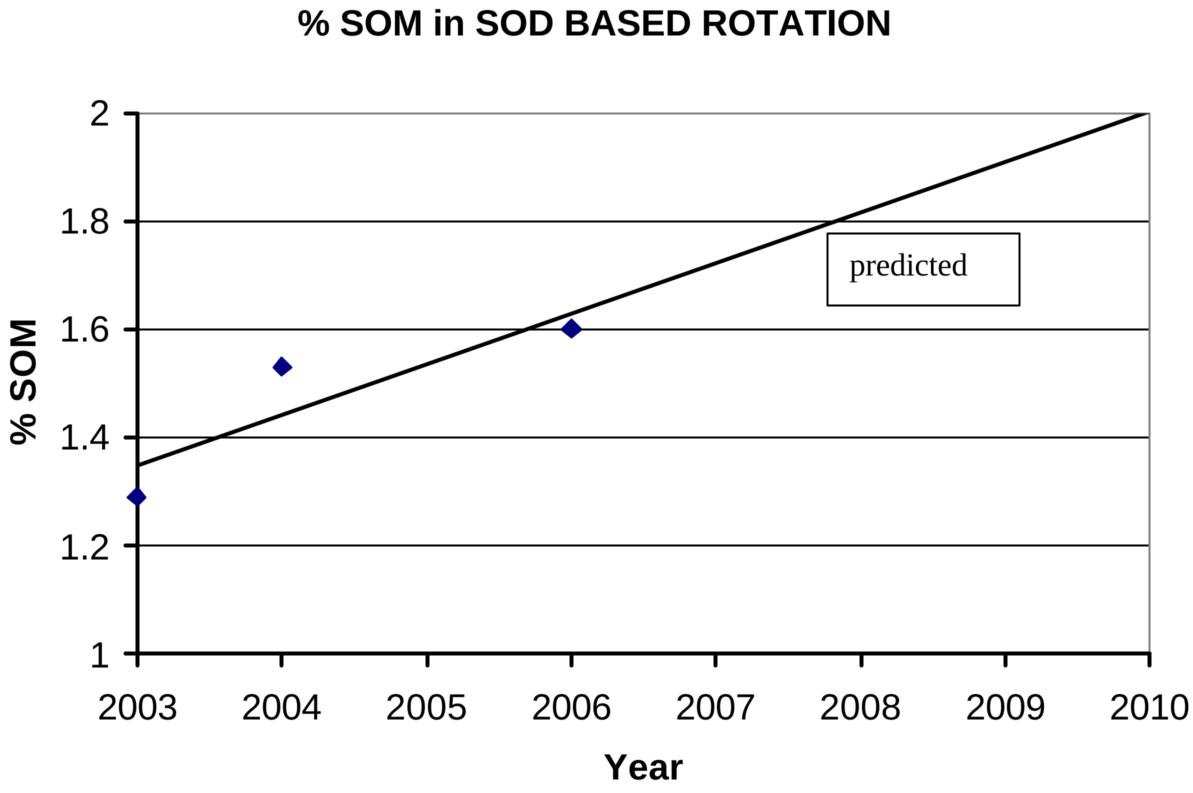


Fig. 3. The increase in SOM in cotton in a rotation of bahiagrass-bahiagrass-peanut-cotton.

DISCUSSION

The data thus far indicate that the SOM in the sod-based rotation is increasing over time at a rate of approximately 0.1% per year. If this trend were to continue until 2010, the field plot SOM will reach approximately 2%. The following discussion considers what the impact might be on North America's C budget if the sod-based rotation were widely practiced in the southeast. For the purpose of this discussion we assume that 1,000,000 acres will be under this practice.

Approximately 1468,000,000 tons of C released into the atmosphere in North America is not sequestered and is responsible in part for the increase in greenhouse gasses. If 1,000,000 acres of sod-based rotation were established, this unsequestered C might be reduced by about 0.05% (Fig. 4).

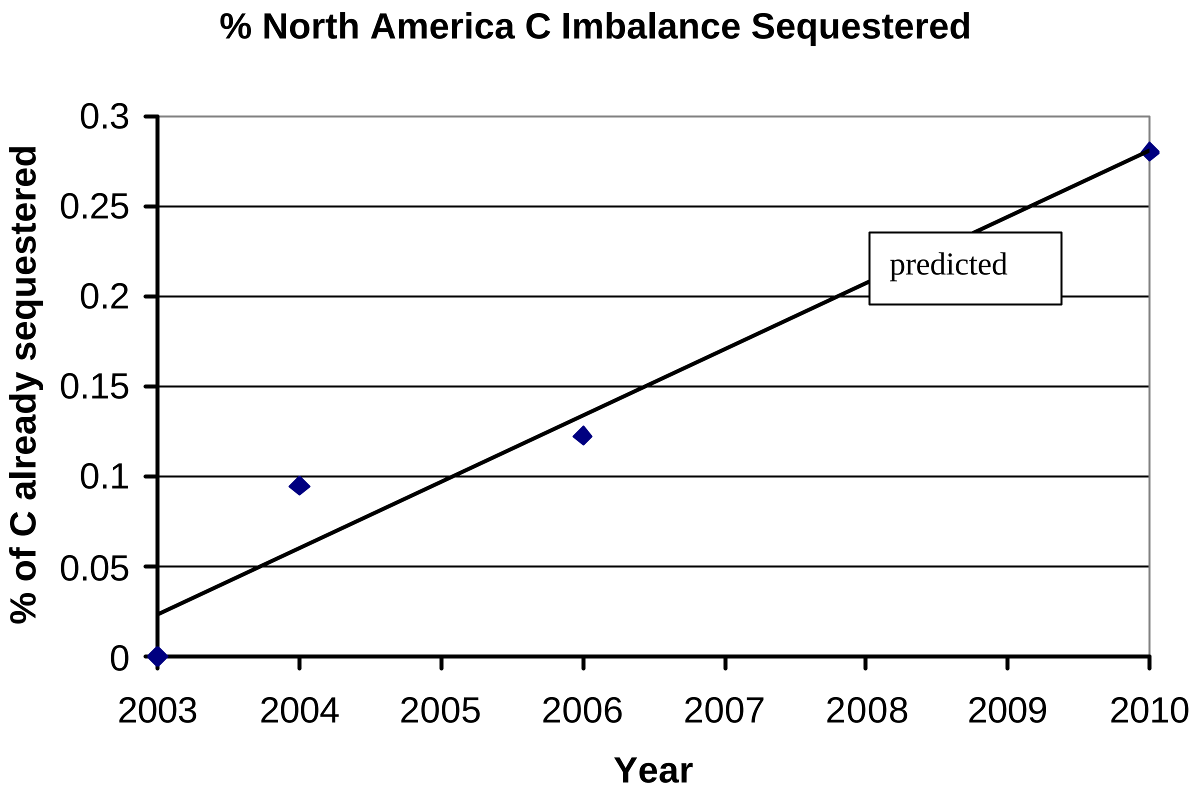


Fig 4. The impact of 1,000,000 acres of sod-based rotation in the southeast on the North America C imbalance.

At present, about 30% of the C released into the atmosphere is captured in plant growth. If the sod-based rotation were to be used on 1,000,000 acres, there could be an increase of about 0.1% per year more C sequestered in the soil reservoir (Fig. 5).

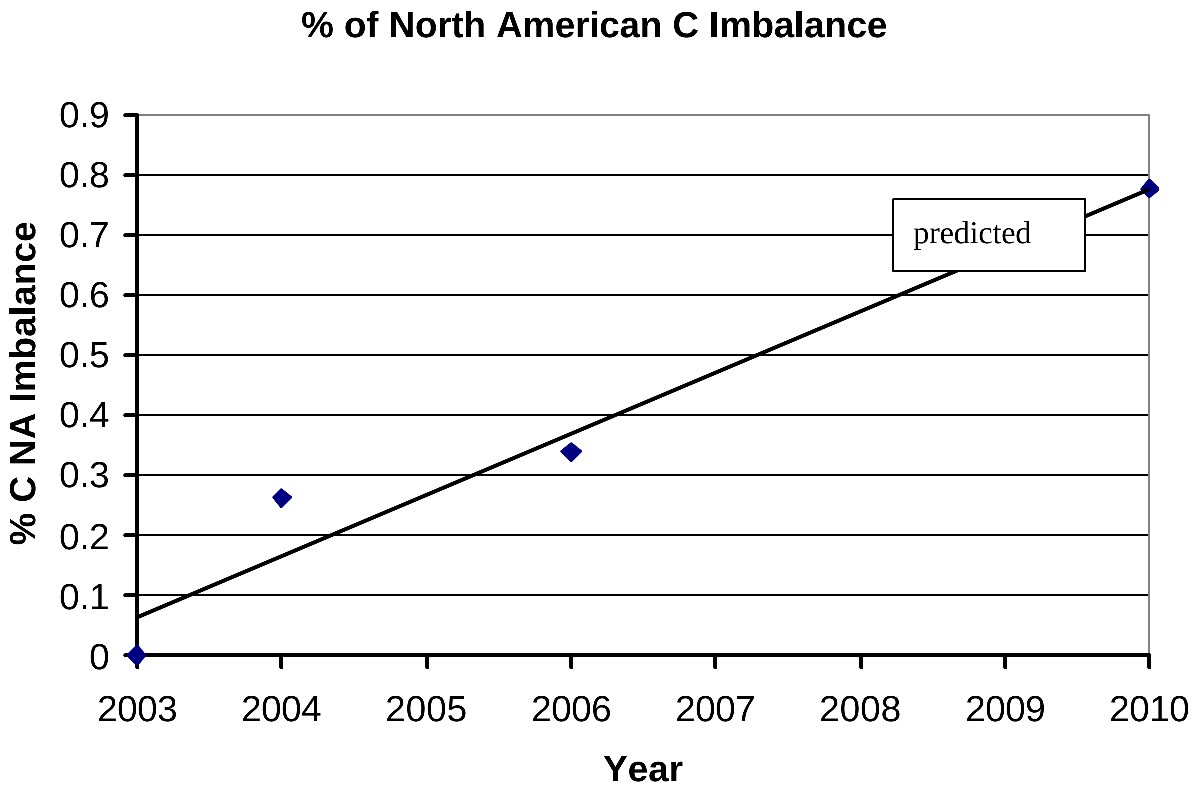


Fig 5. The impact of 1,000,000 acres of sod-based rotation in the southeast on the North America C imbalance.

In conclusion, the potential impact of sod-based rotation on global warming through reducing greenhouse gasses may be minimal. However, taken at a local level, lets suppose that a farmer has 500 acres and is interested in converting his farm to the sod-based rotation. Assuming that burning 1 gallon of gasoline releases 7.5 lb of C into the atmosphere, the farmer would be able to sequester the C from nearly 700,000 gallons of gasoline over 8 years of the rotation, or about 100,000 gallons per year (Fig. 6).

Think Globally, Act Locally.

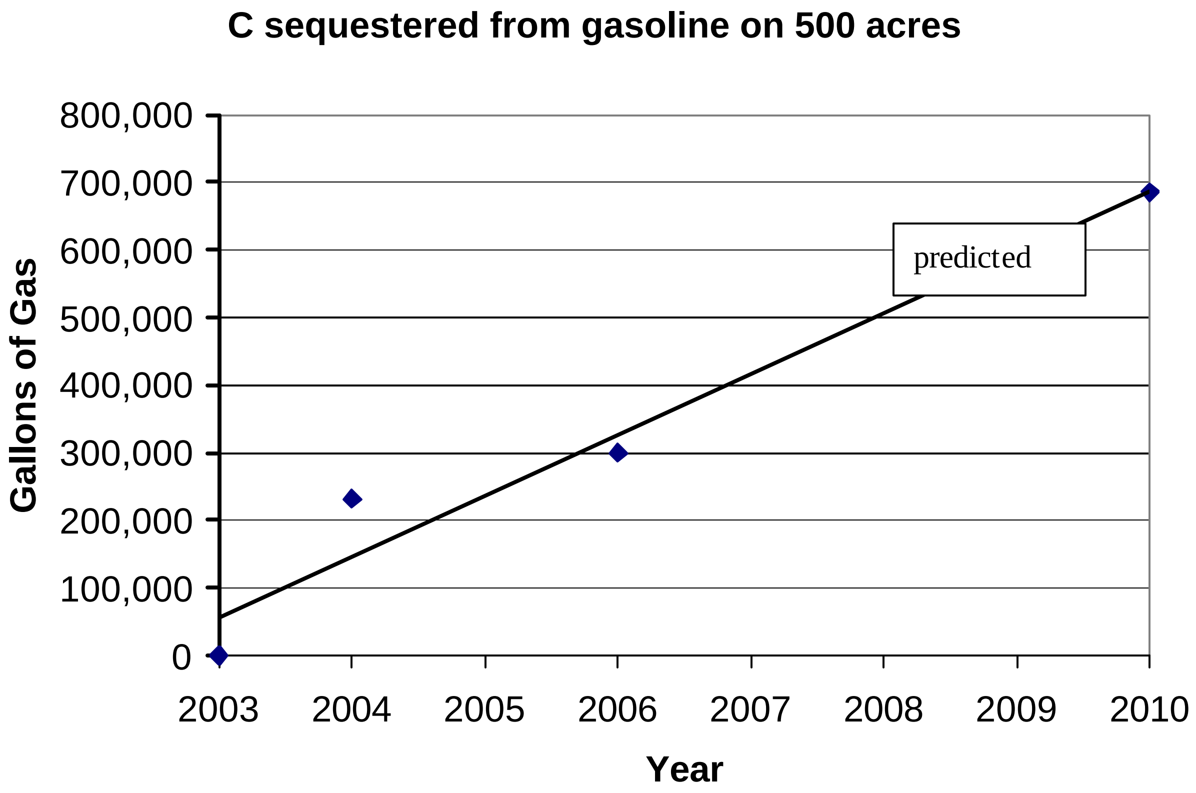


Fig. 6. C from gasoline sequestered on a 500 acre farm in the sod-based rotation.

REFERENCES

Flach, K. W. and M. G. Cline. 1954. Does cropping affect soil organic matter? Farm Res. 20:13.

Flach, K. W., T. O. Barnwell, Jr., and P. Crosson. 1997. Impacts of agriculture on atmospheric carbon dioxide. Pages 3-13. In: Soil Organic Matter in Temperate Agroecocsystems. Ed Paul, E.A., K. Paustian, E.T. Elliott and C. V. Cole. CRC Press, Inc. Boca Raton, FL.

Katsvairo, T.W. Wright, D.L., J.J. Marois, D.L. Hartzog, K.B. Balkcom and J.R. Rich.. 2007. Peanut and cotton yield in sod-based cropping systems Agron. J. (In Press).

King, A. W., L. Dilling, G. P. Zimmerman, D. M. Fairman, R. A. Houghton, G. H. Marland1, A. Z. Rose, and T. J. Wilbanks. 2007. United States Climate Change Science Program Synthesis and Assessment Product 2.2 The First State of the Carbon Cycle Report (SOCCR): North American Carbon Budget and Implications for the Global Carbon Cycle Executive Summary CCSP Product 2.2 Draft Subsequent from NOAA Review March 2007 ES-1.

Lal, R., D. L. Reicosky, J. D. Hanson. 2007. Evolution of the plow over 10,000 years and the rationale for no-till farming. Soil and Tillage Research 93:1-12.

Omonode, R. A., T. J. Vyn. 2006. Vertical distribution of soil organic matter and nitrogen under warm-season native grasses relative to croplands in west-central Indiana, USA. Agricutlure Systems & Environment 117:159-170.

Sainju, U. M., B. P. Singh, Whitehead, W. F. and Wang, S. 2006. Carbon supply and storage in tilled and nontilled soils as influenced by cover crops and nitrogen fertilization. Journal of Environmental Quality 35:1507-1517.

Stevenson, F. J. 1994. Humus Chemistry (2nd edition). John Wiley and Sons, New York. 496 pp.

THE EFFECT OF TRAFFIC PATTERNS ON SOIL COMPACTION

Alan D. Meijer[1*]
[1]NC State University, 207 Research Station Rd, Plymouth, NC 27962
[*]Corresponding author's email address: alan_meijer@ncsu.edu

ABSTRACT

Soil compaction is a common problem in the southeastern United States, especially on sandy soils as found in the Coastal Plain of NC. One of the main causes of soil compaction is equipment traffic in fields. The objective of this study was to determine the amount of traffic occurring in North Carolina fields and the effect that the level of traffic had on soil compaction as measured by soil bulk density. GPS was used to map all traffic on these fields in 2006. Using measurements of tread widths and wheel spacing, a series of processes in a GIS was performed to generate a map indicating the level of traffic that occurred in each area of the field. After all field operations were complete as well as the GIS analysis, fields were sampled for bulk density again. Sample locations were then based on the number of passes that had occurred. Initial results showed that 65-85% of the field's area was tracked. Bulk density ranged from 0.5 to 0.8 g/cm^3 in the organic soil, and from 1.6 to 1.8 g/cm^3 in the sandy soils. Initial results show that in the organic soil, areas of the field that were tracked at least four times had significantly higher bulk density in the 0-10 cm depth than the areas that received no tracks.

INTRODUCTION

Soil compaction has been known to be a serious problem in coastal plain soils for years. Many studies have described the negative effects of soil compaction on soil structure and plant growth (Barber, 1971; Unger and Kaspar, 1994; Vepraskas, 1994). One of the main causes of soil compaction is machine traffic in the field (Naderman, 1990; Hillel, 1980). Other studies have shown that around 80% of soil compaction occurs in the first pass of a vehicle (Kelly et al. 2004). Also, research has shown that up to 90% of a field's surface area can be tracked in a given year, when using conventional tillage practices (DeJonge-Hughes et al., 2001). Few studies have involved the use of GPS to track vehicles in a field to actually map the traffic pattern in a crop year.

The objective of this study was to determine what percentage of land area is tracked in a given year using Global Positioning Systems (GPS); and what effect the amount of traffic had on soil compaction, as measured by bulk density.

MATERIALS AND METHODS

This study was carried out on two farms in the lower coastal plain region of eastern NC. Fields L1 and L2 were located in Bertie County adjacent to the Roanoke River, while field P10 was located in Hyde County, in what as known as the Tidewater region of the lower coastal plain – an area characterized by organic soils.

The soil type at the Bertie County site was predominated by Tarboro loamy sand (Mixed, thermic Aquic Udipsamment) and Conetoe loamy sand (Loamy, mixed, thermic Arenic Paleudult). These fields are part of a corn-peanut-cotton rotation. One of these fields, "L1", was strip-tilled and planted in cotton in 2006, while "L2", and was planted in corn after being disked. The soil type in the Hyde County field "P10" was a Ponzer muck (Loamy, mixed, dysic thermic Terric Medisaprist). This field was being managed for organic grain production, and was planted in corn during the 2006 growing season.

Bulk density was determined at each location to get a picture of the current level of soil compaction in the fields. Fields L1 and L2 were sampled in a grid pattern prior to spring field operations in 2006. Soil cores were taken at depths of 0-4", 4-8", 8-12", and 12-16", using an AMS Soil Core Sampler (AMS Inc., American Falls, ID), that had a core of approximately 2" in diameter and 4" in height. Samples of increasing depth were taken adjacent to the spot where the previous (shallower) sample was taken, so as to eliminate the risk of sampling soil that may have been compacted by action of sampling the shallower sample previously. These samples were dried in an oven for 24 hours at 105^o C, and weighed. Bulk density was calculated by dividing weight of the sample by the volume of the sample (corer).

Field P10 is located in the Tidewater region of the lower Coastal Plain. This area is traditionally known as "the blacklands" because of the high organic content of the soils. The land here was originally swampland and drained in the early to mid 1900s by logging and the digging of an extensive series of canals and ditches. These fields have a unique history in how they were created that can affect their current management. Ditches were dug 330' apart to drain the land. The trees were cut and the logs removed. After the land was logged, the stumps and residue were pulled to the center of each field where these piles were burned repeatedly until the wood was gone. The fields were shaped with a crown in the center to enhance drainage. These fields were shaped with a crown in the center to enhance drainage. This resulted in some topsoil being pulled from near the ditch bank towards the center of the field. The end result is that there is the topsoil tends to be deeper near the center of the field than near the ditch. Thus, P10 was sampled by transecting the field from ditch bank to ditch bank taking 5 samples across the field and performing 3 such transects down the length of the field. This was done in an attempt to characterize the differences in bulk density that may be present due to the creation and shaping of the field. Bulk density was calculated from these samples in the same manner as those from L1 and L2.

All traffic was mapped on all 3 fields starting after that point. Traffic was mapped by mounting a Trimble AG132 differential-corrected GPS unit (Trimble, Sunnyvale, CA) to the tractor, sprayer, or combine cab, and recording the path the vehicle took using SiteMate software (FarmWorks, Hamilton, IN). For each event, the wheel spacings were recorded as well as tire widths themselves. This was also done for any wagon (i.e., boll buggy) towed behind the tractor.

Tracks were created in ArcGIS software (ESRI, Redlands, CA) by creating polygons that accurately reflected the spacing and widths of the tire tracks. This was done by creating and manipulating a series of buffers based on the measurements taken of each machine. Front and rear (inner) tires were counted as one track, although the maximum width of their combined footprint was used to create the track. This was done for all events for all three fields. Each track was saved as separate file and then converted to a grid. Each grid file consisted of thousands of cells that represented the area of the field. If a tire track crossed a cell, the cell received a value of "1". If there was no tire-track at that location, the cell received a value of "0". Then, using a process called Map Algebra; all the events were "added" together. In this process, the cells are "lined up" and their values are added together. The result is a grid file with cells that contain numerical values equal to the number of tracks that occurred at that particular point. From this file, the area of the field that was tracked, as well as the number of tracks that occurred was determined.

Bulk density samples were taken again in areas of the field that received 0, 1, 2, and 4 tracks to see if the amount of traffic affected bulk density. Fields L1 and L2 were sampled in randomized complete block where the treatment was the level of traffic, and replicated four times. Samples were only taken from the area of the field mapped as Conetoe loamy sand in these fields. At field P10, the experimental design was the same. However, this design was applied to three different sections of the field as noted earlier: P10Center is the middle 5th of the field; P10Ditchbank is the outer 2/5ths of the field, while P10Middle is the 2/5ths of the field that are between the ditchbank and crown areas of the field. Analysis of variance was performed using PROC GLM in SAS (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Pre-season Bulk Density

Initial bulk density was much greater in L1 and L2 than at P10 (Figure 1). Bulk density ranged from 1.43 to 1.65 g/cm^3 at L1 and L2, while ranging from 0.68 to 0.75 g/cm^3 at P10.

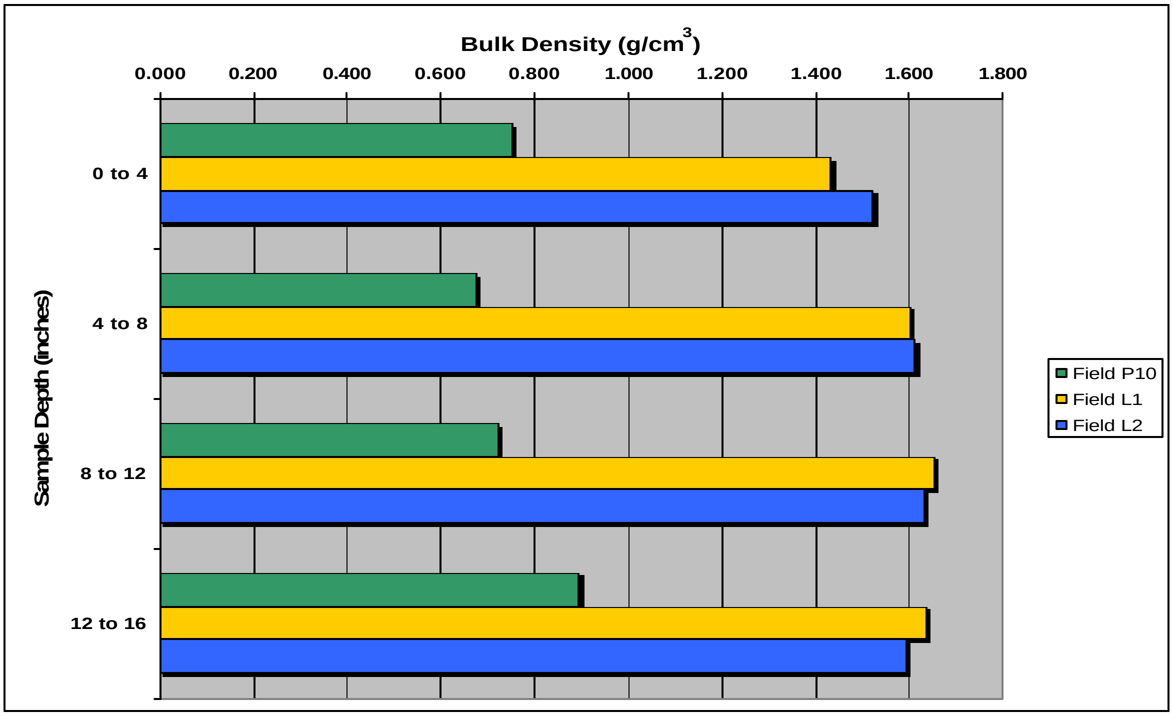


Figure 1. Bulk density for 3 sites at 4 depths prior to start of mapping.

At L1 and L2, bulk density increased noticeably between the 0-4 inch depth and the three samples below. At P10, bulk density actually decreased somewhat below the 0-4 inch depth and then becoming greater than that at the surface at the 12-16 inch depth.

Traffic Mapping

Table 1 shows the different field events that were mapped for each field. Since P10 was being managed for organic grain production, it saw more traffic than L2, which was also planted in corn, but not for organic production.

Table 1. List of field events at all sites in 2006.

P10 – Hyde County	**L1 – Bertie County**	**L2 – Bertie County**
Crop: Organic Corn	Crop: Cotton (Strip Till)	Crop: Corn (Conv. Till)
Chicken Litter Application	Strip-Till	Disk
Dynadrive	Plant	Bed
Field Cultivation	Roundup-Orthene	Plant
Plant	Herbicide (Sequence)	Nitrogen Application
Spring Tooth Harrow I	Pix Application I	Herbicide (Roundup)
Spring Tooth Harrow II	Nitrogen Application	Combine
Spring Tooth Harrow III	Pix Application II	
Danish Tyne Cultivation I	Hood Spray	
Danish Tyne Cultivation II	Defoliation	
Combine	Cotton Picker	
Auger Cart (Grain wagon)	Boll Buggy	
Total: 11 Events	**Total: 11 Events**	**Total: 6 Events**

Significant portions of the field were tracked at least once during the course of the growing season. In fact, 85% of the field surface area in P10 was tracked during the course of the season (Figure 2). While also planted in corn, only 65% of L2 was tracked. This correlates with the fact that P10 was managed for organic corn production and received more trips across the field than L2.

The surface area that received more than one track was calculated as well (Figure 3). Significant portions of the fields received more than one track. For example, more than 5% of the field area in L1 was tracked a total of 6 times. L2 was tracked the least overall, and therefore showed the least amount of area that was tracked multiple times.

Post-season Bulk Density

Bulk density measurements made after the growing season were similar to those made in the spring. Since P10 was divided up into 3 regions, more detail came to light in that field. Figure 4 shows the mean bulk density for each field and depth. Bulk density at L1 and L2 followed a

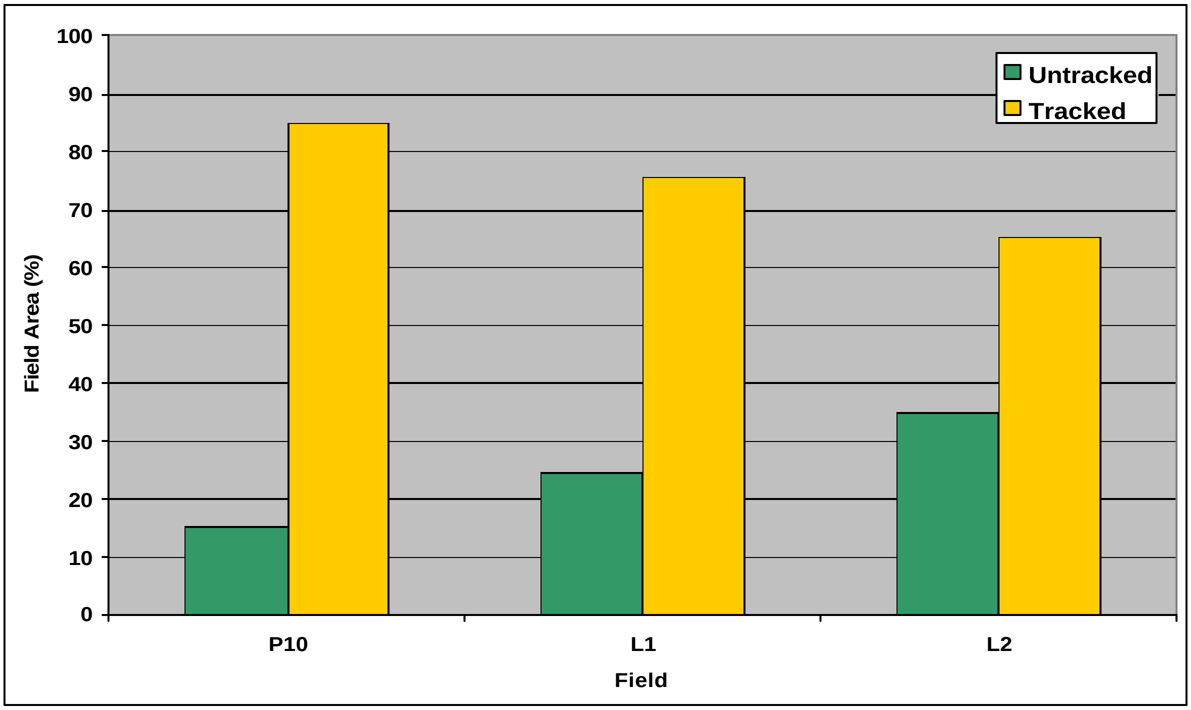


Figure 2. Percent land area tracked or untracked at 3 locations in 2006.

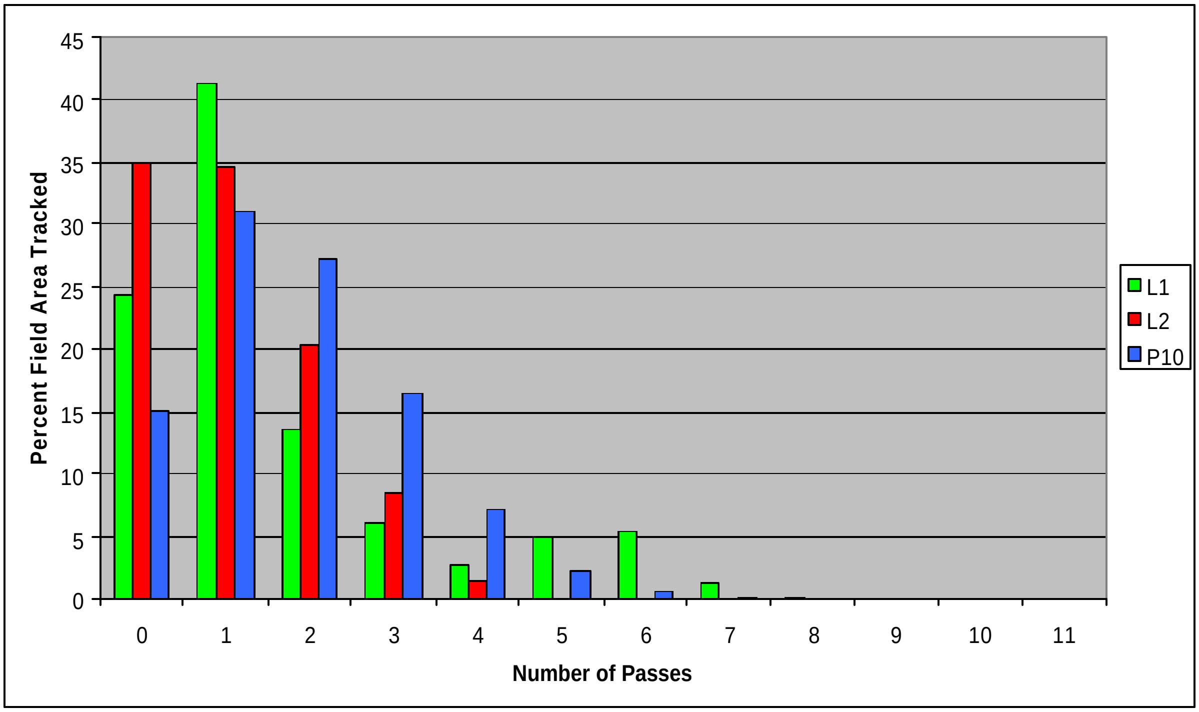


Figure 3. Number of tracks per given land area (percent land area) at 3 locations in 2006.

similar pattern with bulk densities starting at around 1.6 g/cm3 at the 0-4 inch depth and increasing somewhat to around 1.75g/cm3 at the 8-12 inch depth before dropping off slightly one sample deeper. These bulk densities are in the range of limiting root growth. The pattern of increasing bulk density with depth is also common. At P10, bulk densities were much lower, as would be expected in an organic soil. However, there was a distinct difference between the bulk densities of the samples taken from the ditchbank area of the field versus those taken from the center or middle of the field. Bulk densities in the center of the field and adjacent to the center (middle) started around 0.7 g/cm3 at the 0-4 inch depth and decreased some what with depth. In contrast, bulk density at the ditchbank started a little higher at around 0.8 gm/cm3 and rose first a little at the 4-8 inch depth and then increased steadily as the samples were deeper. This reflects the fact that much of the organic topsoil has been removed and the sandy layer is much shallower near the ditches (outer edges of the field).

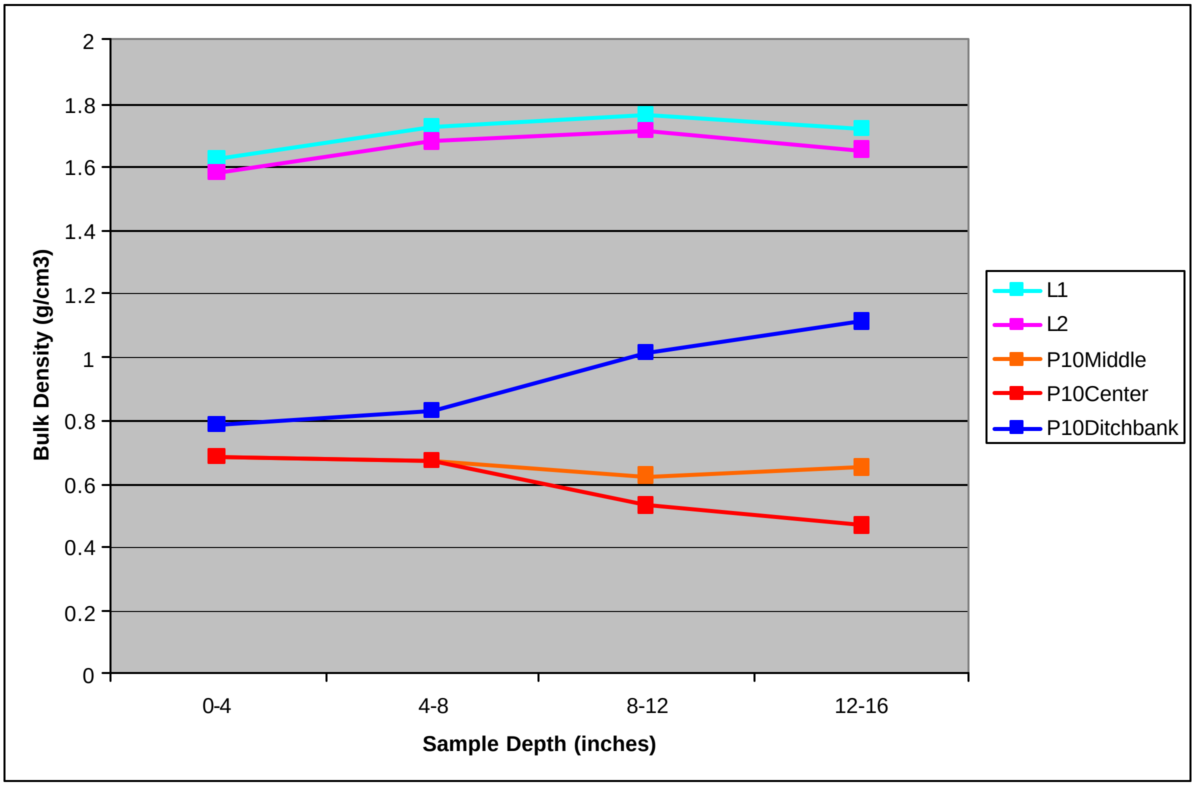


Figure 4. Post-harvest bulk density by sample depth at 3 locations. (P10 divided into 3 separate regions – center, middle, ditchbank.)

The effect of traffic (number of passes) was significant at some depths in some fields (Table 2). In P10Middle and L2, there was a significant difference in bulk density between the level of tracks at the 0-4”depth at the alpha = 0.05 and alpha = 0.10 levels respectively. P10Center was found to have significant differences in bulk density at the alpha = 0.10 level. One reason that differences in bulk density between levels of traffic were not found across the board may be due to the fact that the fields already exhibited a level of compaction prior to the start of the test. Li et al. (2006) stated that the field demonstration of the occurrence and impact of soil compaction is often confounded by the difficulty of establishing a non-compacted control.

Table 2. ANOVA results for the effect of level of traffic on bulk density at all sites in 2006.

Field	Sample Depth 0-4”	4-8”	8-12”	12-16”
L1	0.4029	0.7316	0.7112	0.8266
L2	*0.0645	0.2779	0.414	0.6479
P10Middle	**0.0361	0.5517	0.6321	0.9031
P10Center	0.779	0.6057	*0.0877	0.3603
P10Ditchbank	0.8421	0.2517	0.1694	0.2601

* Pr > F value is significant at the 0.10 level of probability.
** Pr > 5 value is significant at the 0.05 level of probability.

While Table 2 showed that the level of traffic did not affect bulk density in a majority of the treatments, the effect of location was significant at some depth in most fields (Table 3). This basically signifies that there were soil changes throughout the field that resulted in different bulk densities at each site.

Table 3. ANOVA results for the effect of location on bulk density at all sites in 2006.

Field	Sample Depth 0-4”	4-8”	8-12”	12-16”
L1	*0.0945	0.9281	0.4525	0.6699
L2	0.3710	0.1314	0.2714	0.4368
P10Middle	**0.0173	**0.0068	0.1276	0.1509
P10Center	*0.0802	**0.0121	0.3823	0.4191
P10Ditchbank	**0.0071	**0.0007	**0.0003	**0.0033

* Pr > F value is significant at the 0.10 level of probability.
** Pr > 5 value is significant at the 0.05 level of probability.

Figure 5 shows the effect that traffic had on bulk density at P10Middle in 2006. At the 0-4” depth range the bulk density was significantly greater in areas that were tracked four times as compared to areas that were not tracked at all. This might be explained by the relative increase in sand content in the upper layer of this organic soil as organic matter is oxidized over the years. Particle-size analysis will be done on these samples to help determine whether this hypothesis is feasible.

Figure 6 shows the effect that traffic had on bulk density at L2 in 2006. At the 0-4” depth, the bulk density was significantly greater in areas that received 3 tracks when compared to areas that were not tracked at all during the growing season. It is difficult to determine an explanation for why these two treatments were the only ones that differed significantly.

While at most depths at all locations, bulk density was not affected by traffic, a key issue affecting these results is that the fields were not subsoiled or chisel plowed prior to the start of the test in order to reduce their bulk density. In other words, all fields already demonstrated a level of compactness prior to any traffic. Therefore, since it has been discussed that most of the compaction occurs in the first pass of the field, subsequent traffic passes would make little difference. Li et al (2006) noted that it is difficult to obtain an uncompacted control in a field situation.

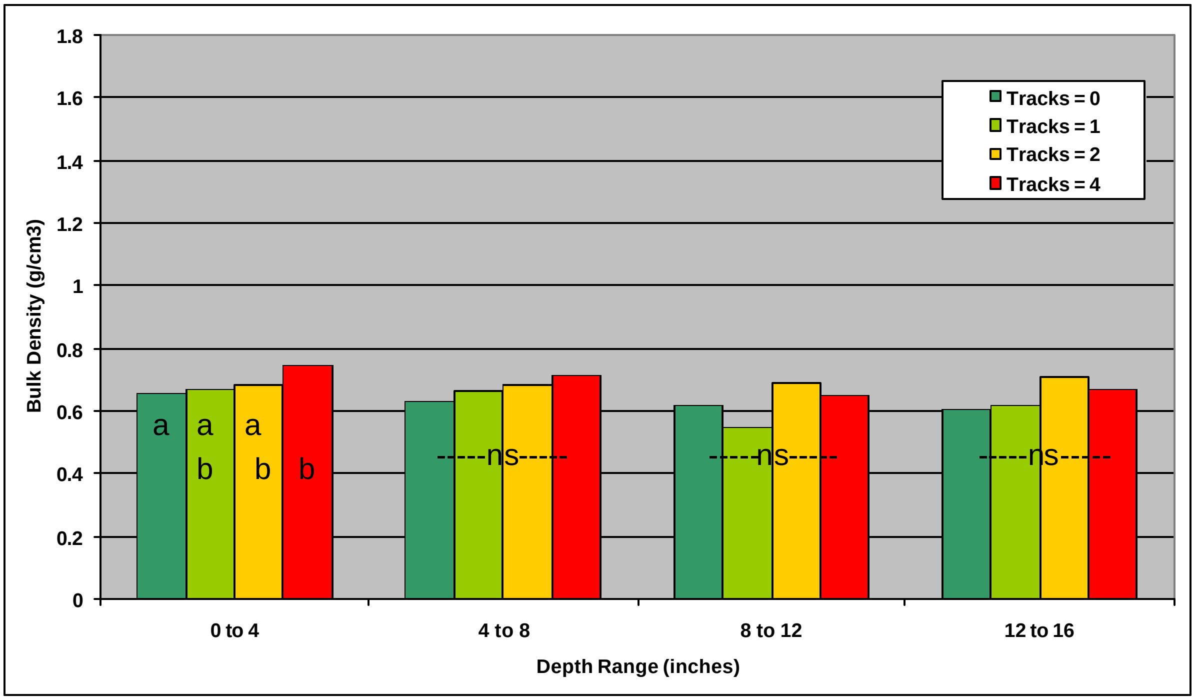


Figure 5. Post-harvest bulk density by sample depth at P10Middle in 2006. Within groups of bars, means labeled by different letters are significantly different at the 0.05 probability level.

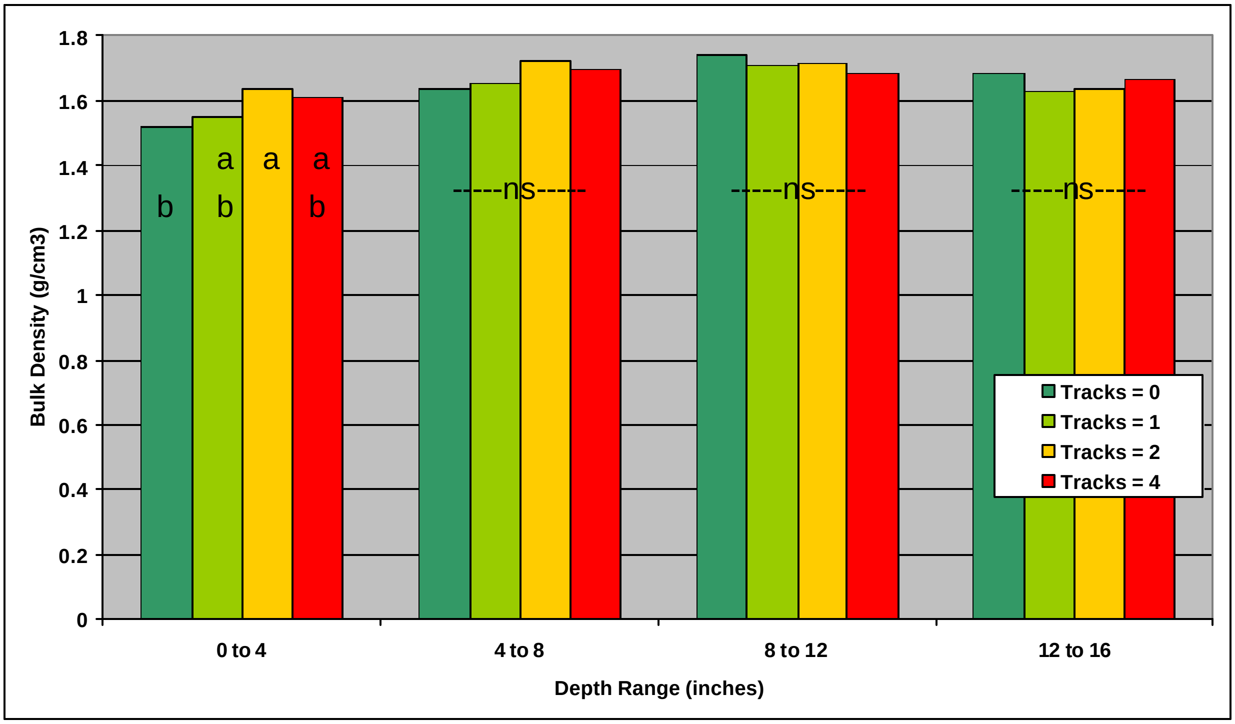


Figure 6. Post-harvest bulk density by sample depth at L2 in 2006. Within groups of bars, means labeled by different letters are significantly different at the 0.05 probability level.

CONCLUSIONS

Soil compaction has been understood to be a problem for a long time, as has the idea that vehicle traffic on fields is the major cause. However, it remains a key issue for growers, extension personnel and researchers to contend with. This study was designed to shed new light on this issue, but using GPS to get a true picture of traffic patterns in various situations in eastern North Carolina.

A key discovery in this study is the significant percentage of land area that is tracked in a given season, under a variety of cropping situations in eastern North Carolina. Results showed that 65-85% of the land area is covered in a cropping season. This does follow what has been reported in the literature. The use of GPS in determining the traffic patterns is also beneficial in that it allows for other analyses to be performed on what occurred. This is very useful from a research point of view, but also for extension, as growers can get a true visual representation on what goes on in their field on a year to year basis.

Significant differences in bulk density between levels of traffic were only noted in a few instances. These results suggest that while organic soils are not compacted near as much as on sandy soils, they are affected by the level of traffic, at least in certain situations like at P10Middle. They also show that more significant and noticeable differences in bulk density may have been discovered had soil compaction been alleviated as much as possible via tillage, prior to the start of the season.

REFERENCES

Barber, S.A. 1971. Effect of tillage practice on corn (Zea mays L.) root distribution and morphology. Agron. J. 63:724-725.

DeJong-Hughes, J., J.F. Moncrief, W.B. Voorhees, and J.B. Swan. 2001. Soil compaction: Causes, Effects, and Control. www.extension.umn.edu/distribution/cropsystems/DC3115.html. University of Minnesota Extension.

Hillel, D. 1980. Environmental Soil Physics. Academic Press. San Diego, CA.

Li, Y.X., J.N. Tullberg, and D.M. Freebairn. 2006. Wheel traffic and tillage effects on runoff and crop yield. Soil and Tillage Research. (In press.)

Kelly, R., T. Jensen, and Radford B. 2004. Precision Farming in the northern grains region: Soil compaction and controlled traffic farming. www2.dpi.qld.gov.au/ fieldcrops/ 3166.html. Qyeensland Government, Department of Primary Industries and Fisheries.

Naderman, G.C. Jr., 1990. Subsurface Compaction and Subsoiling in North Carolina: An Overview. North Carolina Agricultural Extension Service. Raleigh, NC.

Unger, P.W. and T.C. Kaspar. 1994. Soil compaction and root growth: A review. Agron J. 86:759-766.

Vepraskas, M.J. 1994. Plant response mechanisms to soil compaction. p.263-287 In: R.E.Wilkinson (ed.). Plant-environment interactions. Marcel Dekker, Inc., New York.

Evaluation of overhead, low-pressure irrigation and no-till production systems in California''s Central Valley

Jeff Mitchell
University of California, Davis
9240 S. Riverbend Avenue
Parlier, CA 93648
Phone: (559) 646-6565
Fax: (559) 646-6593

Abstract

While center pivot and linear move irrigation systems are commonly used in many parts of the world, they are not widely used in California. Coupling the use of these irrigation systems with no-till production practices may, however, be a means for addressing a number of economic and resource conservation goals in this region. In 2006, we initiated a study in Five Points, CA to compare a traditional furrow-irrigated crop rotation with three conservation tillage crop rotations that are irrigated with an automated overhead linear move system. The alternative systems include an "intensified" traditional rotation that uses no-till and strip-till planting and transplanting techniques to enable greater crop intensity and diversity within a given time period, a strip-till system that will include direct-seeding crops that have not been strip-tilled yet in California, and a no-till biofuel / forage system. These systems are being evaluated in terms of their productivity, profitability, water use efficiencies, labor requirements and impacts on soil quality indicators.

INFLUENCE OF PASTURE PLANTING METHOD ON ANNUAL COOL SEASON PASTURE FORAGE AVAILABILITY FOR GRAZING BY GROWING BEEF CATTLE – A FOUR YEAR SUMMARY

R.O. Myer, A.R. Blount, J.N. Carter, C. Mackowiak, and D.L. Wright
University of Florida, North Florida Research and Education Center, Marianna, FL 32446 and Quincy, FL 32351

INTRODUCTION

The planting of cool season annuals, such as ryegrass (*Lolium multiflorum*), oats, rye and (or) wheat, is common in the Coastal Plain region of the southeastern USA to provide grazing for beef cattle during the late fall-winter-spring season (usually from November to May). The length of the grazing season and amount of pasture forage can be influenced by many factors other than weather. Some of these factors include 1) forage species, 2) forage variety within species, 3) planting a single species (mono-crop) vs. blend of forage species, 4) species used within a forage blend, 5) pasture cultivation/planting method, 6) planting date, 7) soil fertility, and 8) dryland or irrigated management (Ball et al., 1998).

The objective of the study reported here was to compare clean tilled (prepared seedbed) and sod-seeded pastures with different combinations of cool season annual forages in regards to forage yield and quality, and weight gain and total grazing days by grazing growing beef cattle over the late fall-winter-spring (November to May) grazing season.

MATERIALS AND METHODS

The study consisted of two experimental cool season grazing trials (experiments) that were conducted at the North Florida Research and Education Center (NFREC) of the University of Florida located at Marianna in northwest Florida. These trials, each lasting two years, were carried out over four consecutive years from 2001 to 2005 during the months of October through May. Both trials were designed as a 2 x 2 factorial to evaluate two different pasture forage types -- small grains (rye and oats mix; RO) with or without ryegrass (RG) for the first two years (Exp. 1), and oats with ryegrass or ryegrass only for the last two years (Exp. 2). For both trials, the winter annuals were planted by two pasture land preparation/planting methods -- tilled or prepared seedbed (PS) and sod-seeded (SS).

For each year within each trial, eight 3.2 ac fenced pastures were utilized for grazing by growing beef cattle. The pastures were divided into two groups -- four pastures for the sod seeding treatments and four for the prepared seedbed treatments. Each of the four forage and cultivation combination treatments was assigned to two pastures each year, thereby giving two replicates per pasture treatment per year. The four pastures of the PS treatments were prepared by deep plowing followed by disc harrowing, and the annual pasture crops were planted using a grain drill. In the four pastures assigned for SS treatments, a no-till seed drill was used and the pasture forage treatments were planted into dormant warm season bahiagrass *(Paspalum notatum)***.**

Soil fertility was analyzed every year for each pasture separately. These soils are well drained with a loamy sand surface and a sandy clay loam to sandy clay subsurface, and are typically acidic in nature. Initial fertilization and liming rates were applied to the pastures based on soil analyses by a commercial lab (Waters Agricultural Laboratories, Inc., Camilla, Georgia). The planting dates used for various forage treatments were based on University of Florida-IFAS recommendations (October for PS and November for SS). Grazing was started when the forage was about 8 to 12 inches in height. Grazing ended upon insufficient forage re-growth of the PS pastures. The SS treatments were terminated upon the end of the last PS treatment. All pastures over the four years were grown under dry land conditions. These pastures were top dressed twice with nitrogen fertilizer, each time with 75 lb of actual N per ac, within each year.

For each year within each trial, 32 growing Angus and Angus crossbred heifers and steers for Exp. 1, and 32 heifers only for Exp. 2 (Brahman/Angus cross, Simmental, Brangus, Angus/Brangus cross and Angus/Hereford cross) were utilized. Animals had an average initial body weight (BW) of 565 and 576 lb for year 1 and year 2 (Exp. 1), and 631 and 550 lb for year 3 and year 4 (Exp. 2), respectively. All cattle were allotted equally within replicate into groups of four, known as "tester cattle", based on sex, initial weight, and genetic background. The treatments were assigned at random to groups within replicate within year. The tester animals were allotted to their treatment groups upon initiation of grazing of the first pasture. The animal groups whose pastures were not ready for grazing were fed hay (bermudagrass) and supplement (80:20, rolled corn: cottonseed meal) until their assigned pastures were ready to graze. The tester cattle were weighed before pasturing and the experimental period started. While grazing, the tester cattle were weighed every 28 d as well as at the end of the experimental grazing periods. The weights were taken after fasting the animals overnight. Along with these groups of four tester animals, some extra cattle from the same calf crop as the testers, known as "put and take" cattle, were also used when available forage in the pastures was greater in quantity than the tester cattle could graze. The number and days the put and take cattle used in each pasture were also recorded. All the animals were offered a free-choice mineral supplement recommended for beef cattle on pasture.

Three exclusion cages per pasture, about 4 ft x 4 ft x 4 ft in size, were placed just before the start of grazing each year at random locations within each pasture to provide an ungrazed area for forage sampling. For each year of both trials, forage samples were collected from a square meter area within each cage at the start of grazing of the pastures and twice monthly thereafter until the end of grazing season. The start and end dates of grazing were different each year due to differences in planting dates that were due to differences in weather conditions and moisture availability during the late fall-winter-spring grazing seasons. Thus, all years did not have the same months represented.

Forage samples collected from the cages were dried at 120-130° F, weighed, sub-sampled, and ground in a Wiley mill to pass through a 2 mm stainless steel screen. The final sample obtained per pasture per sampling date was a pooled sample of the three sampling points per pasture. The weight taken was used to estimate forage dry matter (DM) yield of each pasture. The forage samples were further pooled by month before analyses at the laboratory. A portion of each sample was submitted to the Forage Evaluation Support Lab (FESL) of the Agronomy Department at the University of Florida to determine crude protein (CP) and in vitro organic matter digestibility (IVOMD) concentrations. The IVOMD was determined according to a modification of the two-stage Tilley and Terry (1963) technique by Moore and Mott (1974). Forage CP was determined by measuring total nitrogen on an Alpkem autoanalyzer (Alpkem Corporation, Clackamas, OR, USA) as described by Noel and Hambleton (1976).

Data collected included weight gain of the "tester" cattle, animal grazing days ("tester" plus "put and take" cattle), estimated pasture forage DM yield, and pasture forage quality (CP, IVOMD). Estimated cattle weight gain per acre was also measured and was calculated from average daily gain of the tester cattle and total animal grazing days per acre. For each trial (Exp.), data were analyzed as a 2 x 2 factorial design combined over years. The main effects evaluated included pasture forage type and pasture planning/cultivation method. Since the main effect of pasture planting/cultivation was similar for both trials, data were also combined and analyzed over all four years. Monthly pasture forage yield and quality data were also analyzed over all four years for the main effect of pasture planting/cultivation using repeated measures with month as the repeated measure. The months of November and May were not included in the yield results due to limited complete month data.

RESULTS AND DISCUSSION

The overall average monthly rainfall amounts and temperatures over the four years of the study during the October to May period were similar to the thirty-year average at Marianna except for the month of May (Table 1). The month of May, on average, was drier and hotter than the thirty-year average. As expected, there was much year-to-year variation in weather. This year-to-year variation resulted in differences between the years in regards to most of the parameters measured (i.e. animal grazing days, pasture forage DM yield, cattle weight gain per acre; $P<0.01$ to $P<0.10$). However, no meaningful year by treatment interactions ($P>0.10$) were noted. The results therefore were combined and averaged over the two years within each experiment.

For each year within each trial, we were able to graze the PS pastures sooner than the SS pastures (Table 2). In Exp. 1, adding RG to the RO pasture forage delayed the start, but increased the grazing season into May for the second year but not the first year. Dry conditions during year 1 of Exp. 1 forced us to terminate grazing sooner than planned. In Exp. 2, we were able to start grazing sooner for the ORG blend pastures than the mono-crop RG pastures for the second year, but not the first year. Dry conditions during the fall delayed planting and unusually cold and dry conditions during late fall and winter delayed the start of grazing for first year 1 in

Exp. 2. Weather conditions were more favorable during the second year of Exp. 2, however, we had to temporarily take the cattle off of some pastures during January because of the lack of forage growth due to cool growing conditions. The cattle were given hay and supplement and weight gains and grazing days were adjusted.

Even though the SS pastures were on average planted 40 days later than the PS pastures in Exp. 1 and 20 days later in Exp. 2, grazing did not start until an average of 58 days and 42 days after the start of grazing of the PS pastures (Table 2). Thus, average length of grazing was greater ($P<0.01$) for the PS pastures than the SS pastures (Tables 3 and 4) in each trial. In Exp. 1, forage treatment did not result in an increase ($P>0.10$) in grazing season (Table 3) even though we were able to graze the RORG pastures into May of the second year. In Exp. 2, planting with a blend of O and RG resulted in an overall slightly longer ($P=0.07$) grazing season than pastures seeded with RG alone (Table 4).

Estimated forage DM yield averaged 48 and 19% in Exp. 1 and 2, respectively, greater for the PS pastures than that noted for the SS pastures ($P>0.01$; Tables 3 and 4). The PS pastures had greater ($P<0.01$) DM yield earlier in the grazing periods than the SS pastures, but by March and continuing through April, yields were similar ($P>0.10$; March and April together). In Exp. 1, pasture forage treatment had no effect ($P>0.01$) on overall pasture forage DM yield (Table 3). In Exp. 2, the ORG blended pastures tended, on average, to have greater DM yield ($P=0.08$) over the grazing seasons than the RG only pastures (Table 4).

Total number of cattle grazing days for the PS pastures averaged 79 and 33% greater for Exp. 1 and 2, respectively, than for the SS pastures ($P>0.01$; Tables 3 and 4). Cattle grazing days are a combination of the grazing days of the "tester" and "put and take" cattle. Average stocking density, however, was less ($P<0.01$) for the PS pastures in each trial as compared to the SS pastures (Tables 3 and 4). These differences were probably due to the longer period of time that the PS pastures were grazed during the coolest time of the year (November through February) when forage growth was limited. Estimated cattle weight gain per acre of pasture, as expected, was greater ($P<0.01$) for the PS pastures than the SS pastures (Tables 3and 4) in both trials. Within either trial, pasture forage treatment had no effect ($P>0.10$) on estimated cattle weight gain per acre. This lack of an effect was in spite of the slightly greater forage DM yield and animal grazing days noted for the ORG pasture compared to RG pastures in Exp. 2. The reason for this was that cattle on the ORG pastures had a lower average daily gain ($P=0.04$; Table 4) than cattle on the RG only pastures.

Since planting/cultivation method was the same in both trials, when averaged over all four years, the PS pastures resulted in greater animal grazing days per acre (196 for PS vs. 126 for SS; $P<0.01$, SE = 5), pasture forage DM yield (4232 vs. 3083 lb/ac; $P<0.01$, SE = 201), and estimated cattle weight gain (462 vs. 266 lb/ac; $P<0.01$, SE = 16) than the SS pastures. Monthly pasture forage DM yield over all four years is depicted in Figure 1. As expected, PS pastures out yielded ($P<0.01$) the SS pastures early on in the grazing periods with the SS pastures out yielding

($P<0.01$) the PS pastures during April. This increase for the SS in April may be due to the emerging warm season bahiagrass increasing total yield.

As expected, both lVOMD and CP values of pasture forage samples were high (Tables 3 and 4). Monthly averages over all four years for PS and SS are depicted in Figures 2 and 3. Within each trial, the PS pastures had slightly but significantly higher IVOMD ($P<0.01$) and CP ($P<0.01$) than the SS pastures. The differences noted were due to differences during the latter part of the grazing seasons (Tables 3 and 4; Figures 2 and 3). This may have been the result of the emerging lower quality bahiagrass diluting the values obtained. Botanical composition of the pasture forage samples was not determined. Within Exp. 1 or 2, pasture forage treatment affected IVOMD but not CP (Tables 3 and 4). Again, the differences with IVOMD were small but significant ($P<0.05$ for Exp. 1 and $P< 0.01$ for Exp. 2). The CP and IVOMD values were highest early in the grazing season and lowest late in grazing season. The slightly lower IVOMD for the ORG forage compared to the RG noted in Exp. 2 may have contributed to the lower ADG noted for the cattle grazing the ORG pastures compared to RG.

The main reason for the increased pasture forage DM yield and subsequently increased animal grazing days for the PS pastures was the longer grazing season for planting/cultivation method compared to SS as noted above. The longer season was due mainly to the earlier planting dates for the PS pastures (Table 2). Another reason may be the competitive effect of the bahiagrass. There is evidence from other studies that bahiagrass, even when dormant, can have a negative effect on the growth of the crop seeded into the sod of this grass (Wright et al., 1982). The delay in peak forage DM yield noted (Figure 1) for the SS pastures compared to the PS pastures may also be a result of this effect. However, the longer period between planting and grazing for the SS compared to the PS pastures may be due more to the influence of the cooler weather on plant growth than competition from the bahaigrass.

The planting of a blend of forages, in particular a blend of a cereal (or cereals) with annual ryegrass, is recommended as a means to increase forage yield, grazing season length, and to hedge against varied weather conditions (Ball et al., 1998). However, in our study we saw only a small advantage. The lack of a larger impact may have been due to dry and hotter weather encountered during May over the four years. Under good growing conditions, annual ryegrass can extend the growing season well into May and even into June (Ball et al., 1998) in the Coastal Plain region of the southeastern USA.

The overall results of all four years of the overall study indicated a large advantage to planting cool season annual pastures into a clean tilled, prepared seedbed. Our results overall, indicated about a 50% advantage in regards to grazing season length, animal grazing days and most important, cattle weight gain per unit of land. Our results, however, were not as dramatic as that of an earlier study done in southern Georgia in which an almost two fold difference was noted (Utley et al., 1976). This advantage of planting into a prepared seedbed, however, would have to be weighed against increased land preparation costs compared to sod-seeding. Perhaps if the SS pastures can be planted earlier, then their productivity may be similar to PS pastures.

CONCLUSION

The planting of cool season annuals into a prepared seedbed resulted in increased pasture productivity during the late fall-winter-spring grazing season than planting (sod-seeding) into dormant warm season bahiagrass. Unfortunately, this pasture planting/cultivation method goes against the philosophy of reduced tillage. However, many diversified farms (i.e., row crops and cattle) will have open land available during the late fall-winter-spring period that can benefit from the planting of cool season annuals as a cover crop. This cover crop can provide high quality grazing for beef cattle.

REFERENCES

Ball, D. M., C. S. Hoveland, and G. D. Lacefield. 1988. *Southern Forages* (2nd Ed.). Potash and Phosphate Institute and the Foundation for Agronomic Research, Norcross, GA, USA.

Moore, J. E., and G. O. Mott. 1974. Recovery of residual organic matter from in vitro digestion of forages. *Journal of Dairy Science* 57:1258-1259.

Noel, R. J., and L. G. Hambleton. 1976. Collaborative study of a semiautomated method for the determination of crude protein in animal feeds. *Journal of Association of Official analytical chemists* 59:134-140.

Tilley, J. M. A., and R. A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. *Journal of British Grass Society* 18:104-111.

Utley, P. R., W. H. Marchant, and W. C. McCormick. 1976. Evaluation of annual grass forages in prepared seedbeds and overseeded into perennial sods. *Journal of Animal Science* 42:16-20.

Wright, D. L., R. D. Barnett, and M. A. Eason. 1982. Influence of tillage methods and previous crop on wheat production. *Agronomy Facts.* No. 132, Coop. Ext. Ser., UF-IFAS, University of Florida, Gainesville, FL, USA.

Table 1. Average monthly 24 hr mean temperature and rainfall during the experimental periods

	Month							
Year[a]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Temperature °F								
2001-02	66	64	58	52	51	58	72	75
2002-03	71	56	50	46	54	63	68	76
2003-04	68	62	48	50	50	62	65	75
2004-05	71	61	50	48	56	58	64	73
Avg.	69	61	51	49	53	60	67	75
30 Yr Avg[b]	67	58	51	49	53	59	65	73
Rainfall, in								
2001-02	1.50	1.69	0.51	3.82	2.44	5.51	5.87	2.09
2002-03	5.16	7.52	7.50	0.24	6.27	7.35	4.61	2.84
2003-04	1.69	4.19	1.58	3.19	7.67	0.90	4.37	1.19
2004-05	3.90	4.98	3.25	3.36	2.37	8.04	6.70	1.72
Avg.	3.06	4.60	3.21	2.65	4.69	5.45	5.39	1.96
30 Yr Avg[b]	2.90	4.12	3.86	6.09	4.81	6.11	3.84	4.21

[a] 2001-02 and 2002-03, Exp. 1; 2003-04 and 2004-05, Exp. 2.
[b] Marianna, FL, USA.

Table 2. Experimental grazing periods

	Planting Date		Grazing start		Grazing end	
Experiment 1						
Treatment[a]	First year[b]	Second year[b]	First year[b]	Second year[b]	First year[b]	Second year[b]
PS RO	2 Oct	3 Oct	7 Dec	20 Nov	25 Apr	9 Apr
PS RORG	3 Oct	13 Oct	7 Dec	18 Dec	25 Apr	20 May
SS RO	28 Nov	14 Nov	31 Jan	12 Feb	25 Apr	20 May
SS RORG	28 Nov	14 Nov	31 Jan	12 Feb	25 Apr	20 May
Experiment 2						
PS ORG	31 Oct	12 Oct	16 Jan	24 Nov	30 Apr	12 May
PS RG	31 Oct	12 Oct	16 Jan	7 Dec	30 Apr	25 May
SS ORG	17 Nov	2 Nov	12 Mar	11 Jan	30 Apr	25 May
SS RG	17 Nov	2 Nov	12 Mar	8 Feb	30 Apr	25 May

[a] Key: PS = prepared seedbed; SS = sod-seeded into dormant bahiagrass; OR = oats and rye; ORRG = oats, rye, annual ryegrass; ORG = oats and annual ryegrass; RG = annual ryegrass only.
[b] First year = 2001-2002 and Second year = 2002-2003 for Exp. 1, and First year = 2003-2004 and Second year = 2004-2005 for Exp. 2.

Table 3. Main effects of pasture cultivation/planting method and pasture forage blend on pasture forage yield and quality, and on growth performance of growing beef cattle: Exp 1

	Cultivation method		Forage blend			Significance		
Item	PS[a]	SS[b]	OR[c]	ORRG[d]	SEM[e]	Cult[g]	For[h]	C × F[i]
Grazing season length, d	142	89	114	118	-------	NS	NS	NS
Cattle grazing days/ac	221	124	174	170	5	**	NS	NS
Avg. daily cattle wt. gain, lb/d	2.35	2.00	2.20	2.16	0.06	**	NS	NS
Stocking density, head/ac	1.4	1.6	1.5	1.5	0.1	*	NS	NS
Estimated cattle wt gain[j], lb/ac	526	248	399	374	20	**	NS	NS
Forage DM yield, lb/ac:								
Overall	5060	3476	4186	4351	366	*	NS	NS
Dec	900	0	431	467	106	**	NS	NS
Jan	651	0	326	325	58	**	NS	NS
Feb	773	684	780	677	68	**	NS	NS
Mar	1468	1008	1254	1222	63	**	NS	+
Apr	750	1334	907	1175	61	**	*	+
Forage IVOMD, %:								
Overall	82.4	77.4	79.2	80.6	0.2	**	*	NS
Mar - Apr	81.1	76.8	78.6	79.2	0.4	**	NS	NS
Forage CP %:								
Overall	27.7	22.0	23.0	25.9	0.7	**	*	NS
Mar - Apr	24.1	22.6	22.6	24.1	0.7	NS	NS	NS

[a] PS – Prepared seedbed (clean tilled).

[b] SS – Sod-seeded into dormant bahiagrass.

[c] OR – Oats and rye blend.

[d] ORRG - Oats, rye and annual ryegrass blend.

[e] Standard error of the mean; n = 8.

[f] Key: ** = $P<0.01$, * = $P<0.05$, + = $P<0.10$, and NS = $P>0.10$.

[g] Cult – pasture cultivation/planting method (PS vs. SS).

[h] For = pasture forage treatment (OR vs. ORRG).

[i] C x F = Cult x For.

[j] Calculated from tester cattle ADG and total cattle grazing days.

Table 4. Main effects of pasture cultivation/planting method and pasture forage blend on pasture yield and quality, and on growth performance of growing beef cattle: Exp.2

	Cultivation Method		Forage blend			Significance		
Item	PS[a]	SS[b]	ORG[c]	RG[d]	SEM[e]	Cult[g]	For[h]	C × F[i]
Grazing season length, d	115	80	104	90	5	**	+	NS
Cattle grazing days/ac	170	129	163	136	9	**	+	NS
Avg. daily cattle wt. gain, lb/d	2.42	2.31	2.24	2.46	0.07	NS	*	NS
Stocking density, head/ac	1.5	1.7	1.6	1.5	0.1	**	NS	NS
Estimated cattle wt gain[j], lb/ac	399	283	356	326	23	**	NS	NS
Forage DM yield, lb/ac:								
Overall	3402	2690	3285	2807	165	*	+	NS
Dec	288	88	266	110	15	**	**	NS
Jan	292	175	235	231	11	**	NS	*
Feb	441	230	372	298	22	**	+	*
Mar	972	819	1074	717	70	NS	*	NS
Apr	933	937	906	963	43	NS	NS	NS
Forage IVOMD, %:								
Overall	81.2	78.0	78.9	80.2	0.2	**	**	NS
Mar – Apr	80.3	78.9	78.5	80.8	0.3	**	**	NS
Forage CP %:								
Overall	23.2	20.1	21.2	22.1	0.4	**	NS	NS
Mar- Apr	20.6	21.1	19.9	21.7	0.4	NS	*	NS

[a] PS – Prepared seedbed (clean tilled).

[b] SS – Sod-seeded into dormant bahiagrass.

[c] ORG – Oats and annual ryegrass mix.

[d] RG – Annual ryegrass only.

[e] Standard error of the mean; n = 8.

[f] Key: ** = P<0.01, * = P<0.05, + = P<0.10, and NS = P>0.10.

[g] Cult – pasture cultivation/planting method (PS vs. SS).

[h] For = pasture forage treatment (ORG vs. RG).

[i] C x F = Cult x For.

[j] Calculated from tester cattle ADG and total cattle grazing days.

Figure 1. Effect of pasture cultivation/planting method on monthly pasture forage DM yield, lb/ac (PS = prepared seed bed; SS = sod seeded into dormant bahiagrass; SEM = 49; effect of month, P < 0.01; averaged over both Exp 1 and 2 – four years).

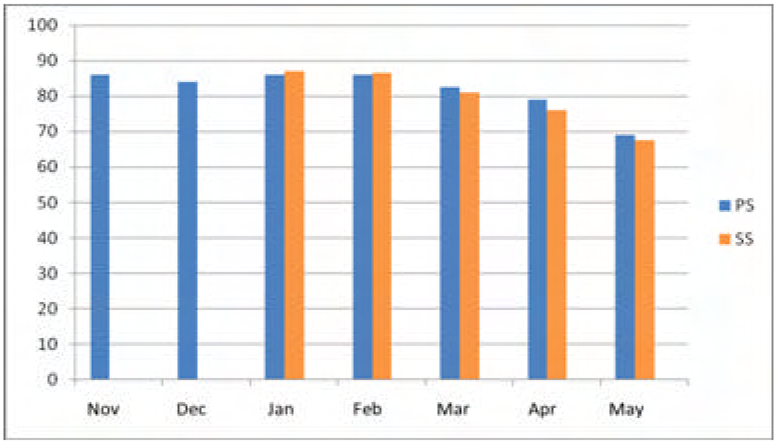


Figure 2. Effect of pasture cultivation/planting method on monthly pasture forage IVOMD, % (PS = prepared seedbed; SS = sod-seeded into dormant bahiagrass; SEM = 1; effect of month, P < 0.01, n = 8, 10, 12, or 16; averaged over Exp 1 and 2 – four yr average; DM basis).

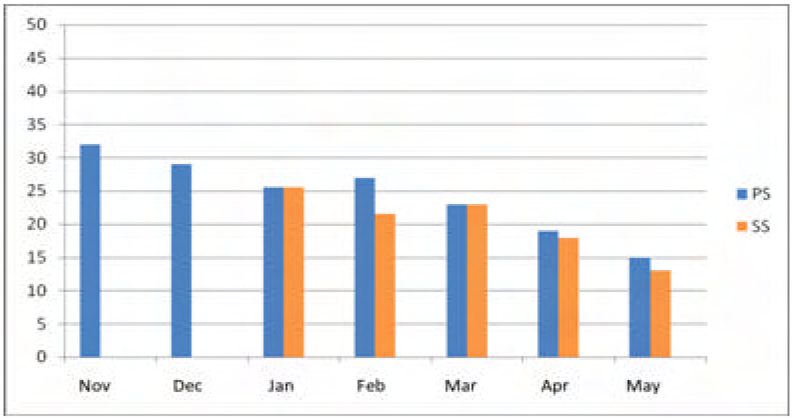


Figure 3. Effect of pasture cultivation/planting method on monthly pasture forage CP, % (PS = prepared seedbed; SS = sod-seeded into dormant bahiagrass; SEM = 1; effect of month, P < 0.01, n = 8, 10, 12, or 16; averaged over Exp 1 and 2 – four yr average; DM basis).

VARIABLE-RATE IRRIGATION: CONCEPT TO COMMERCIALIZATION

Calvin D. Perry and Andrea W. Milton
Bio & Ag Engineering Dept.
University of Georgia
Tifton GA 31793
perrycd@uga.edu

INTRODUCTION

Water conservation has become a critical issue in the southeast U.S. for many reasons including cyclical drought periods (some for extended periods), depleting aquifers, salt water intrusion near the coasts, and the “water wars” between Georgia, Florida and Alabama. Also, the changing population demographics of more people moving into the urban areas is shifting the political balance in favor of these more affluent areas of the states at the expense of the rural, agricultural regions. The increasing urban demands are particularly hard hitting for Georgia farms, where there are over 11,000 center pivot irrigation systems accounting for nearly 1.5 million acres of irrigation farm land (Harrison, 2005). Georgia’s agricultural use of freshwater (irrigation) accounts for 18% of total use (Hutson et al., 2004), with 37% from surface water sources and 63% from groundwater (Harrison, 2005).

Most center pivot irrigation systems currently in use apply a constant rate of water, yet very few fields are uniform. A field's inherently variable nature stems from factors such as soil type, topography, multiple crops, drainage ditches and waterways, and other non-cropped areas (Fig 1). To complicate matters, most fields are irregularly shaped and some even have structures that may be in the pivot path, such as a house or barn. Thus, to optimize crop production and increase water use efficiency, a method is needed for delivering irrigation water in optimal, precise amounts over an entire field.

Over the past decade, many research groups in the U.S., including the University of Georgia-Tifton Campus, USDA/ARS in Florence, SC, and Ft. Collins, CO, University of Idaho, and Washington State University, have all developed different research systems for applying irrigation water in more precise amounts. Evans et al. (2000) and Sadler et al. (2000) provide excellent literature reviews of ongoing precision irrigation projects around the country, indicating a substantial interest in spatially-variable irrigation by researchers.

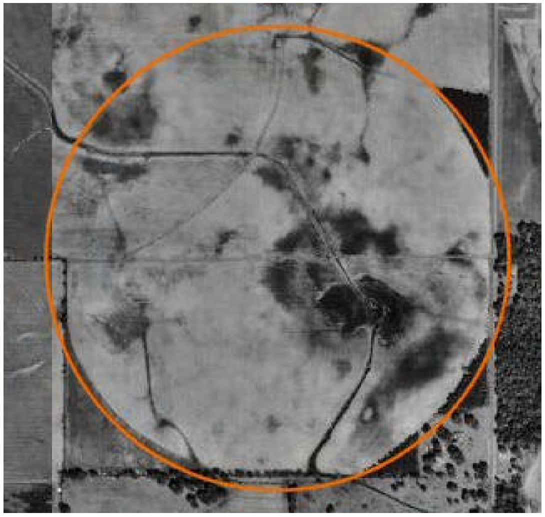


Figure 1. Bare soil image of typical South Georgia center pivot field.

MATERIALS AND METHODS

Variable-Rate Irrigation System

Beginning in 1999, the University of Georgia (UGA) Precision Ag team partnered with an Australian company, Farmscan (Computronics Corp. Ltd., Bentley, Western Australia), to develop a user-friendly and reliable/robust Variable-Rate Irrigation (VRI) control system for center pivot irrigation. The VRI system varies application amounts by cycling sprinklers ON/OFF (based on percent of 1 minute), controlling the end gun and by varying the system's travel speed. Application rates are based on percent of "normal" application as selected by the center pivot operator by his/her choice of system travel speed. To reduce application in relation to "normal", the VRI system will increase system travel speed and/or cycle sprinklers. To increase application in relation to "normal", the system will decrease travel speed. For example, to achieve a 50% application rate, the VRI system either increases speed or signals a sprinkler control zone such that the sprinkler valves in that zone open for 30 sec and then close for 30 sec, repeating continuously. A rate of 80% would correspond to 48 sec ON and 12 sec OFF. A rate of 100% (the "normal" amount) is, again, set by travel speed of the pivot. Any rate over 100% would require slowing of the travel speed accordingly.

The UGA/Farmscan VRI system (Fig 2) controls each sprinkler ON/OFF by a normally-open, pneumatically-actuated, flow-control valve. System sprinklers are typically grouped into control zones with multiple sprinklers each. An electronically-actuated air solenoid valve provides control actuation to the sprinkler valves in a control zone via 8 mm diameter air tubing. A 120 VAC air compressor mounted on the mainline near the pivot point supplies compressed air for valve actuation. Travel speed and end gun are controlled by interrupting the normal center pivot "walk" signal line and end gun signal line and injecting the VRI system's own signals. The VRI system retrofits on existing center pivot systems and integrates GPS positioning to continuously determine location/angle of the mainline. The system is designed with several "fail-safes" to insure the center pivot operator can apply water if there is an error or failure in the VRI system. Perry et al. (2002) describes the development of the UGA/Farmscan system in greater detail.

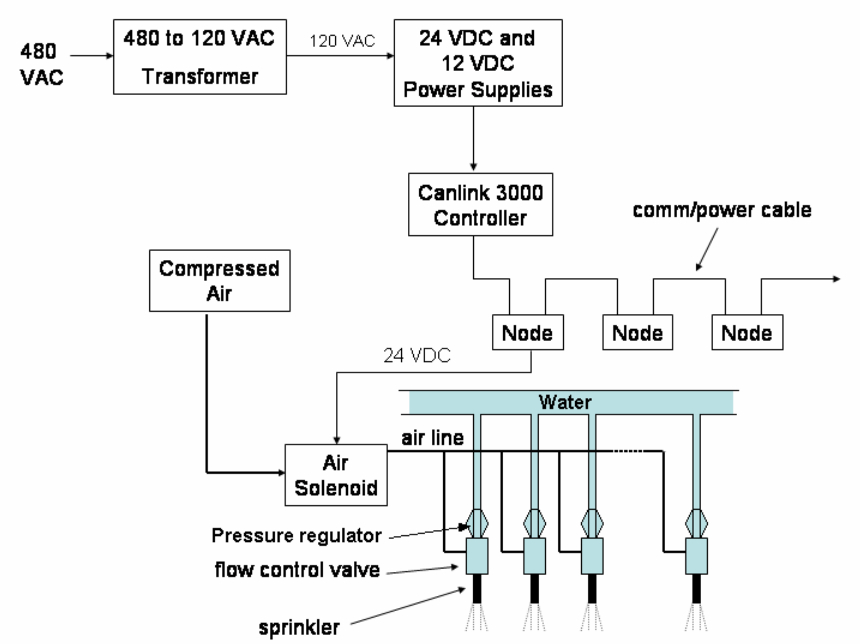


Figure 2. Diagram of UGA/Farmscan VRI control system.

The Farmscan Irrigation Manager PC software (Fig 3) provides for development of application maps. The software allows multiple pivots to be defined and allows each pivot to have multiple application maps defined. The software allows a pivot to be divided into wedges from 2 to 10 degrees "wide" (either full or partial circle) with up to 48 control zones radially along the pivot mainline. The number and size of the control zones are determined by features/anomalies in the field to be managed and by the installation of valve control hardware. Once a pivot and its irrigation control zones have been defined, a pie-shaped grid is displayed (divided into sections corresponding to the defined control zones). Using a legend of application rates (0 to 200%) the user selects a rate from the legend with the mouse and then "paints" each control zone of the map with an application rate. The resultant map is then digitally stored and copied to a PCMCIA SD memory card and uploaded to the master controller at the center pivot. At the present time, the water application map is a static map created with the aid of the farmer's knowledge of the field, aerial images of soil and/or crops, soil maps, yield maps, etc.

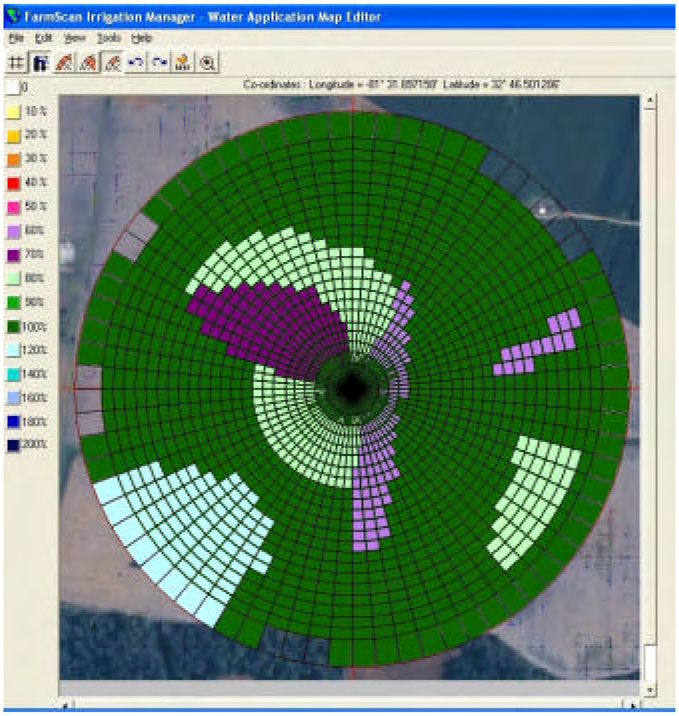


Figure 3. Farmscan software used to generate irrigation application maps.

The process for using the UGA/Farmscan VRI system is as follows:

1. Pivot information is entered into PC software;
2. Desired application rates are defined in the desktop software;
3. A control map is generated by the software;
4. Control map is transferred from PC to controller via SD data card;
4. The controller determines pivot angle via GPS;
5. Based on the control map, the controller optimizes pivot speed and/or cycles sprinklers (and/or end gun) to set application rate.

System Evaluation

Researchers have evaluated the UGA/Farmscan VRI system in various ways. Perry et al. (2003b) reported on the effectiveness of the VRI system to achieve targeted application rates in various sprinkler zones. The VRI system was able to achieve target application amounts fairly well, especially at higher rates. However, these tests measured variations in application only along the pivot mainline. Perry et al. (2003b) and Dukes and Perry (2006) evaluated water application uniformity while under VRI control and found the VRI system's cycling of sprinklers ON/OFF to vary application rate did not alter the uniformity.

To evaluate the VRI system in the "real world", the UGA Precision Ag team installed prototype VRI systems on 5 farmer-owned center pivot systems in Georgia. Each of these systems presented a unique combination of crops, soils, and irrigation system hardware. In each case, the farmer took the lead in developing a water application map for the VRI controller. The farmers used yield maps, aerial photos, soil survey maps, and, of course, first-hand knowledge of the fields to aid in development of the application maps. The prototype systems were used by the farmers for 2-4 years and performed quite well. One common aspect of each installation was the potential for water conservation with VRI. It became apparent that a method for varying irrigation across a field could also lead to substantial water savings, as many fields have areas that require less water or no water at all.

To verify water savings resulting from use of VRI, Perry et al. (2003a) evaluated three methods for calculating water savings and compared them to actual water savings. The calculation methods used included a) calculating gallons/min delivered in each sprinkler zone; b) calculating acre-inches delivered to each sprinkler zone; and c) calculating savings using summary data provided in the Farmscan PC software. The actual savings were determined by mounting a flow meter onto the system mainline. The group looked at three center pivot systems fitted with VRI controls that were operated with and without VRI engaged. Each calculation method produced a reasonable estimate of water savings, with the method using the software summary data being the easiest to calculate. Each of the three methods underestimated water savings or additional water usage. The application map shown in Figure 3 would produce a calculated water savings of 7%.

Commercialization

During the summer of 2004, several interested groups partnered to move the VRI technology beyond the prototype stage and into commercialization. The Flint River Soil and Water Conservation District of Georgia, the Georgia office of the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), The Nature Conservancy, and UGA jointly developed a plan to utilize federal NRCS Environmental Quality Incentives Program (EQIP) funding to provide a 75/25 cost-share opportunity for growers in the Flint River basin of Georgia to install VRI on suitable pivots/fields. UGA helped NRCS develop a ranking system and narrowed an original sign-up list down to 23 systems. Additionally, the Conservation District, NRCS and The Nature Conservancy jointly funded a position in the Flint River basin in southwest Georgia tasked with promoting water conservation, in particular VRI, to area farmers.

Also, in late 2004, a research/extension team from UGA and Clemson University in South Carolina was awarded over $500,000 through the NRCS Conservation Innovation Grant (CIG) program to install VRI controls on additional suitable center pivot systems, primarily in Georgia and South Carolina, by providing a 75/25 cost-share. The CIG grant also provided funds to demonstrate the use, benefits, and effectiveness of VRI for irrigation management, water conservation, and optimal application efficiency through a series of workshops/field days.

Hobbs and Holder, LLC. (Ashburn, GA) (www.betterpivots.com) was selected as the vendor to provide the VRI hardware, installation, training, and support via a licensing agreement with Farmscan. This start-up company was created by the partnering of two experienced crop consultants with a keen interest in precision agriculture and technology.

RESULTS AND DISCUSSION

Hobbs and Holder began commercial VRI installations in December 2004 and continued through late winter 2005 and had all original 23 NRCS EQIP-funded systems operational for the 2005 crop season.

Also in 2005, Hobbs and Holder began installing CIG funded VRI systems in Georgia and South Carolina. Currently, 10 CIG grant-funded VRI systems have been installed in Georgia and 5 have been installed in South Carolina. With approval of NRCS, the CIG grant has also funded one VRI installation in Arkansas and one in Alabama in 2006. Several more installations in Georgia and South Carolina are in the planning phase.

The Georgia NRCS received additional EQIP funds in late 2005 to install more VRI systems during Winter/Spring 2006 at the same 75/25 cost-share. Similarly, NRCS in Mississippi and South Carolina developed cost-share programs to cover VRI installations in their respective states.

The total number of VRI installations has now reached 44 (Table 1). This number includes a variety of center pivot manufacturers, system sizes (length and capacity), ages, nozzle configurations, etc. Most VRI systems have been installed on irrigation systems on row-crop farms. However, four VRI systems have been installed on turf farms. For the 44 systems installed currently, the water savings averages 12% (using the summary data calculation method). Table 1 lists the VRI installations completed to date.

Table 1. VRI installations completed by state and funding source.

State	CIG Installs	EQIP Installs	Other Installs	Total
Georgia	10	22	1	33
South Carolina	5	1	0	6
Alabama	1	0	0	1
Florida	0	0	1	1
Mississippi	0	0	1	1
Arkansas	1	0	0	1
North Dakota	0	0	1	1
TOTAL	17	23	4	44

During the 2005 and 2006 growing seasons, the UGA/Farmscan VRI systems performed well. As with any first generation product, there were occasional problems that Hobbs and Holder had to resolve. Problem resolution often involved the in-field replacement of a controller, circuit board, or GPS unit. These components were returned to Farmscan for repair or replacement.

CONCLUSIONS

The UGA/Farmscan VRI system has been shown to be capable of optimizing crop production and increasing water use efficiency by delivering irrigation water in optimal, precise amounts over an entire field. With VRI, the soil moisture needs of crops on varying soil types can be met while limiting over-applying or under-applying irrigation water. Similarly, the system can reduce or eliminate water application to non-cropped areas.

Commercialization of the UGA/Farmscan VRI system has progressed well. With cost-share funding from NRCS EQIP and from a NRCS CIG grant, 40 systems have been installed. Four systems have been purchased without cost-share assistance.

Reasons that farmers have expressed an interest in having a VRI system have ranged from environmental stewardship, conservation, economics, and enhanced productivity. Current VRI systems are installed on farms that grow some of the more traditional crops (peanuts, cotton, and corn) to the less conventional crops (i.e., turf).

Future Directions

UGA researchers have been working on wireless communication to/from soil moisture smart sensor arrays. The smart sensor arrays were developed to measure soil moisture and temperature using off-the-shelf components to keep costs down. The next challenge is to integrate the smart sensor array with the VRI controller.

Once this is achieved, growers will have the ability to control variable rate irrigation in real time using data collected with the smart sensor array. An example of what this technology will enable is the following: As the pivot travels around the field, the amount of water applied to the predetermined irrigation management zones will be a function of current soil water status as measured by the smart sensor array rather than a predetermined amount based on a static prescription map.

REFERENCES

Dukes, M.D. and C. Perry. 2006. Uniformity testing of variable-rate center pivot irrigation control systems. Precision Agriculture 7(3):205-218.

Evans, R.G., G.W. Buchleiter, E.J. Sadler, B.A. King, and G.B. Harting. 2000. Controls for precision irrigation with self-propelled systems. *In* Evans, R.G., B.L. Benham, and T.P. Trooien. Proceedings of the 4th Decenial National Irrigation Symposium. American Society of Agricultural Engineers. St. Joseph, MI. November 14-16. pp. 322-332.

Harrison, K. A. 2005. Irrigation Survey for Georgia. In K. J. Hatcher (ed.) Proceedings of the 2005 Georgia Water Resources Conference. Univ. of Georgia Institute of Ecology, Athens, Ga.

Hutson, S.S., N.L. Barber, J.F. Kenny, K.S. Linsey, D.S. Lumia, and M.A. Maupin. 2004. Estimated use of water in the United States in 2000. USGS Circular 1268, U.S. Geological Survey, Reston VA.

Perry, C., S. Pocknee, O. Hansen, C. Kvien, G. Vellidis, and E. Hart. 2002. Development and testing of a variable-rate pivot irrigation control system. ASAE Paper No. 02-2290, ASAE, St. Joseph, MI.

Perry, C.D., S. Pocknee, and C. Kvien. 2003a. Documenting Water Savings from Variable Rate Irrigation Control Systems, ASAE Paper No. 03-2144, ASAE, St. Joseph, MI.

Perry, C., S. Pocknee, and O. Hansen. 2003b. A variable rate pivot irrigation control system. *In* J. Stafford and and A. Werner (eds), ECPA 2003, Proceedings of the Fourth European Conference on Precision Agriculture, pp. 539-544.

Sadler, E.J., R.G. Evans, G.W. Buchleiter, B.A. King, and C.R. Camp. 2000. Design considerations for site specific irrigation. *In* Evans, R.G., B.L. Benham, and T.P. Trooien. Proceedings of the 4th Decenial National Irrigation Symposium. American Society of Agricultural Engineers. St. Joseph, MI. November 14-16. pp. 304-315.

Sadler, E.J., R.G. Evans, K.C. Stone, and C.R. Camp, Jr. 2005. Opportunities for conservation with precision irrigation. Journal of Soil and Water Conservation. 60(6):371-379.

Viral Suppression Through the Use of Conservation Tillage Systems in Peanut

Diane Rowland
USDA-ARS, NPRL
1011 Forrester Dr. SE
Dawson, GA 39842
Phone: (229) 995-7430
Fax: (229) 995-7416

Abstract

Tomato spotted wilt virus (TSWV) causes dramatic yield and economic losses to the peanut industry. The virus is vectored by thrips; but insecticide suppression of TSWV may be linked to genetic and physiological responses to these chemicals rather than thrips population control. Conservation tillage (CT) has also been shown to decrease the negative effects of TSWV, but many questions remain: 1) is TSWV infection actually lowered in CT?; 2) do all peanut cultivars exhibit TSWV resistance in CT?; and 3) what is the interaction between CT and insecticides? To answer these questions, a factorial experiment examining two tillage systems (conservation, conventional), four insecticide treatments (aldicarb, phorate, phorate + prothioconazole, no insecticide), and three peanut cultivars (Georgia Green, GA-02C, AP3) was initiated in Dawson, GA in 2006. As expected, CT systems had lowered TSWV symptoms which were linked directly to decreases in viral infection rates. Cultivars varied in the percent of TSWV suppression in the CT system and responded to insecticides differently. However, the interaction between infection and yield indicated that the benefits of using an insecticide were not linked solely to infection decreases, but possibly to changes in crop physiology. Lastly, an interaction between tillage and insecticide treatment indicated that some insecticides were more effective at reducing TSWV infection in CT systems than others.

ROTATION OF ANNUAL CROPS WITH SOD IN NO-TILLAGE SYSTEMS

Glover Triplett, William Kingery, and Mark Shankle

Department of Plant and Soil Sciences, Mississippi State University, Mississippi State, MS 39763

E-mail: gtriplett@pss.msstate.edu

INTRODUCTION

Before and during the 1950's, sod based cropping systems were almost universal in the Midwest. Typically, a meadow crop, such as alfalfa or red clover, often seeded with a cool season perennial grass, was produced for one to three years. Then the legume and grass mix was incorporated with tillage and corn was planted. The N produced by the legume crop was utilized as a fertilizer source by the corn crop. After the corn was harvested, a small grain, spring oats or winter wheat crop was planted. In addition, a legume crop of alfalfa or red clover was seeded with the oats or frost seeded into the wheat in late winter. Following grain harvest, the legume developed and was harvested for forage during succeeding years. When productivity declined, the meadow was tilled and the cycle repeated. Ruminant animals were an important component of this system and served as a means of marketing the forage produced. Failures of meadow seedings, primarily alfalfa, began to occur as increased N rates were applied to improve wheat yields. This problem was solved by summer seeding following wheat harvest. As N fertilizer became less expensive, it supplemented N from legumes to produce a second year of corn. Increased production of annual crops, corn and soybean, replaced the meadow component, provided cash flow from grain sales, reduced the need for livestock to consume forage, and increased the potential for soil loss since fields were tilled more frequently. A joke was that some Midwest farmers were following a CBM rotation: corn, beans and Miami.

Crop rotations like those described above were never widely used in the Southeast, primarily because no suitable perennial legumes were available for the region. Agronomists trained in Northern Universities and employed in the South might spend the first five yrs of their career trying to establish rotation systems to illustrate their benefits, but Southern growers never adopted these practices. Cleared land was labeled as "New ground" and highly prized in the South. Land was cleared, tilled, and farmed in annual crops until productivity declined. At this point, the focus shifted from annual crop production to pasture or tree establishment and the owners moved west in search of new areas to clear and farm. This was hardly a sustainable system and today there are no new areas to clear and farm. Therefore, in order to maintain the viability of agriculture a more sustainable approach must be achieved. Fortunately, under permanent vegetation, land degraded by intensive cropping recovers organic matter and soil structure that will support increased levels of crop productivity. Eroded soils with shallow depth to an impervious layer, such as chalk in the Black Belt, would be an exception. The latest cycle in cropping occurred during the 1970's when soybean prices were as high as $8 to $10/bu. Fences were removed, trees were pushed up and cleared land was tilled and planted to soybeans. In short order, both productivity and prices declined to unprofitable levels. When another surge in commodity prices occurs, land now in pasture or the Conservation Reserve Program (CRP) will become a candidate for annual crop production. Development of sustainable production systems that will protect the land resource while growing annual crops should be a high priority.

No-tillage crop production in sod retains soil organic matter and soil structure developed under perennial vegetation. Soil loss is reduced to levels that will sustain long term productivity, compared to tilled culture and macropores developed under the sod are not destroyed but remain functional. However, no-tillage development has been slow across the Southeast. In early no-tillage development in the Midwest, corn was planted into sod comprised of cool season (C-3) grasses that were controlled with applications of atrazine alone or atrazine plus paraquat. Dicamba and/or 2,4-D controlled forage legumes as well as a wide range of perennial broadleaf species. Triplett et al. (1979) reported that the sward did not have to be tilled to make N contained in legumes available for the corn crop that followed. Warm season perennial grasses common in the Southeast were not controlled with herbicides available at the time and without satisfactory vegetation control, no-tillage does not function properly.

Development of genetically modified crops tolerant to post-emergence applications of broad-spectrum herbicides (glyphosate, glufosinate) make possible no-tillage crop production in sod comprised of warm season perennial grass species. In our studies, we plant corn or soybean into sod and make a preemergence application of glyphosate or paraquat. At this time, late March or early April, the sward is comprised of cool season annuals near the reproductive stage and warm season perennials initiating spring growth. In three to 4 wks, after crop emergence and regrowth of species in the sod is initiated, an application of glyphosate is made. Some species present in the sod survive and regrow, including annuals from seed present in the soil, but are usually not competitive with the crop. Bermudagrass survives this treatment, insuring continuity of the sward. Undesirable species surviving include horsenettle and root knot foxtail. If more aggressive treatment is necessary, a second application of glyphosate is available. Stage of growth of vegetation and timing of application can influence herbicide effectiveness with control of cool season grasses more difficult as plant development proceeds from vegetative to reproductive stages (Triplett, 1985). This appears to be true for vegetation in southeastern swards, but has not been fully established. Also, early vegetation control decreases soil moisture use by the developing sward thereby making more water available for the annual crop.

MATERIALS AND METHODS

In 2001 and 2002 research studies were established at the Pontotoc Experiment Station Bude silt loam soil (fine, silty, mixed, thermic, Glossaquic Fragiudalf) to evaluate weed control in corn and soybean sod based systems. The herbicide treatments used for soybean and corn systems are given in Tables 1 and 2.

RESULTS AND DISCUSSION

In these studies, we have recorded soybean yields near 40 bu/a (Table 1). This was achieved with sequential POST applications of glyphosate. Insect pressure was an issue both years. Therefore, it is possible to produce even higher yields if fields are scouted and insect populations are minimized. In the corn system, a yield of 133 bu/A was achieved with a single POST application of glyphosate in 2001(Table 2). Timely rainfall events did not occur in 2002, but yield was still 115 bu/A with a sequential application of glyphosate. These results indicate that the sod-based system is possible and economical.

While producing crops in sod comprised of warm season perennials is made feasible by changes in technology, economics will determine acceptance of the practice. The cow-calf producer nets $30 to $50 per cow on an annual basis, according to budgets generated by economists. With 2 to 3 acres required for grazing and hay production to support each cow, return per acre ranges from $10 to $15. Even so, these prices of calves have been reduced in recent months, reflecting the increases in corn and soybean prices so that presently the net may be even less. Budgets for soybean production list direct costs at $150/A. If soybean prices are in the $5.50 range and yields average 40 bu, returns above direct expenses would be <$70/A, probably not enough to interest limited scale producers in beginning production. Presently, with prices in the $7.50 range, returns of $150/A. could generate interest in planting soybeans in sod.

While the most common use for sod systems is on-farm animal grazing, a ready market exists in the region for hay to feed cattle and horses, and could offer an alternative for the sod phase of the system. This market prefers weed- and mold-free, especially for horses. Weeds, especially coarse-stemmed ones, slow curing and lead to moldy pockets in the resulting hay. A rotation system in which profitable crops were available for each year of the rotation could make it easier, or less expensive, for hay producers to maintain weed free bermudagrass stands.

Budgets for corn have greater expense, partly because of N fertilizer costs, with direct costs at $270/A. At an estimated yield of 130 bu/A, corn at $2.50/bu (2006 mid-year prices) would gross $325/A, providing a return above direct expenses of $55/A. At $3.50/bu, a gross of $455/A would provide a return of $180/A above direct expenses and could interest growers.

CONCLUSIONS

A sod-based rotation of annual crops planted with no-tillage offers producers several advantages:

1. Annual crop production is possible on many sloping fields while staying in compliance with Federal restrictions on soil loss. Fields can be cropped for one or several years and managed for sod recovery.
2. Producers can respond to favorable price levels for grain crops by rapidly expanding production.
3. Rotating through an annual crop can improve forage quality and productivity of the sward. In one trial planted into a field infested with smutgrass, control was 80 to 90 percent, other undesirable vegetation is controlled, as well. Pastures containing toxic tall fescue can be renovated while producing an economic crop, then replanted following harvest. Soil amendments, lime and fertilizer applied for the annual crop, will increase forage productivity in years that follow.
4. Weed competition is a factor in unsatisfactory performance of alfalfa in the humid Southeast. With development of glyphosate tolerant alfalfa cultivars, maintaining alfalfa stands for multiple years becomes a possibility that should be investigated. If so, sod

based rotations with alfalfa furnishing much of the nitrogen required for a grain crop, such as corn, should be investigated.

5. Except for harvest machinery, equipment investment should not be prohibitive for small-scale growers.

REFERENCES

Triplett, G. B., Jr., F. Haghiri, and D. M. Van Doren, Jr. 1979. Plowing effect on corn yield response to N following alfalfa. Agron. J. 71: 801-803.

Triplett, G. B., Jr. Principles of weed control for reduced-tillage corn production. 1985. *In*: A. F. Wiese (ed). Weed control in limited tillage systems. Weed Science Society of America.

Table 1. Herbicide treatments and yield of soybean planted into established sod at Pontotoc, MS.

Treatment Name	Rate	Application	Yield 2001	Yield 2002
	lb ai/ac	Timing	bu/ac	
Roundup Canopy Prowl Roundup Roundup	1 0.22 0.75 0.75 1	PRE* PRE PRE 2WAP** 4WAP	36	18
Roundup Roundup Roundup	1 0.75 1	PRE 2 WAP 4 WAP	39	24
Roundup Roundup	1 1	PRE 3 WAP	31	20
Roundup Roundup Roundup Roundup	1 0.5 0.5 0.5	PRE 2 WAP 3 WAP 4 WAP	32	22
Paraquat Canopy Prowl Roundup Roundup	1 0.22 0.75 0.75 1	PRE PRE PRE 2WAP 4WAP	38	18
Paraquat Roundup Roundup	1 0.75 1	PRE 2 WAP 4 WAP	33	16
Paraquat Roundup	1 1	PRE 3 WAP	29	9
Paraquat Roundup Roundup Roundup	1 0.5 0.5 0.5	PRE 2 WAP 3 WAP 4 WAP	30	13
No herbicide			1	0
LSD .05			7.3	6.4

*PRE – Herbicide applied prior to emergence of the annual crop.
**WAP- Herbicide applied weeks after planting.

Table 2. Herbicide treatments and yield of corn planted into established sod at Pontotoc, MS.

Treatment Name	Rate lb ai/ac	Application Timing	Yield 2001 bu/ac	Yield 2002
Roundup Roundup	1 1	PRE* 3WAP**	133	99
Roundup Roundup Roundup	1 1 0.75	PRE 3WAP 6WAP		115
Roundup Bicep Atrazine	1 2.8 0.5	PRE PRE PRE	74	84
Roundup Bicep Atrazine Roundup	1 1.4 0.25 0.75	PRE PRE PRE 3WAP	115	101
Roundup Roundup Exceed	1 1 0.64 oz	PRE 3WAP 3WAP	116	86
Roundup Roundup Weedar 64	1 1 0.5	PRE 3WAP 3WAP	121	97
Roundup Roundup Simazine	1 1 3	PRE 3WAP 3WAP	124	97
Paraquat + Surf. Roundup	0.625 1	PRE 3WAP	97	90
Paraquat + Surf Bicep Atrazine	0.625 2.8 0.5	PRE PRE PRE	52	75
Paraquat + Surf Bicep Atrazine Roundup	0.625 1.4 0.25 0.75	PRE PRE PRE 3WAP	105	89
Paraquat + Surf Roundup Exceed	0.625 1 0.64 oz	PRE 3WAP 3WAP	60	61
Paraquat + Surf Roundup Weedar 64	0.625 1 0.5	PRE 3WAP 3WAP	116	77
Paraquat + Surf Roundup Simazine	0.625 1 3	PRE 3WAP 3WAP	69	69
LSD 0.5			40.4	21.4

*PRE – Herbicide applied prior to emergence of the annual crop.

**WAP- Herbicide applied weeks after planting.

INFLUENCE OF BAHIAGRASS (*PASPALUM NOTATUM* FLUEGGE) ROTATION IN THE SUPPRESSION OF TOMATO SPOTTED WILT OF PEANUT IN QUINCY, FL .

F. K. TSIGBEY*, J. J. MAROIS, AND D. L. WRIGHT

University of Florida, North Florida Research and Education Center, Quincy FL. 32351.

E-mail: fktsigbey@ifas.ufl.edu

Abstract

Rotation plots were established in Quincy, FL during 2000 to study the impact of a conventional Peanut-Cotton-Cotton-Peanut rotation (PCCP), and a Cotton-Bahiagrass-Bahiagrass-Peanut (CBBP) rotation on peanut diseases. Disease monitoring from 2003-2006 established that growing peanut after two years in rotation with bahiagrass significantly reduced TSW incidence and severity as compared to peanut in a conventional rotation involving two years of cotton. Incidence of TSW on peanut ranged 5.5-16.3, 23.5-37.5, 20.8-36.7, 18.3-25% in 2003, 2004, 2005, and 2006 respectively in a CBBP rotation, whereas the incidence ranged 15.3-24.4, 27.5-72.5, 28.3-76.7, 38.8-53.1% in 2003, 2004, 2005, and 2006 respectively in a PCCP. TSWV is vectored by thrips. Peanut seedlings suffered more severe thrips feeding damage, 100% incidence, under the PCCP rotation as compared to 45% incidence under the CBBP rotation. Thrips population on peanut seedlings were similarly higher on the PCCP than the CBBP rotation in 2005. Other peanut diseases were lower in the CBBP than the PCCP rotation in all years. Peanut pod yield was higher in the rotation of peanut with bahiagrass, 3,353 kg/ha than in the conventional system 2,633 kg/ha averaged across all four years. Other benefits of the bahiagrass rotation system will be presented.

INTRODUCTION

Tomato Spotted Wilt, caused by the TSW Virus (TSWV), a tospovirus in the Bunyaviridae family, is one of the major peanut diseases in the southeastern US. TSW of peanut is difficult to manage for various reasons: 1) insect (thrips) transmitted, 2) unavailability of effective chemical control options, 3) limited availability of plant resistance, and 4) increasing cost of peanut production with decreasing commodity prices. Tobacco thrips [*Frankliniella fusca* Hinds (Sakimura)] and western flower thrips *F. occidentalis* (Pergande) are confirmed vectors of peanut TSW and these insects are prevalent in the southeastern US (Todd et al., 1993; Todd et al., 1995).

Use of minimum tillage in peanut has been reported to reduce the impact of TSW and early leaf spot (ELS) (*Cercospora arachidicola* S. Hori,), late leaf spot (LLS) [*Cercosporidium personatum* (Berk. & M.A. Curtis) Deighton], and rust (*Puccinia arachidis* Spegg) as compared to conventional tillage (Baldwin et al., 2001; Johnson et al., 2001; Monfort, 2002). The most prevalent peanut cropping system in southeastern US is two years of cotton followed by peanut with a winter small grain (wheat, oats) cover crop. All of these crops are hosts to several species of thrips [*Frankliniella fusca* Hinds (Sakimura)]; *Frankliniella occidentalis* (Pergande); *Thrips tabaci*). Cotton seedlings are often affected by thrips, particularly tobacco thrips (*F. fusca*), which also is the predominant species on peanut during the seedling stage. Management of peanut TSW poses tremendous challenges since chemical control of thrips have not been shown to effectively manage TSW on peanut as reported by Todd et al. (1996), possibly due to the mode of virus transmission and vector mobility. In-furrow application of phorate has been reported to suppress TSW epidemics on peanut. Ames (2007) reported that spraying foliar insecticide in an addition to phorate application could successfully manage TSW, though the plant growth stage at application was not indicated.

No-till and minimum tillage systems for peanut have become an economic option for peanut cultivation in the southeastern US. Cantowine et al. (2006) reported the interacting effect of cultivar and tillage method on the suppression of leaf spot and TSW. Tillage systems have significant influence on thrips populations as well as feeding injury with less of both occurring in a strip-till and no-till system (Brown et al., 1996; Campbell et al., 1985). However, the role of soil type and rotation crops in the survival of thrips and their impact on TSW has not been thoroughly studied. Barbour et al. (1994) found fewer thrips emerging from soils than those collected on open-sticky cards in North Carolina, and concluded that soils from peanut fields were not a major source of thrips. Combined treatment of aldicarb and flutolanil or aldicarb alone significantly reduced thrips feeding damage but there was no significant difference for rotation (Timper et al., 2001). Culbreath et al. (2003) proposed the integration of chemical, genetic, and cultural practices involving planting date, manipulation of plant population, tillage practices, and row pattern as well as in-furrow insecticide application among other options in the management of TSW on peanut. The recommendation to manipulate plant population resulted in the adoption of the twin-row planting system to enhance early canopy closure (Culbreath et al., 2003).

Long-term management of TSW will require the use of TSWV-resistant varieties. Magbanua et al. (2000) reported that the nucleocapsid (N) gene of TSWV have been used to impart resistance to plants, and the first use of such approach was reported by Gielen et al. (1991) for engineered resistance to TSWV in tobacco. Sreenivasulu et al. (1991) attempted transforming peanut for resistance by using the N gene obtained from lettuce. Magbanua et al. (2000) successfully transformed peanut with the N gene and found that infection of plants with the N gene were lower in the transgenes than in untransformed plants. Chemical applications could also initiate a series of metabolic and genetic changes in plants, and Gallo-Meagher et al. (2001), reported that the mechanism of TSW control in phorate-applied peanuts appeared to be due to defense gene activation. Though genetic resistance holds promise to manage most peanut diseases, incorporating of resistance to all the economic diseases of peanut with acceptable yield and quality is a major challenge. For instance, a variety such as Georgia Green, which is widely planted in Florida and Georgia, gives good yield and field resistance to TSWV; however it is susceptible to both early and late leaf spot fungi (Cantowine, 2006). The advantages of using perennial grasses such as bahiagrass in peanut disease management has been well documented for leaf diseases and leaf spot diseases (Brenneman et al., 1995; Timper et al., 2001). However there is little information of the same system in the management of TSW.

The objectives of this research were to; 1) to assess the potential ability of bahiagrass rotation in peanut on TSW epidemics, 2) investigate possible mechanisms of TSW suppression.

MATERIALS AND METHODS

Rotation and Cultural Practices- Experiments were conducted at the North Florida Research and Education Center in Quincy, Florida from 2003 to 2006. Rotation plots were first established in year 2000 and consisted of a Bahiagrass rotation with peanut and a conventional rotation for peanut. Except for 2005 where some plots were in one year bahiagrass rotation (PCBP), and two years of consecutive peanut (CCPP), the cropping sequence for the Bahiagrass rotation involved the growing of cotton in the first year and then followed by bahiagrass for two consecutive years and in the fourth year the plots were cultivated to peanut for one year (CBBP), whereas the conventional rotation consisted of growing peanut in the first year with cotton in the two subsequent years followed by peanut in the fourth year (PCCP). Weed and other crop management practices were done based on the Florida Cooperative extension Services recommendations. Each plot measured 22.8 m in length by 18.4 m (20 peanut rows).

Tomato Spotted Wilt Assessment. Peanut plants were assessed by examining twenty plants within two rows at each time of assessment, and different rows were assessed at each point in time. Plants were examined at 2 m intervals within rows for TSW symptoms on leaves and scored using a modified scale of 1-3: where 1= presence of TSW symptoms on at least one leaf on the plant; 2 = symptoms on majority of leaves with moderate stunting of plant; and 3 = severe stunting of plant, and associated death.

Thrips infestation studies- Other rotations cotton-cotton-peanut-peanut (CCPP) and peanut-cotton-bahiagrass-peanut (PCBP) besides CBBP and PCCP were monitored during 2005 During 2005 thrips feeding injury as well as population on peanut seedling was assessed by sampling peanut seedlings 14 and 45 DAP for each rotation.

RESULTS

Hitherto all the beneficial effect of bahiagrass rotations to suppress diseases in peanut has only been directed at the leaf spot and soil-borne diseases, but has not been thoroughly studied for TSW. Tomato spotted wilt (TSW) epidemics in these fields were variable each year, however it remained significantly ($P \leq 0.05$) higher in the PCCP rotated peanut than the CBBP peanut in all four years irrespective of which variety was grown (Fig. 1). Similarly, TSW severity across years (2003-2006) regardless of the variety was significantly higher ($P \leq 0.05$) in the PCCP than the CBBP rotation. The progression of TSW in 2003 is shown in Fig. 2. with significant differences between the rotations observed for both incidence and severity 32 DAP, with the peanut in the PCCP rotation having 39% incidence vs. 22% (LSD = 16.2) in the CBBP rotation. TSW severity was similarly higher in the PCCP rotation than in the CBBP rotation at all times. TSW progression over time during 2004 is represented in Fig. 3. Peanut seedlings first exhibited thrips feeding damage as was observed in 2003 and were clearly visible two weeks after planting. Incidence of TSW 40 DAP was significantly different ($P \leq 0.05$) between the two rotations; 38 and 24 % respectively on PCCP and CBBP rotations.

Epidemics of TSW on peanut during 2005 under the different rotations are presented in Fig 4. with disease progression for CCPP and PCCP comparable as was for PCBP and CBBP. TSW incidence and severity was consistently higher and significantly different ($P \leq 0.05$) at each time of assessment on peanut in the PCCP than the CBBP rotation as represented in Figs. 4. during 2005 on AP3 variety. Progression of TSW incidence on AP3 peanut in the rotations during 2006 is presented in Fig. 5. Throughout the season, incidence and severity of TSW was significantly higher ($P \leq 0.05$) in the PCCP rotation than in the CBBP rotation.

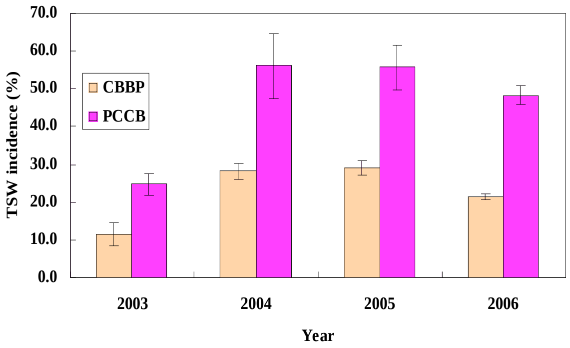


Fig. 1. Effect of rotations on incidence of TSW on peanut in Quincy, FL from 2003-2006. The standard error bars are displayed in the chart and represent 4-7 assessment times within a cropping cycle. B = bahiagrass, P = peanut, C = cotton.

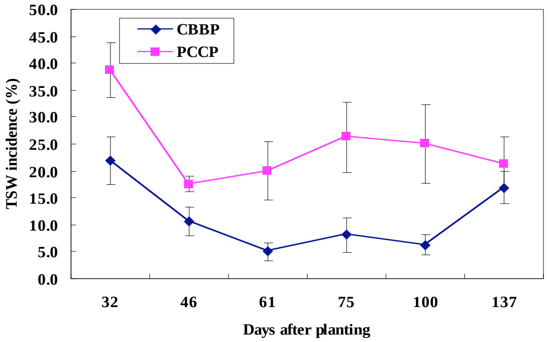


Fig. 2. Effect of bahiagrass (CBBP) and conventional (PCCP) rotation on progression of TSW incidence on Georgia Green peanut during 2003 in Quincy, FL. Treatment means of 20 plants for 8 or 4 replications and the standard error bars are shown for each assessment date.

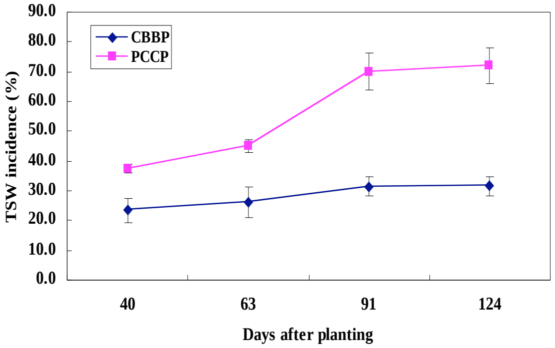


Fig. 3. Effect of bahiagrass (CBBP) and conventional (PCCP) rotation on progression of TSW incidence on Georgia Green peanut during 2004 in Quincy, FL. Treatment means of 20 plants for 10 or 4 replications and the standard error bars are shown for each assessment date.

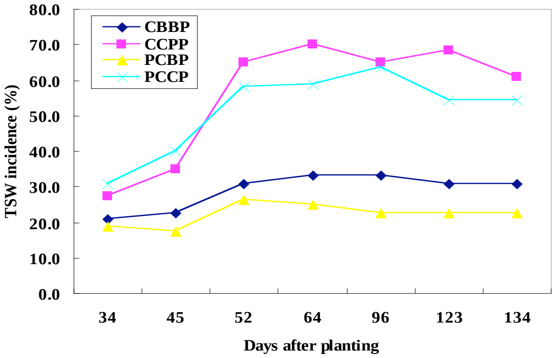


Fig. 4. Effect of different cropping sequences on progression of TSW incidence on AP3 peanut during 2005 in Quincy, FL. Treatment means of 20 plants for 6 replications. Cropping sequences are represented by: B = bahiagrass, C = cotton, P = peanut.

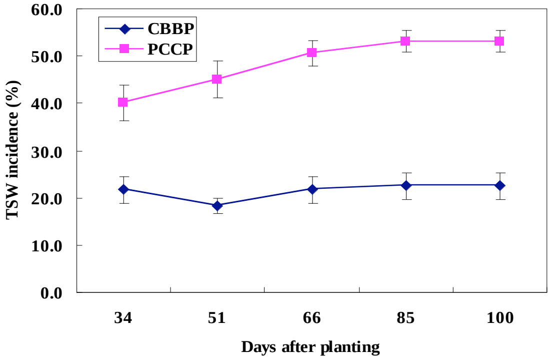


Fig. 5. Effect of bahiagrass (CBBP) and conventional (PCCP) rotation on progression of TSW incidence on Georgia Green peanut during 2006 in Quincy, FL. Treatment means of 20 plants for 6 or 8 replications and the standard error bars are shown for each assessment date.

Monitoring of thrips population, feeding damage and its impact on TSW on peanut- Thrips feeding began early on peanut seedlings just as the hypocotyl was breaking the soil surface resulting in feeding scars. Peanut in the CCPP rotation had higher numbers of thrips per plant (42); PCCP (22); CBBP (6); and PCBP (4) (Fig. 6). The number of seedlings exhibiting feeding damage is shown in Fig. 7, with a later correspondence to final TSW incidence on plots (Fig. 4). Thrips feeding damage was variable on the rotations in 2005 with the most damage on the PCCP, followed by CCPP, CBBP, and PCBP with averages of 19, 12, 8, and 5 damaged plants respectively out of the twenty plants sampled (Fig. 7). Correspondingly, the incidence of TSW followed a similar trend with the highest observed on CCPP and the least on PCBP (Fig. 4). The above trend observed was equivalent to the generation of differential epidemics. Differences in the feeding damage correlated with the number of thrips per plant, (r = 0.60, Pearson correlation). Similarly there was a stronger correlation, r = 0.94, between the number of thrips per seedling and the final TSW incidence. On average 13 out of 20 plants showed damage on the CCPP rotation and resulted in higher final 61% TSW incidence, compared with 5 damaged plants on PCBP with a final TSW incidence of 23% (Fig. 4). The number of thrips per peanut plant had a significant impact on the final incidence of TSW with a correlation coefficient, r = 0.94. The PCCP rotation mimicked what was found on the CCPP plots with 22 thrips per plant and a final TSW incidence of 54%.

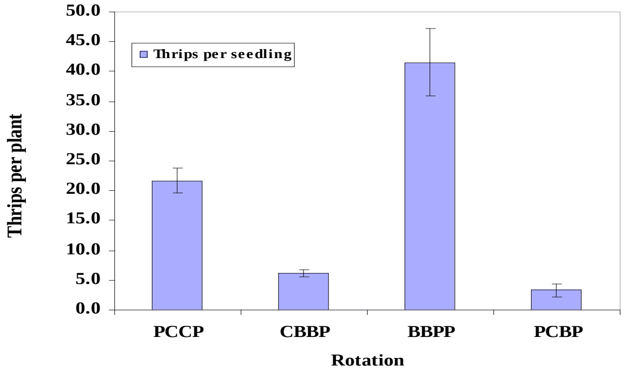


Fig. 6. Effect of different cropping sequences on thrips population on AP3 peanut seedlings during 2005 in Quincy, FL. Treatment means of 20 plants for 6 replications. Cropping sequences are represented by: B = bahiagrass, C = cotton, P = peanut.

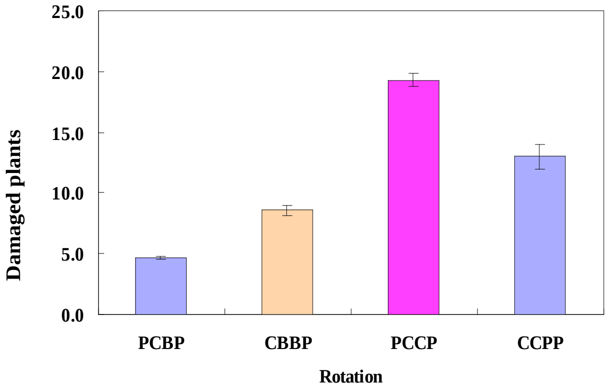


Fig. 7. Effects of rotations on thrips feeding damage on peanut seedlings in Quincy FL during 2005. Points represent average number of plants damaged out of 20 in plots with different cropping sequences represented. Points represent mean number of plants assessed 14 and 54 DAP. Cropping sequences are represented by: B = bahiagrass, C = cotton, P = peanut.

DISCUSSION

TSW incidence and severity on peanut was significantly suppressed by two years of bahiagrass rotation (CBBP), compared to the conventional (PCCP) rotation system over the course of four years (2003-2006) in a consistent manner. Brenneman et al. (1995) reported that a one year rotation in bahiagrass suppressed leaf spot as equally well as a two-year system and reduced stem rot of peanut, and limb rot could as well be a good alternative, though the data on TSW epidemics was not reported. It was observed in this experiment that, one year rotation in bahiagrass also suppressed TSW epidemics by reducing thrips population, and feeding damage, thus confirming the reports of Brenneman et al. (1995) that one year of bahiagrass rotation has some advantages comparable to a two-year bahiagrass rotation. Incidence and severity of TSW varied between years but was consistently higher on the PCCP rotation than in the CBBP rotation. The TSW suppressive effect of bahiagrass rotation had not been thoroughly researched, though its advantages in the management of soil-borne, and leaf spot diseases have been shown (Timper et al., 2001; Brenneman et al., 1995). TSW incidence remained in the range 12-32% in the CBBP rotation, compared to the PCCP rotation of 21-72% across years, with the highest severity in 2004 for both rotations.

TSW on peanut is transmitted by thrips hence their population dynamics on peanut play significant role in disease incidence and severity. Based on thrips population and damage data in 2005, it appeared the initial damage at the seedling stage could be one of the most important factors in determining the incidence and severity of TSW over time. In this study thrips damage as a result of feeding did not have a high correlation with thrips population(r = 0.60); however it could be explained by the fact that a single thrips is capable of causing multiple damage on plants by virtue of their mobility. Number of plants damaged was highly correlated (0.84) with the final incidence and severity of TSW. The high correlation coefficient (r = 0.94) observed between number of thrips per seedling and the final TSW incidence is consistent with the general assumptions of the influence of thrips population on TSW incidence (Culbreath et al., 1999). This research suggests that the initial thrips population on the field even before seedling emergence could significantly affect TSW incidence and may be supported by the number of thrips per seedling in the CBBP rotation was low in both 2005 that resulted in lower final spotted wilt incidence. Similarly, higher population of thrips in the PCCP rotation resulted in higher TSW incidence.

Differences in the population of thrips on PCCP and PCBP plots that were adjacent to each other that resulted in lower feeding damage and TSW incidence may be attributed to the following; 1) bahiagrass might have not been a good host as evidenced in the low number of thrips recorded on it and thus did not support thrips reproduction when compared to oats, 3) decomposing bahiagrass residue may have been releasing some volatile compounds that could serve to repel thrips from such plots. The contribution of volunteer peanuts in adjacent plots to TSW epidemics have been suggested but not quantified hence their role could be aggravated when there is already an existing reproductive host. Strip tillage has been investigated and reported to suppress diseases in peanut (Monfort et al., 2004) and Cantowine et al. (2006) also reported the reduction of TSW and leaf spots diseases in peanut under a strip tillage system compared to the conventional tillage system and attributed the reduction to the mechanisms suggested by Culbreath et al. (1999). Culbreath et al. (2003) hypothesized that, reduction in TSW on peanut under a strip tillage system could be attributed to modifications in thrips recognition of peanuts by virtue of the presence of stubble. It should be noted that the plots under study in this research were strip tilled, yet revealed significant differences in TSW epidemics in the two systems, suggesting that other mechanisms could be in play in TSW suppression in the CBBP rotation. Bahiagrass rotation has been reported to influence other soil properties (Katsvairo et al., 2007), such as better root system that could enhance plant vigor and tolerance to pest and disease attack and influence yield.

During 2005, and 2006 when AP3 variety was planted in a twin-row pattern, the percentage increase in yield between the PCCP and CBBP rotations were less than in 2003 and 2004 when GA Green variety was planted in a single-row pattern. This trend suggested that the twin-row pattern did reduce the impact of yield loss due to TSW, confirming the recommendations of Culbreath et al. (2003). The mechanism employed by the twin-row system in affecting TSW epidemics was reported to be possibly due to visual interference of migrating thrips in host recognition (Culbreath et al., 2003). Since the plots studied in this experiments were all strip tilled, and planted in a twin-row pattern in 2005 and 2006, the low percentage increase in yield (data not presented) between the PCCP and CBBP rotations could be attributed to plant compensation, in which severely stunted plants in the rotation were smothered by other healthy plants thus reducing the impact of TSW severity in the PCCP plots. Under these circumstances there are other yield qualities such other kernels (data not presented), which was significantly higher in the PCCP rotations could better reflect the severity of spotted wilt on the PCCP rotation than the actual harvestable and grades of the pods.

In conclusion, planting peanuts after two years of bahiagrass consistently reduced peanut TSW epidemics and improved yield. Bahiagrass rotation reduced number of thrips per peanut seedling, number of damaged peanut seedlings and TSW incidence and severity. This reduction in thrips and TSW may have contributed to the observed increase in peanut yield and quality.

LITERATURE CITED

Baldwin, J. A, Todd, J. W., Weeks, J. R., Gorbet, D. W., Culbreath, A. K. et al., 2001. A regional study to evaluate tillage, row patterns, in-furrow insecticide, and planting date on the yield, grade, and tomato TSW virus incidence of the Georgia Green peanut cultivar. Proc. Southern Cons. Tillage Conf. Sustain. Agric. 24: 26–34.

Barbour, J. D., Brandenburg, R. L. 1994. Vernal infusion of thrips into North Carolina peanut fields. J. Econ. Entomol. 87:446–51.

Black, M. C., Andrews, T. D., Smith, D. H. 1993. Interplot interference in field experiments with TSW disease of peanut. Proc. Am. Peanut Res. Ed. Soc. 25:65 (Abstr.).

Brenneman, T. B., Summer, D. R., Baird, R. E., Burton, G. W., and Minton, N. A. 1995. Suppression of foliar and soilborne peanut diseases in bahiagrass rotations. Phytopathology 85:948-952.

Brown, S. L., Todd, J. W., Culbreath, A. K. 1996. Effect of selected cultural practices on tomato TSW virus and populations of thrips vectors in peanuts. Acta Hortic.431:491–98.

Campbell, W.V., Sullivan, G. A., Register, E. W. 1985. Comparison of pests and pest damage in no-till and conventionally planted peanuts. Proc. Am. Peanut Res. Edu. Soc. 17:61 (Abstr.).

Cantowine, E. G., Culbreath, A. K., Stevenson, K. L., Smith, N. B., and Mullinex, Jr. B. G. 2006. Integrated management disease management of leaf spot and TSW of peanut. Plant Dis. Vol. 90, No. 4. pp. 493-500.

Culbreath, A. K., J. W. Todd, D. W. Gorbet, F. M. Shokes, and H. R. Pappu. 1997. Field response of new peanut cultivar UF 91108 to tomato TSW virus. Plant Dis. 81:1410-1415.

Culbreath, A. K., Todd, J. W., and Brown, S. L. 2003. Epidemiology and management of Tomato TSW in peanut. Ann Rev. Phytopathol. 2003. 41:53-75.

Gallo-Meagher, M., Chengalrayan, K., Davis, J. M., McDonald, G. E. 2001. Phorate-induced peanut genes that may condition acquired resistance to tomato spotted wilt. Proc. Am. Peanut Res. Edu. Soc. 33:29 (Abstr.).

Gielen, J. J. L., de Haan, P., Kool, A. J., Peters, D., van Grinsven, M. Q. J. M., Goldbach, R. W. 1991. Engineered resistance to tomato spotted wilt virus, a negative-strand RNA virus. Bio/technology 9: 1363–1367.

Johnson. W. C III, Brenneman, T. B., Baker, S. H., Johnson, A. W., Sumner, D. R. 2001. Tillage and pest management considerations in a peanut-cotton rotation in the southeastern coastal plain. Agron. J. 93:570–576.

Katsvairo, T. W., Wright, D. L., Marois, J. J., Hartzog, D. L., Rich, J. R., and Wiatrak, P. J. 2006. Sod–Livestock Integration into the Peanut–Cotton Rotation A Systems Farming Approach. Agron. J. 98:1156-1171 (2006).

Katsvairo, T. W. David L. Wright, James J. Marois, Dallas L. Hartzog, Kris B. Balkcom, Pawel J. Wiatrak and Jimmy R. Rich. 2007. Cotton Roots, Earthworms, and Infiltration Characteristics in Sod–Peanut–Cotton Cropping Systems. Agron. J. 99:390-398 (2007).

Magbanua, Z. V., Wilde, H. D., Roberts, J. K., Chowdhury, K., James J A, Moyer, J. W., Wetzstein, H. Y., and. Parrott, W. A. 2000. Field resistance to Tomato spotted wilt virus in transgenic peanut (*Arachis hypogaea* L.) expressing an antisense nucleocapsid gene sequence. *Molecular Breeding* 6: 227–236.

Monfort, W. S. 2002. Effects of reduced tillage, cultivar susceptibility and reduced fungicide programs on leaf spot of peanut (*Arachis hypogaea* L.). MS thesis. Univ. Ga., Athens. 78 pp.

Timper, P., Minton, N. A., Johnson, A. W., Brenneman, T. B., Culbreath, A. K., Burton, G. W., Baker, S. H., and Gascho, G. J. 2001. Influence of Cropping Systems on Stem Rot (*Sclerotium rolfsii*), *Meloidogyne arenaria*, and the Nematode Antagonist *Pastueria penetrans* in Peanut. Plant Dis. 85:767-772

Todd, J. W., Culbreath, A. K., Chamberlin, J. R., Beshear, R. J., Mullinix BJ. 1995. Colonization and population dynamics of thrips in peanuts in the southern United States. In: Thrips Biology and Management: Parker BL, Skinner M, Lewis T, eds. 1995. New York: Plenum. pp. 453–60.

Todd, . J. W., Culbreath, A. K., Demski J.W. 1993. Insect vectors of groundnut viruses. Proc. Meet. Consult. Group Collaborative Res., 5th, Dundee, Scotland, 15-19 Aug., pp. 23–24. Patancheru, India: ICRISAT Cent.

Todd, J. W., A. K. Culbreath, and S. L. Brown. 1996. Dynamics of vector populations and progress of TSW disease relative to insecticide use in peanuts. Acta Hortaculturae 431:483-490.

Sreenivasulu, P., Demski, J. W., Reddy, D. V. R., Naidu, R. A. 1991. Purification and some serological relationships of tomato spotted wilt virus isolates occurring on peanut (*Arachis hypogaea)* in the USA. Plant Path 40: 503–507.

WHOLE-FARM ECONOMIC EVALUATION OF CONSERVATION TILLAGE WINTER SMALL GRAINS FORAGE PRODUCTION IN ARKANSAS

K. Bradley Watkins,[1*] Paul A. Beck,[2] Don S. Hubbell, III,[3] Merle M. Anders,[1] Stacey A. Gunter,[2] Shane Gadberry,[4] and Keith S. Lusby[5]

[1]University of Arkansas, Rice Research and Extension Center, 2900 Hwy 130 E, Stuttgart, AR 72160.
[2]University of Arkansas, Southwest Research and Extension Center, 362 Hwy 174 N, Hope AR 71801.
[3]University of Arkansas, Livestock and Forestry Branch Station, 70 Experiment Station Dr. Batesville AR 72501.
[4]University of Arkansas, Cooperative Extension Service, 2301 South University Ave. Box 391 Room 308F, Little Rock AR 72203.
[5]University of Arkansas, Department of Animal Science, AFLS Bldg., Room B111C, Fayetteville AR 72701.
[*]Corresponding author's e-mail address: kbwatki@uark.edu

The project was supported by the National Research Initiative of the USDA Cooperative State Research, Education and Extension Service, grant number 2005-35101-15344.

ABSTRACT

Winter grazing of stocker cattle on small grain pastures may be a profitable income option for cattle and wheat producers in Arkansas. However, a large portion of land that could potentially benefit from this production system is highly erodible. This study evaluates the profitability of conservation tillage winter wheat/rye pasture production and grazing for a 100-head cow-calf operation. The study uses Mixed Integer Programming (MIP) to maximize whole-farm returns and select the optimal machinery complement for hay and winter forage production. Results indicate that no-till winter small grains forage production can enhance profitability for a cow-calf operation if steer calves are retained past weaning and placed on winter forage and if additional steer calves are purchased to fully utilize available winter forage capacity. However, profitability is highly dependent on the amount of capital available for purchase of additional steers.

INTRODUCTION

Winter wheat is one of the most common winter annuals grown in the United States due to its high forage quality and adaptability to a wide rage of climates. Soft red winter wheat is the common wheat type grown in the southern United States and is the primary wheat type produced in Arkansas. Soft red winter wheat is almost exclusively produced for grain in the state, with nearly 80 percent of total wheat area planted in eastern Arkansas.

Production systems that integrate stocker cattle with soft red winter wheat may have value both in Arkansas and the southern United States. Research conducted from 1996 to 2001 at the Livestock and Forestry Branch Station (LFBS) near Batesville, Arkansas demonstrated that stocker calves can be productively grazed on soft red winter wheat during the winter (Daniels et. al., 2002). However, conventional “clean till” planting methods were used exclusively in this research. Much of the land area that could potentially be used for production of winter wheat forage in Arkansas is highly erodible, and practices that maintain surface residue such as reduced till or no-till may be more appropriate in areas susceptible to soil erosion.

A second study conduced from Fall 2003 - Spring 2006 at the LFBS used partial budget analysis to evaluate the profitability of grazing stocker calves on soft red winter wheat and rye forage planted with conservation tillage methods (Gadberry et al., 2007). Steer weight gain and forage production data were used to calculate returns and costs to Clean-Till (CT), Reduced Till (RT), and No-Till (NT). The NT system produced the largest average return per acre during the study period ($69.18/acre), followed by the RT system ($40.15/acre). The CT system had a negative average return over the study period (-$16.69/acre). Lower forage production costs and higher fall weight gains were the primary reasons for greater profitability of the conservation tillage systems relative to the CT system.

The latter study demonstrated that conservation tillage systems can be more profitable than clean till systems in the production of winter small grains forage but provided no evidence that such systems would enhance profitability for a typical cattle operation in Arkansas. Cow-calf operations account for the majority of cattle operations in the state, with most calves born in the spring and sold at weaning in the fall (Troxel et al., 2004). Winter small grains forage production may allow some cow-calf operators to retain ownership of their calves beyond the fall or purchase additional calves to be sold in the spring when the winter pasture is grazed out. However, production of winter small grains forage requires additional machinery and equipment that may not be available on most Arkansas cattle farms.

This study uses Mixed Integer Programming (MIP) to evaluate the whole-farm profitability of conservation tillage winter wheat/rye pasture production and grazing for a 100-head cow-calf operation. The MIP model incorporates steer weight gain and forage dry matter yield data from the ongoing LFBS conservation tillage study and selects the optimal machinery complement for hay and winter small grains forage production, the optimal number of pasture, hay, and grazeout acres, and the optimal number of animal units sold to maximize whole-farm returns for the 100-head cow-calf operation.

MATERIALS AND METHODS

A 100-head cow-calf operation is modeled using secondary data from Hogan et al. (2006) and King Brister et al. (2002a). The model cow-calf operation has 250 pasture acres, owns its own hay equipment, and harvests it own hay. Eighty-seven animal units of various types are sold each year for the cow-calf operation. Additional details on pasture acres and types of animal units sold for the cow-calf operation are presented in Table 1.

A stocker enterprise is modeled for the cow-calf operation to allow steers to be grazed on winter wheat/rye pasture from mid-November through April. Steer calves in the stocker enterprise are grazed both in the fall and the spring. During the fall grazing period, steer calves from the cow-calf operation may be retained and placed on grazeout pasture with additional steer calves purchased as needed to fully utilize fall grazeout pasture. Additional steers may also be purchased during the spring grazing period to fully utilize spring grazeout pasture capacity. All additional steers are purchased using borrowed capital at 9% interest. Fall steers (retained and purchased) are placed on grazeout pasture beginning in mid-November and sold at the end of April. Additional spring purchased steers are placed on grazeout pasture at the beginning of March and sold at the end of April. Information on the purchase weights, sell weights, and prices used in the stocker enterprise are presented in Table 1.

The MIP model selects optimal machinery complements for both hay production and winter small grains forage production. Three possible systems are allowed for winter small-grains forage production: Clean-Till (CT); Reduced Till (RT); and No-Till (NT). The CT strategy consists of chisel plowing to a depth of 10 inches and heavy disking followed by use of a light disc or cultivator for weed control. Winter wheat and rye seed are planted into the prepared seedbed using a grain drill. The RT strategy consists of applying glyphosate one week prior to planting, followed by no more than two light disking passes with 50 percent residue remaining on the soil surface. A broadcast spreader is used to plant winter wheat and rye seed, and a harrow is used to drag the field to cover the seed. The NT strategy controls weeds exclusively using one application of glyphosate 2 weeks prior to planting. Wheat and rye seed is planted directly into the stubble using a no-till drill.

Annual machinery ownership expenses (depreciation, interest, housing, insurance, and taxes) are estimated for each tractor and implement using American Society of Agricultural Engineers (ASAE) standard formulas (ASAE, 2003a,b) and are adjusted downward by the ratio of the used price to list price to reflect used rather than new equipment. Machinery complements and annual ownership expenses for the cow-calf operation with and without winter small grains pasture are presented in Table 2. Machinery operating expenses are also estimated using ASAE standard formulas. Machinery operating expenses include repairs and maintenance, fuel, engine oil, and labor. Balance rows are included in the model to purchase machinery labor at $8.12/hr and off-road diesel at $2.20/gallon. An additional $0.33/gallon is added to the off-road diesel price to account for oil expenses. Non-machinery operating expenses related to seed, fertilizer, and herbicides are estimated based on average input data from the experimental winter small grains pastures at the LFBS.

Fall and spring wheat/rye forage production for the three tillage treatments is modeled using forage dry matter yield data from the LFBS (Bowman et al. 2005). Pasture utilization is estimated to be 73% for fall forage and 78% for spring forage based on the amount of forage left in the field as non-consumptive losses reported in Krenzer et al. (1996). The amount of fall and spring forage demanded per steer is estimated by multiplying the average grazing days for the LFBS study during the fall 2003–spring 2006 period by a forage consumption rate of 14 lbs per day obtained from Krenzer et al. Dry matter yields, pasture utilization, and pasture forage demand data for fall, spring, summer, and hay pasture in the cow-calf operation are obtained from King Brister et al. (2002a). Steer receiving expenses used in the MIP model for fall purchased steers, spring purchased steers and retained steers are presented in Table 3. Steer receiving expenses are estimated based on historical receiving data from the LFBS and data reported in King Brister et al. (2002b). Other operating expense data for the cow-calf operation (salt and minerals, vaccination, health management, yardage, and other miscellaneous expenses) are obtained from Hogan et al.

RESULTS AND DISCUSSION

Two scenarios are modeled in the study: Scenario 1 – no rented pasture included; and Scenario 2 – rented pasture included. For Scenario 1, the model selects the optimal number of grazeout acres from existing pasture for the stocker operation with available pasture held constant at 250 acres. For Scenario 2, additional pasture may be rented at $22/acre to ensure the total number of cow-calf animal units sold is held constant at 87 animals for a 100-head cow-calf operation. Cash rent for pasture is estimated as the average of the pasture rent reported for Missouri and that reported for Louisiana in 2005 by the USDA National Agricultural Statistics Service (USDA, NASS, 2006).

Optimal results under Scenario 1 are presented by capital level for the cow-calf operation in Table 4. The optimal net return for the 100-head cow-calf operation without winter grazeout is $5,041, with 136 spring and fall pasture acres, 82 summer pasture acres, and 32 hay acres. The optimal solution remains unchanged when zero capital if available. However, when available capital is set at $10,000 or more, the operation includes winter grazeout with NT always chosen as the optimal forage production method. Weaned steers from the cow-calf operation are retained for the stocker operation in all instances where capital funds are available. However, additional steers must be purchased either in the spring or in both the spring and the fall to achieve maximum returns. Optimal winter grazeout acres increase as available capital increases. However, grazeout acres are taken from available pasture acres, leaving fewer acres available for the cow-calf operation. The number of cow-calf units sold as well as the number of retained steers declines as available capital increases. Optimal net farm income ranges from $5,041 at zero capital available to $10,068 at $50,000 capital available.

Optimal results under Scenario 2 are presented by capital level for the cow-calf operation in Table 5. Rented pasture relaxes pasture acreage constraints for the cow-calf operation and allows additional pasture acres to enter the optimal solution. The number of cow-calf animal units sold remains constant across alternative capital levels, allowing the full allotment of weaned steers to be retained for the stocker enterprise. Winter grazeout acres enter the optimal solution even with no capital available to purchase additional steers. At zero capital available, the optimal solution calls for the operation to rent 33 pasture acres, produce 30 winter grazeout acres using NT, and retain all 43 weaned steers for the stocker enterprise. Additional capital available allows more pasture acres to be rented, increases the number of optimal winter grazeout acres, and allows the operation to purchase additional steers in either the spring or in both the fall and the spring. Optimal net farm income is enhanced by additional rented pasture acres and ranges from $5,496 with zero capital available to $12,438 with $50,000 capital available.

CONCLUSION

The results provide evidence that grazing stocker cattle on no-till winter small grains forage can enhance profitability for a cow-calf operation. The farm operator may hold steer calves beyond weaning and graze them on winter grazeout pasture for sale in the spring rather than in the fall. However, the whole-farm profitability of grazing stocker cattle on no-till winter small grains forage appears to be highly dependent on the amount of capital available for purchase of additional steers. The results imply that additional steers must be purchased to fully utilize available winter forage capacity and achieve maximum returns. Available capital is very important for overall whole-farm profitability even when additional pasture acres may be rented to relax pasture constraints for the cow-calf operation. Thus the practice may not be profitable in instances where cow-calf operators lack the necessary capital to purchase additional steers.

REFERENCES

ASAE. 2003a. ASAE standards, agricultural machinery management. St. Joseph, Michigan: ASAE-The Society for Engineering in Agriculture, Food, and Biological Systems, ASAE Publication No. EP496.2, 2003a.

ASAE. 2003b. ASAE standards, agricultural machinery management data. St. Joseph, Michigan: ASAE-The Society for Engineering in Agriculture, Food, and Biological Systems, ASAE Publication No. D497.4, 2003b.

Bowman, M.T., P.A. Beck, K.S. Lusby, S.A. Gunter, and D.S. Hubbell, III. 2005. No-till, reduced tillage, and conventional tillage systems for small-grain forage production. Ark. Animal Science Department Report 2005, Ark. Agri. Exp. Stat. Res. Series 535:80-82.

Cheney, S. and T. Troxel. 2006. Livestock market news roundup 1985-2005. Arkansas Livest. Grain Market News Serv. Arkansas Coop. Ext. Ser. Little Rock.

Daniels, L.B., K.F. Harrison, D.S. Hubbell, III, Z.B. Johnson, T.E. Windham, E.B. Kegley, and D. Hellwig. 2002. Production systems involving stocker cattle and soft red winter wheat. Ark. Agri. Exp. Stat. Res. Rep. 967.

Gadberry, S., M. Anders, P. Beck, and B. Watkins. 2007. Impact of conservation tillage practices on winter wheat production for grazing stocker cattle. Arkansas Coop. Ext. Ser. FSA3116-PD-4-07N.

Hogan, R. Jr., S. Gadberry, S. Gunter, and C. DeArmond. 2006. Estimating 2006 income and costs of production, cow-calf budget-100 cow herd, purchase replacement heifers. Arkansas Coop. Ext. Service. AG-969-4-06.

King Brister, S.K., M.P. Popp, and C. West. 2002a. Beef cow-calf production budgets for Arkansas, 2002. University of Arkansas, Department of Agricultural Economics and Agribusiness.

King Brister, S.K., M.P. Popp, and C. West. 2002b. Feeder cattle production budgets for Arkansas, 2002. University of Arkansas, Department of Agricultural Economics and Agribusiness.

Krenzer, E.G., Jr., A. R. Tarrant, D.J. Bernardo, and G.W. Horn. 1996. An economic evaluation of wheat cultivars based on grain and forage production. J. Prod. Agric., 9(1):66-73.

Troxel, T., J. Jennings, S. Gadberry, J. Powell, and T. Windham. 2004. Beef Cattle Production. Arkansas Coop. Ext. Serv. MP184-PD-5-04RV.

USDA, NASS. 2006. Land values and cash rents 2006 summary. November 2006.

Table 1. Select Input Data Used by the Mixed Integer Programming Model

100-Head Cow-Calf Operation	Head[1]	Sell Weight (lbs)[1]	Sell Price ($/cwt)[2]
Cull Cows	18	1,000	43.76
Cull Bulls	1	1,800	55.98
Open Replacement Heifers	7	850	49.92
Weaned Steer Calves	43	530	100.69
Weaned Heifer Calves	18	500	96.04
Total Cow-Calf Units Sold	87		

Stocker Enterprise	Purchase Weight (lbs)	Sell Weight (lbs)[3]	Purchase Price ($/cwt)[2]	Sell Price ($/cwt)[2]
Fall CT Steers	400	731	116.69	94.55
Fall RT Steers	400	737	116.69	94.55
Fall NT Steers	400	759	116.69	94.55
Spring CT Steers	525	735	98.33	94.55
Spring RT Steers	525	747	98.33	94.55
Spring NT Steers	525	743	98.33	94.55

Pasture	Acres[1]
Spring-Fall (Fescue)	136
Summer (Bermuda)	82
Hay (Bermuda)	32
Total Pasture	250

[1] Based on secondary data from Hogan et al. (2006) and King Brister et al. 2002.

[2] Five year average prices for the period 2001-2005 from Cheney and Troxel (2006).

[3] Derived from steer weight gain data reported in Gadberry et al. (2007).

Table 2. Machinery Complements and Annual Machinery Ownership Expenses for Cow-Calf Operation With and Without Winter Small Grains Forage Production.

		Winter Forage Production:		
Tractor/Implement	Cow-Calf	With CT	With RT	With NT
2wd 75	1	1	1	1
Hay Disk Mower - 10'	1	1	1	1
Hay Tedder - 17'	1	1	1	1
Hay Rake, Double - 17'	1	1	1	1
Hay Bailer, Large Round	1	1	1	1
Fertilizer Spreader - 20'	1	1	1	1
Sprayer, Broadcast - 27'			1	1
Disk - 10 '		1	1	
Harrow - 12 '		1		
Cultipacker - 12'		1	1	
Grain Drill 12'		1		
No-Till Grain Drill - 10'				1
Ownership Expense ($/year)	8,043	9,396	8,924	9,625

Table 3. Receiving Expenses for Purchased and Retained Steers

Expense Item	Fall Steers Purchased	Spring Steers Purchased	Retained Steers
	------------------------------------	($/steer)	------------------------------------
Death Loss [1]	16.34	18.07	0.00
Shrinkage [2]	21.06	21.04	21.06
Labor (Pasture Checking)	3.90	2.34	3.90
Minerals	4.28	3.55	1.47
Vet and Medical	12.00	8.00	0.00
Checkoff	1.00	1.00	1.00
Hauling	8.00	8.00	4.00
Total	66.57	61.99	31.43

[1] Death loss calculated as 3.5 percent mortality multiplied by steer purchase value.

[2] Shrinkage calculated as 3 percent of steer sale value. Shrinkage may occur during the sales process due to stress during transport (King Brister et al. 2002b).

Table 4. Optimal Cow-Calf Operation MIP Model Output, Scenario 1 (No Rented Pasture)

		Alternative Capital Levels ($)					
Output Item	100-Head Cow-Calf Herd	0	10,000	20,000	30,000	40,000	50,000
		Pasture (Acres)					
Spring and Fall (Fescue) Pasture	136	136	120	119	115	110	106
Summer (Bermuda) Pasture	82	82	72	72	69	66	64
Hay Land (Bermuda)	32	32	31	33	34	35	35
Winter Grazeout	0	0	27	27	33	39	46
Rented Pasture	0	0	0	0	0	0	0
Total Pasture Used	250	250	250	250	250	250	250
		Cow-Calf Units Sold (Head)					
Cows	18	18	16	16	15	15	14
Bulls	1	1	1	1	1	1	1
Open Replacements	7	7	6	6	6	6	5
Weaned Steer Calves	43	43	0	0	0	0	0
Weined Heifer Calves	18	18	16	16	15	15	14
Number Cow-Calf Units Sold	87	87	39	39	37	36	34
		Steers Grazed on Winter Grazeout (Head)					
CT Fall Weaned Steers	0	0	0	0	0	0	0
CT Fall Purchased Steers	0	0	0	0	0	0	0
CT Spring Purchased Steers	0	0	0	0	0	0	0
RT Fall Weaned Steers	0	0	0	0	0	0	0
RT Fall Purchased Steers	0	0	0	0	0	0	0
RT Spring Purchased Steers	0	0	0	0	0	0	0
NT Fall Weaned Steers	0	0	38	37	36	35	33
NT Fall Purchased Steers	0	0	0	0	10	20	31
NT Spring Purchased Steers	0	0	19	39	49	59	69
Total Steers Grazed on Winter Pasture	0	0	57	76	95	114	133
Whole Farm Net Return	5,041	5,041	5,882	7,394	8,314	9,191	10,068

Table 5. Optimal Cow-Calf Operation MIP Model Output, Scenario 2 (Rented Pasture Included)

		Alternative Capital Levels ($)					
Output Item	100-Head Cow-Calf Herd	0	10,000	20,000	30,000	40,000	50,000
Pasture (Acres)							
Spring and Fall (Fescue) Pasture	136	137	137	137	137	137	137
Summer (Bermuda) Pasture	82	82	82	82	82	82	82
Hay Land (Bermuda)	32	34	36	37	39	41	43
Winter Grazeout	0	30	30	30	35	42	49
Rented Pasture	0	33	35	37	43	52	60
Total Pasture Used	250	316	320	323	335	353	371
Cow-Calf Units Sold (Head)							
Cows	18	18	18	18	18	18	18
Bulls	1	1	1	1	1	1	1
Open Replacements	7	7	7	7	7	7	7
Weaned Steer Calves	43	0	0	0	0	0	0
Weined Heifer Calves	18	18	18	18	18	18	18
Number Cow-Calf Units Sold	87	44	44	44	44	44	44
Steers Grazed on Winter Grazeout (Head)							
CT Fall Weaned Steers	0	0	0	0	0	0	0
CT Fall Purchased Steers	0	0	0	0	0	0	0
CT Spring Purchased Steers	0	0	0	0	0	0	0
RT Fall Weaned Steers	0	0	0	0	0	0	0
RT Fall Purchased Steers	0	0	0	0	0	0	0
RT Spring Purchased Steers	0	0	0	0	0	0	0
NT Fall Weaned Steers	0	43	43	43	43	43	43
NT Fall Purchased Steers	0	0	0	0	6	16	26
NT Spring Purchased Steers	0	0	19	39	53	63	74
Total Steers Grazed on Winter Pasture	0	43	62	82	102	122	142
Whole Farm Net Return	5,041	5,496	7,067	8,637	9,991	11,214	12,438

EFFECTS OF PERENNIAL GRASSES ON SOIL QUALITY INDICATORS IN COTTON AND PEANUT ROTATIONS IN VIRGINIA

J. Michael Weeks, Jr., Joel C. Faircloth, Mark M. Alley, Patrick M. Phipps and Chris Teutsch
6321 Holland Rd. Suffolk, Virginia USA

INTRODUCTION

Crop rotation has long been recognized as an important cultural practice for sustaining soil quality, economic stability and yields (Bullock, 1992). Rotations of continuous row crops such as corn and soybean are common in farming systems of the Southeast, particularly utilizing no-till and minimum tillage strategies with cover crops planted to reduce soil erosion and increase organic matter (Wright et al., 2002). Winter cover crops, though effective in reducing soil loss through wind and water erosion, offer little to no over all soil improvement due to their short duration in the field (Wright et al., 2002). Incorporation of perennial grasses into traditional row crop rotations may enhance economic and environmental returns. Potential environmental benefits of perennial grasses include enhanced soil carbon sequestration, soil stabilization and decreased nutrient loss (Bullock, 1992). Potential benefits to the producer are increased yield in row crops following perennial grasses through soil enhancement with minimal purchased inputs as well as a more economically stable system when livestock is included (Siri-Prieto et al., 2002, Prechac et al., 2002).

While carbon dioxide is the fundamental gas from which dry matter is built through photosynthesis and the Calvin cycle, its increasing atmospheric concentration through the burning of fossil fuels and other natural means contributes to the warming of the planet through the greenhouse effect (Mosier et al., 2005). Agricultural practices can alter this increasing greenhouse gas concentration. Soil that is constantly disturbed can act as a source of carbon dioxide through the respiration of organic carbon by soil microbes, while undisturbed soils may act as a sink for carbon (Gebhert et al., 1994, Al-Kaisi et al., 2005). Soils planted to perennial grasses that are undisturbed for several seasons are potential carbon sinks because the grass crops are adding organic matter to soils through root growth, and organic matter decomposition is reduced by not tilling the soil (Paustian et al., 1997, Conant et al., 2001, Gentile et al., 2005). Further, soils that have been depleted by continuous row crop agriculture utilizing tillage, such as those historically in peanut and cotton rotations, that are placed into perennial grasses offer large potential as carbon sinks (Paustian et al., 1997). In a review of published data, all but one of the cultivated crop lands converted into perennial grass pastures showed an increase in soil carbon (Conant et al., 2001). This data reflected an average yearly increase over 3% C concentration or 1,010 kg $C \cdot ha^{-1} \cdot yr^{-1}$ by mass over a 23-year sampling period for cultivated land converted to well managed pasture. This can be attributed to the minimal disturbance of soil under perennial grass, as well as the extensive root system of perennial grass crops which can increase potential for subsoil carbon sequestration (Gentile et al., 2005).

A review of a series of cropping systems experiments in Uruguay by Prechac et al. (2002) presents data that displays a trend for soil carbon content to increase to a maximum after

4 years in perennial grass, at which point row crops begin drawing down carbon pools until perennials are rotated back in. This is in comparison to a continuous cropping system that continually decreased the soil carbon pool over the 26-year period of the experiment. This data set illustrates the potential for a sustainable soil carbon pool when perennial grasses are utilized in rotation with row crops.

Irrigation of cotton and peanuts in the Virginia peanut production region is an exception due to the lack of easily available irrigation water sources. Producers typically rely on stored soil moisture from the winter and rain fall events during the growing season. When rooting is limited to the dominantly sandy upper horizons of the soil profile where available soil moisture retention is low, growing season rainfall events are the major source of crop moisture.

Row crops that follow perennial grasses in rotation may experience less drought stress than those in continuous row cropping. There are several mechanisms which may create this effect. First, perennial grasses have the potential to grow deep roots over several seasons. This allows roots of perennial grasses to grow through restrictive plow layers creating channels in plow pans for roots of subsequent row crops to reach greater depths for moisture and nutrients (Prechac et al., 2002). This allows row crops to access greater volumes of soil and available water. Further, the lower horizons that are often restrictive to root growth tend to have a higher clay content and water holding capacity (Wright et al., 2002). Perennial grass crops can increase soil organic matter and evidence indicates that increases in soil organic matter are tied directly to increases in available water between field capacity and the permanent wilting point. According to B.D. Hudson (1994), an increase in soil organic matter by mass from 1 to 3% would double the plant available water across diverse soil types. Increasing plant available water is of particular importance in Virginia cotton and peanut production where irrigation is rare and rainfall is relied upon. Greater rooting depth along with greater soil moisture allows for fewer drought days and greater access to nutrients allowing for more vigorous above ground growth often reflected in measurements such as leaf area index, plant height, and yield (Pettigrew 2004, Katsvairo et al., 2006).

The overall objective of this project was to determine if production of perennial grass crops in selected crop rotations with cotton and peanuts will improve the sustainability of crop production on typical southeastern Virginia soils.
Specific objectives are:

1. Measure changes in soil quality parameters such as organic matter, bulk density, resistance to root penetration, moisture holding capacity and water infiltration rate in crop rotations with and without perennial grasses.
2. Measure the influence of crop rotations with and without forage crops on the overall yield and quality of cotton and peanuts.

The latter objective will not be discussed in this paper.

Materials and Methods

The study was conducted at the Tidewater Agricultural Research and Extension Center. Eight crop rotations were selected for study and are shown in Table 1. The rotations were arranged in a Randomized Complete Block Design with four replications. Plots were 8-rows (7.38 m, 24 ft) wide by 12.3 m (40 ft) long. Thirty foot alleyways were established between blocks for maneuvering equipment. The experiment was located on a Nansemond fine loamy sand soil series (Coarse-Loamy, Siliceous, Subactive, Thermic Aquic Hapludults).

Table 1. Eight crop rotations selected for study and the sequence of crops in each rotation for the years 2003-2007.

Rotation	2003	2004	2005	2006	2007
1	Peanut	Cotton	Cotton	Cotton	Cotton
2	Peanut	Cotton	Corn	Cotton	Peanut
3	Peanut	Cotton	Peanut	Cotton	Peanut
4	Peanut	Tall fescue	Tall fescue	Cotton	Peanut
5	Peanut	Orchardgrass	Orchardgrass	Cotton	Peanut
6	Peanut	Tall fescue	Tall fescue	Tall fescue	Peanut
7	Peanut	Orchardgrass	Orchardgrass	Orchardgrass	Peanut
8	Peanut	soybean	Cotton	Cotton	Peanut

*follow all row crops after 2005 with wheat cover after row crop harvest and until spring planting

Plots were sampled for intact soil cores using 2 inch copper pipe segments with two inch diameters, taped end to end to a length of 6 inches. In two locations in each plot, the pipe was driven into the soil using a rubber mallet. Soil cores were then excavated and sliced into 2 inch segments. Measurements of water holding capacity (WHC) were made on the upper 2 inch segment and lower 2 inch segment of each intact core. The middle sections were discarded as availability of copper rings required the reuse of the center section. Cores were saturated for 24 hrs and weighed. Water holding capacity was measured using pressure pots equilibrated to 1/3 bar (field capacity), 1 bar, or 15 bars (permanent wilting point). After each equilibration period (4 days, 1 week, and 2 weeks respectively) cores were weighed and re-saturated. After the final equilibration at 15 bars, cores were dried and weighed to determine the total water held at each pressure as well as bulk density of the soil in each core.

Saturated infiltration measurements were made August 4 through 8, 2006 using three double ring Turf-Tech infiltrometers. Six total runs were made per plot only in row middles which had not experienced wheel traffic. The time to infiltrate a 5 cm column of water was recorded with a subsequent recording of the time for the same column to infiltrate 8 cm. The difference in these two times provided a relative measure of the saturated infiltration. Bulk density samples were taken simultaneously with infiltrations using 6” copper cylinders with a 2” diameter driven into the soil, then removed and sealed with plastic wrap. Samples were weighed for a wet weight and then dried at 105^{o} C for 24 hours then weighed again. These samples in addition to bulk density provided soil moisture contents at the time of the infiltrometer runs.

Soil resistance to penetration was used to determine depth to any root growth restrictive zones in the profile. All plots will be evaluated to see if depths to root restrictive zones are associated with treatment effects. A Field Scout SC 900 data-logging Soil Compaction Meter will be used to sample resistance with at least 6 readings taken between crop rows. Samples will be taken during the season following adequate rainfall when soil is near field capacity in order to eliminate differences in soil resistance associated with moisture status. If adequate rainfall does not occur in a given season, irrigation may be employed to bring soil to field capacity for sampling of resistance to penetration.

Soil samples will be collected in April and August from the 6 inch surface layer of each plot. Twenty cores will be taken from each plot using a soil probe, homogenized and tested for pH, fertility levels and organic carbon content. Samples will be processed by the Virginia Tech Soil Testing Lab for available pH, P, K, Ca, Mg, and organic matter content by loss upon ignition. Changes in organic matter content due to rotation effects will also be assessed using carbon and nitrogen content and ratio with a carbon-nitrogen analyzer. Soils will be sampled from 0-3” and 3-6” for carbon-nitrogen content.

RESULTS

No statistically significant differences were found between treatments in measurements of saturated water infiltration, soil moisture at the time of the measurements, or bulk density.

Statistical analysis has not been conducted on data from soil resistance to penetration measurements. Observation of the data set however indicates that resistance to root penetration is reduced after two years of perennial grasses. The data reported below indicates that cotton following fescue or orchardgrass does not experience a 3000 kPa resistance and would therefore root growth would not be restricted physically. All other rotations reached a limiting resistance by 32 cm with the shallowest restrictive layer in cotton-peanut-cotton-peanut rotations at 25 cm. Resistance curves are shown below in figure 1.

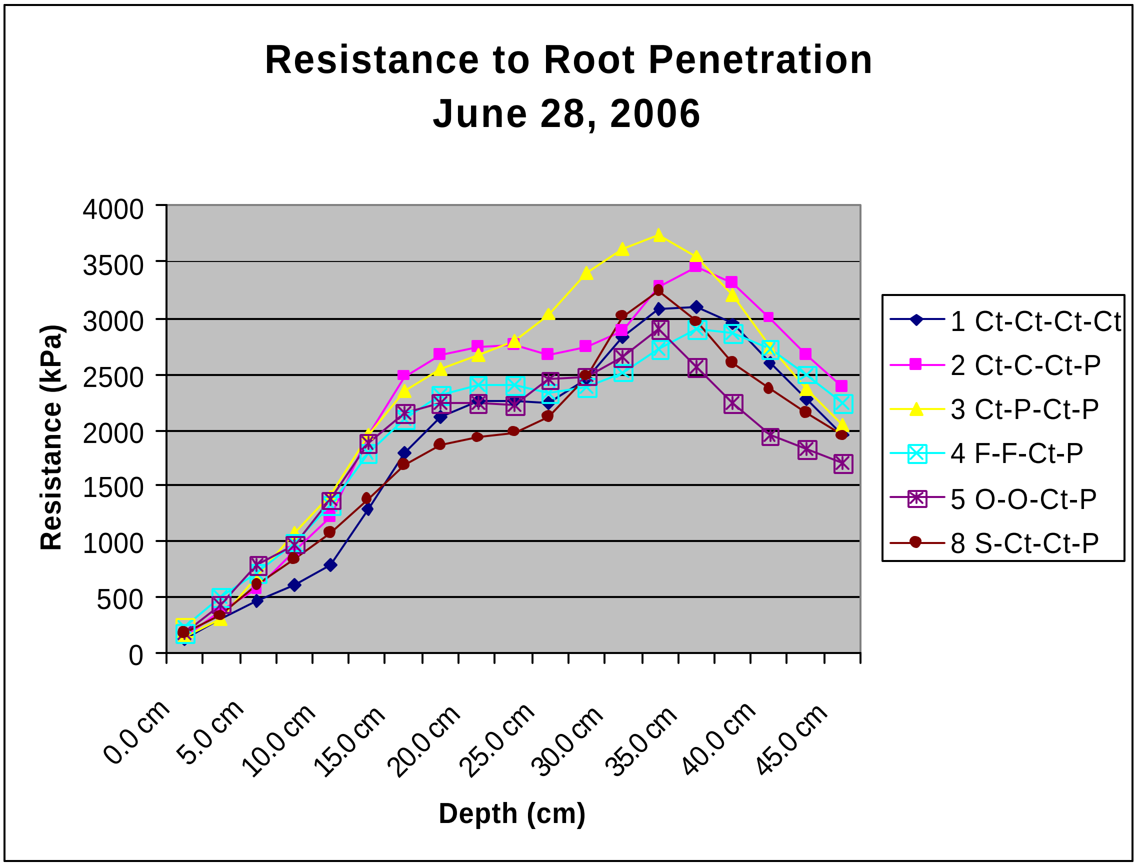


Figure 1: Soil resistance to penetration as measured by a data logging penetrometer on the 28th of June.

No significant difference was found in available water content at either the 0-2" (table 1a) depth or 4-6" (table 1b) depth.

Water content of intact soil core at a depth of 0-2 in.				
	mg water per liter soil			
Treatment	**0 bar**	**1/3 bar**	**1 bar**	**15 bar**
Ct-Ct-Ct-P	**16.147 a**	**5.485 a**	**4.861 a**	**4.086 a**
Ct-C-Ct-P	**15.464 a**	**5.614 a**	**4.965 a**	**4.232 a**
Ct-P-Ct-P	**14.952 a**	**4.656 a**	**4.087 a**	**3.469 a**
F-F-Ct-P	**16.096 a**	**4.602 a**	**4.015 a**	**3.377 a**
O-O-Ct-P	**15.857a**	**5.606 a**	**4.960 a**	**3.989 a**
S-Ct-Ct-P	**16.017 a**	**4.816 a**	**4.257 a**	**3.711 a**

Table 1a: Water content of intact soil core at depth 0-2 inches over drying regimes. Means followed by the same letter do not significantly differ (P=0.05, LSD)

Water content of intact soil core at a depth of 2-4 in.				
	mg water per liter soil			
Treatment	**0 bar**	**1/3 bar**	**1 bar**	**15 bar**

Ct-Ct-Ct-P	12.928 a	5.596 a	4.977 a	4.150 a
Ct-C-Ct-P	13.052 a	5.147 a	4.437 a	3.565 a
Ct-P-Ct-P	12.605 a	4.897 a	4.247 a	3.598 a
F-F-Ct-P	12.736 a	5.234 a	4.553 a	3.614 a
O-O-Ct-P	12.791a	5.212 a	4.564 a	3.737 a
S-Ct-Ct-P	12.999 a	5.084 a	4.431 a	3.806 a

Table 1b: Water content of intact soil cores at depth 4-6 inches over drying regimes.
Means followed by the same letter do not significantly differ (P=0.05, LSD)

Soil carbon and nitrogen content by weight per volume of soil was statistically the same across all treatments at both a depth of 0-3 inches (table 2a) and 3-6 inches (table 2b). Carbon to nitrogen ratio was also statistically the same across all treatments.

	Carbon and Nitrogen Data, 0-3 inches		
Treatment	mg N / L soil	mg C / L soil	C / N ratio
Ct-Ct-Ct-Ct	101.5 a	1014.5 a	9.8 a
Ct-C-Ct-P	92.2 a	909.4 a	9.8 a
Ct-P-Ct-P	84.5 a	740.8 a	8.8 a
F-F-Ct-P	89.2 a	765.5 a	8.6 a
O-O-Ct-P	67.9 a	562.0 a	8.3 a
S-Ct-Ct-P	87.8 a	740.2 a	8.4 a

Table 2a: Carbon and Nitrogen content at a depth of 0-3 inches.
Means followed by the same letter do not significantly differ (P=0.05, LSD)

	Carbon and Nitrogen Data, 3-6 inches		
Treatment	mg N / L soil	mg C / L soil	C / N ratio
Ct-Ct-Ct-Ct	91.2 a	902.1 a	9.5 a
Ct-C-Ct-P	83.4 a	832.7 a	9.9 a
Ct-P-Ct-P	82.4 a	695.2 a	8.4 a
F-F-Ct-P	82.2 a	693.1 a	8.4 a
O-O-Ct-P	75.0 a	553.1 a	7.4 a
S-Ct-Ct-P	81.5 a	675.9 a	8.3 a

Table 2b: Carbon and Nitrogen content at a depth of 3-6 inches.
Means followed by the same letter do not significantly differ (P=0.05, LSD)

CONCLUSIONS

There was little difference found between treatments in soil quality indicators with the exception of resistance to penetration. However observations of the plots throughout the season would indicate differences which we did not elucidate. Treatments including perennial grass were observed to infiltrate water at a greater rate during actual rain showers. Though not discussed in this paper, yield enhancement was also seen in cotton following perennial grasses compared to other rotations. This may be due to insufficient rain fall during the 2006 growing season. Cotton experiencing lower resistance to root penetration due to inclusion of perennial grass was able to reach soil moisture stored deep in the profile versus shallow depths explored by crops experiencing a hard pan. If this is true yield enhancements may not be seen following perennial grass if there is sufficient rain fall during the season.

In 2007 all rotations with the exception of continuous cotton will be planted to peanut. All of the measurements of soil quality indicators will be taken again. Changes in soil organic matter were hypothesized due to treatment effects however they were not seen. To look more clearly at this, samples will be stratified by the inch to a depth of 6 inches. Also infiltration measurements will be made using an infiltrometer with water rained onto the plot using a Cornell Infiltrometer. This style infiltrometer will also be used to measure aggregate stability. Further pipe collectors will be fabricated to measure water pooling in the plots during actual rain fall events.

REFERENCES

Al-Kaisi, M.M., X. Yin, M.A. Licht. 2005. Soil carbon and nitrogen changes as influenced by tillage and cropping systems in some Iowa soils. Agric. Ecosystems Environ. 105:635-647.

Bullock, D.G. 1992. Crop-Rotation. Critical Reviews in Plant Sciences. 11:309-326.

Connant, R.T., K. Paustian, and E.T. Elliott. 2001. Grassland Management and Conversion Into Grassland: Effects on Soil Carbon. Ecological App. 11:343-355.

Katsvairo, T.W., D. L. Wright, J. J. Marois, D. L. Hartzog, J. R. Rich, and P. J. Wiatrak. 2006. Sod-Livestock Integration into the Peanut-Cotton Rotation: A Systems Farming Approach. Agron. J. 98:1156-1171.

Gebhert, D.L., H.B. Johnson, H.S. Mayeux and H.W. Polley. 1994. The CRP increases soil organic carbon. (Conservation Reserve Program). J. Soil and Water Conservation. 49:488-493.

Gentile, R.M., D.L. Martino, M.H. Entz. 2005. Influence of perennial forages on subsoil organic carbon in a long-term rotation study in Uruguay. Agric. Ecosystems Environ. 105:419-423.

Hudson, B.D. 1994. Soil organic matter and available water capacity. J. Soil Water Conservation. 49:189-195.

Mosier, A.R., A.D. Halvorson, G.A. Peterson, G.P. Robertson, and L. Sherrod. 2005. Measurement of net global warming potential in three agroecosystems. Nutr. Cycl. Agroecosyst. 72:67-76.

Paustian, K., H. P. Collins, and E. A. Paul. 1997. Management controls on soil carbon. Pages 15–49 in E. A. Paul, K. Paustian, E. T. Elliot, and C. V. Cole, editors. Soil organic matter in temperate agroecosystems. CRC Press, Boca Raton, Florida, USA.

Pettigrew, W.T. 2004. Moisture Deficit Effects on Cotton Lint Yield, Yield Components, and Boll Distribution. Agron. J. 96:377-383.

Prechac, F.G., O. Ernst, G. Siri, and J.A. Terra. 2002. Integrating No-Till Into Livestock Pastures and Crops Rotation in Uruguay. Proc. Of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. 74-80.

Siri-Prieto, G., D.W. Reeves, and R.L. Raper. 2002. Conservation Tillage Systems for a Cotton and Peanut Following Winter-Annual Grazing. International Soil Tillage Research Organisation Conference. 1143-1148.

Wright, D.L., J.J. Marois, and P.J. Wiatrak. 2002. Perennial Forage in Rotation with Row Crops in the Southeast. Proc. Of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. 87-92.

CONSERVATION TILLAGE BOOST FROM PERENNIAL GRASSES

David Wright, James Marois, Tawainga Katsvairo, Duli Zhao, Kris Balkcom, Dallas Hartzog,
Cheryl Mackowiak, and Ann Blount

155 Research Road, Quincy, FL

wright@ufl.edu

INTRODUCTION

U.S. farms were diversified and livestock was a necessary part of life for transportation and cultivation of crops in the first half of the 20th century. Perennial grasses were used for livestock feed and grain was grown to supply feed for animals. Mechanization brought concentrated areas of grain production and a two crop system for the mid west. Along with mechanization came improvements in plant breeding, fertilizer and pesticide technology and rapid expansion of annual crops and intensive tillage. Extensive areas of tillage resulted in water and wind erosion with loss of productivity. However, recent systems research utilizing conservation tillage has shown that economics, and the decline in soil and water quality, and the environment can be reversed by reintroducing perennial grasses back into cropping systems (Katsvairo et al., 2006). Currently, over 2/3rds of the worlds food supply is produced by crops that have to be planted annually and most of these are produced using tillage (http://www.landinstitute.org/). The recent increase in corn and soybean prices may result in a slow movement back to perennial grasses in rotations unless a large economic advantage or risk management can be shown. While conservation tillage has resulted in many benefits, farmers are still struggling with relatively small yield increases even using new technology. A tri-state research project with bahiagrass in rotation with cotton and peanut has shown higher yields (30% higher peanut yields as compared to cotton/peanut rotations using conservation tillage with annual cover crops), increased infiltration rates (more than 5 times faster), less soil compaction, and a more economically viable cropping system (2 to 7 times higher). Penetrometer measurements have shown less compaction in April from fall kill vs. spring kill perennial grass in the compaction layer. The system needs further refining for different areas of the country, different perennial grasses and different cropping systems as well as to determine cattle impacts on subsequent crops, soil, and water quality. However, all parameters measured over the course of the study have shown measurable improvements over the conventional rotations using conservation tillage.

Reeves (1997) and others have noted the positive benefits of perennial grasses in rotation with row crops and have reported on the advantages shown by Brazilian farmers using perennial grasses. Conservation tillage techniques are still being slowly adopted by peanut farmers in the SE for peanuts while cotton has had a high adoption rate for conservation tillage. If proper management is worked out for peanuts, yields are just as high as or higher than under conventional tillage procedures. Conservation tillage alone may not increase peanut yields where it may have a more beneficial impact on other row crops. Wright et al. (2006) have shown that time of kill of cover crops can have a major impact on the subsequent crops and the problems observed from dry soil, soil insects, and seedling diseases, and that time of kill of perennial grass can also impact certain soil factors at planting.

It has long been known that Coastal Plain soils have a natural compaction layer that limit root growth starting at 15-20 cm depth and continuing to 30-35 cm (Kashirad et al., 1967). Roots limited to the top 15 cm of soil have a very limited water and nutrient supply in sandy Coastal

Plain soils and impacts summer as well as winter annuals. Annual crops fail to develop deep root systems under these conditions, and are often susceptible to periods of moisture stress. It has been shown that perennial grasses develop a deep root system which can penetrate through the compaction layer (Elkins et al., 1977; Katsvairo, et al., 2006) and therefore can have a major impact on soil quality. When roots die, they decay and leave root channels which impacts soil structure, water infiltration and available water for the following crops (Elkins et al. 1977; Wright et al., 2006, Katsvairo, et al. 2006). Long and Elkins (1983) compared cotton following 3 years of bahiagrass sod with continuous cotton and found a seven fold increase in pore sizes large enough to impact water infiltration rates and allow the subsequent crop roots to follow through the compaction layer.

Perennial grass value can be determined in long term studies from the Midwest which have shown a loss of ¼ to ¾ of the SOM that was present 100 years ago (Magruder, Sanborn, and Morrow plots) when they were first taken out of perennial grasses and tillage was started. Continuous tillage of soils in the U.S. during the past century degraded these soils, and especially OM, to a level ¼ of what it was originally. Generally, OM decays faster in the Southeast due to higher temperatures than the Midwest. It is known that rotations with perennial grasses will increase soil carbon, improve soil structure, and decrease erosion to a higher level than the winter annual cover crops. Winter annual cover crops have a short duration and degrade fast. Cover crops were used mainly for nitrogen production, erosion control, building OM and nematode suppression during the last century. Many studies with various perennial grasses have shown a major impact on yield of following crops (Katsvairo, et. al, 2006). Even though farmers know about yield improvements following perennial grasses, they seldom use the rotation since little research has been done showing that perennial grasses can be used economically in a row crop system. Rotation is always at the top of the list as an important component of producing crops profitably (Wright et al., 2006). The U.S. Geological Survey has reported that 63% of North America that was previously in native grasslands is now cultivated. Recent research indicates that conservation tillage techniques can be altered to use with perennial grasses to get much better results than with annual cover crops for both environmental as well as economic benefit. The objective of this research was to show impacts of bahiagrass on following crops using conservation tillage in comparison to crops in standard rotations using conservation tillage.

MATERIALS AND METHODS

This long term multi-state (GA, FL, AL) project exams the impact of bahiagrass in rotation with peanut and cotton. This project has completed one full rotation in FL and AL and a new site has been started in GA. Each site has the basic rotation of 2 years of bahiagrass followed by peanut followed by cotton. Winter grazing or cover crops are planted behind each of the row crops and sometimes first year bahiagrass if crop conditions are favorable. The basic design of the study at Marianna, FL is shown below and is under a 140 acre center pivot irrigation system:

Bahiagrass going into the 2nd year	Peanuts after bahiagrass planted May of 2007
Winter grazing with bahiagrass planted no till in May of 2007	Cotton after winter grazing planted May of 2007

Cotton and peanut are planted in one quarter of the pivot each year along with the first year bahiagrass, while the bahiagrass going into the second year continues to grow. Winter grazing is planted within 3 weeks of harvest of cotton and peanut for winter grazing each year and the first year bahiagrass may be over seeded if it is grazed down low enough in the fall.

Data collected has included water infiltration, soil carbon, soil fertility, bulk density, weed population, earthworm numbers, penetrometer measurements, soil moisture measurements, yields and grades of crops, cattle weight gain.

RESULTS AND DISCUSSION

When producers plant peanuts after bahiagrass, they do many tillage passes to tear up the “sod”. Getting good stands of peanut after bahiagrass using conservation tillage methods is an unknown in many people’s minds as well as the digging process. Most growers consider it too hard to plant into bahiagrass and that some tillage needs to be done to obtain good yields. Research from this study compared strip tillage in conventional rotations to strip tillage into bahiagrass without tillage. When perennial grasses are killed, there is a high C: N ratio due to the amount of roots as compared to annual crops (2/3rds of the plant biomass vs. 1/3 for annual crops) which may be detrimental to crops requiring high amounts of N. The bacteria breaking down the plant tissue requires N which is tied up and unavailable for plant growth as the dead tissue decays. Root channels from decayed bahiagrass roots are one of the main passage ways for the subsequent crop roots to get through the compaction layer. We know from previous data that cotton roots exploit the channels and developed a more extensive rooting system in the second year after bahiagrass, which utilize more N across a wider soil profile. Higher root biomass, root area and root length were observed in the bahiagrass rotated cotton following peanut (Katsvairo et. al, 2007).

Peanut land had typically been plowed to reduce diseases until the last 5 years. The idea was that if you turned the land you could bury disease organisms and would have less disease. This concept seemed reasonable until the early 80’s when research showed that strip tilled peanuts actually had less white mold and recent research has shown that tomato spotted wilt virus is less in strip till than conventional fields and even less in bahiagrass rotated fields. This concept took many years to overcome and some growers are still convinced that strip tillage will not work with peanuts. Research in the Virginia/Carolina area (Jordan, et. al., 2004) with annual cover crops has shown that peanut diseases are less with strip tillage. However, while bahiagrass is the favored crop to follow with peanut, there are few areas where bahiagrass is abundant enough to have many acres following it so corn or cotton are the rotation crops of choice.

During the last five years of the study, cotton and peanut yields have been monitored with and without irrigation in both a conventional rotation and the bahiagrass rotation at Quincy. Yields of peanuts averaged almost 600 lbs/A higher without irrigation in the bahiagrass system than the irrigated peanuts in the conventional rotation (Fig. 1). When you consider the cost of the irrigation system or rented irrigated land as compared to non irrigated land this amounted to over $200/A more profit than with irrigated. Likewise, there was no difference in peanut yields over the 5 years with peanuts when comparing the conventional rotation with and without irrigation and the bahiagrass system in the same manner. Conservation tillage techniques were used each year in each system with no problem in either planting, digging, or harvesting or in the grades of the peanuts. Therefore, a bahiagrass rotation should be highly considered for peanut production because of the extra yield, lower disease, and higher grades that can be expected.

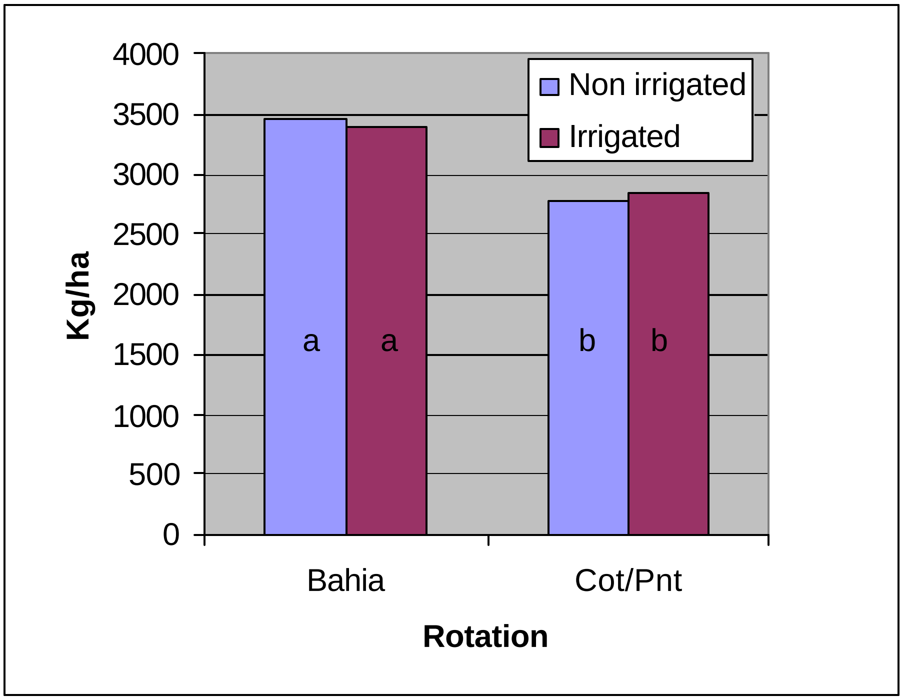


Figure 1. Impacts of bahiagrass and irrigation on peanut yields averaged over a 5 year period (2002-2006) at NFREC, Quincy, FL

Likewise, all of the factors measured such as total plant biomass, LAI, N uptake, and root growth for cotton would indicate that yields would be expected to be higher since all growth parameters were higher in each year (Katsvairo et al., 2007). However, yields are not always higher for cotton in the system. Elkins et al., 1977 reported significantly higher cotton yields when planted after bahiagrass. However, in none of the 4 years at Quincy were cotton yields significantly higher than for the conventional rotation. All of the other crops including the winter cover crops exhibited a significantly higher yield. This includes the peanut crop the year before cotton in the bahiagrass rotation and the winter cover crops both before and after cotton. These enhanced plant growth factors on peanut, cotton, and small grain cover crops resulted in higher yields for all crops except lint yields of cotton. Figure 2 shows that there were no yield differences for cotton over the 4 year period from 2003-2006 in the bahiagrass system. Further research with variable rate irrigation and fertility levels will be used to determine if yield increases can be made to match the increased plant growth that is normally seen in cotton in the bahiagrass rotation.

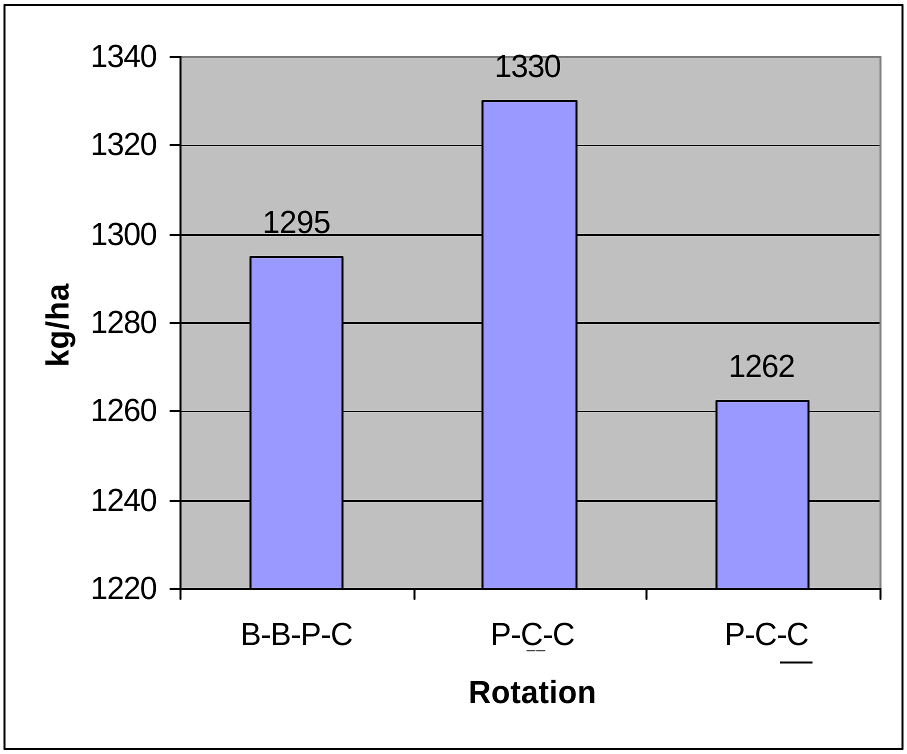


Figure 2. Influence of bahiagrass on cotton yields (2003-2006) in a bahia/peanut/cotton (B-B-P-C) rotation as compared to cotton in a standard cotton/cotton/peanut (P-C-C, or P-C-C) rotation using cover crops and conservation tillage at NFREC, Quincy, FL

Cotton rotated with bahiagrass has been shown to have better top and root growth in every case but it may not translate into yield. However, the benefits that have been shown with peanuts is a big enough economic incentive for most growers to try the system on some part of their farm. The reduction in risks from having half as many acres in “cash crops” is another major factor when you consider that most of the risk from crop production is weather and pest related.

CONCLUSIONS

Bahiagrass can be managed in such a way to allow strip tillage planting to make it more economical to grow peanuts. This system is being refined for different areas of the country, different perennial grasses and different cropping systems and is adding value to conservation tillage planting methods above applied inputs. Perennial grass rotations reduces risks, enhances the environment and offers economic value to producers.

REFERENCES CITED

Elkins, C. B., R. L. Haaland, and C. S. Hoveland.1977. Grass roots as a tool for penetrating soil hardpans and increasing crop yields. Proc. 34th Southern Pasture and Forage Crop Improvement Conf. P. 21-26. April 12-14, 1997, Auburn Univ. Auburn, AL.

Kashirad, A. J., G.A. Fiskell, V.W. Carlisle, and C.E. Hutton. 1967. Tillage pan characterization of selected Coastal Plain soils. Soil Sci. Soc. Am. Proc. 31:534-541.

Katsvairo, T. W., D.L. Wright, J.J. Marois, D.L.Hartzog, J.R. Rich, and P.J. Wiatrak. 2006. Sod-livestock integration into the peanut-cotton rotation: a systems farming approach. Agron. J. 98:1156-1171.

Katsvairo T.W., D.L. Wright, J. J. Marois, D. L. Hartzog, K. B. Balkcom, P. J. Wiatrak and J. R. Rich. 2007. Cotton roots, earthworms, and infiltration characteristics in sod-peanut-cotton cropping systems. Agron J 99:390-398

Long, F. L. and C.B Elkins. 1983. The influence of roots on nutrient leaching and uptake. *In* Lowrance, R., T., Asmussen, L., and Leonard, R. (eds) Nutrient cycling in agricultural ecosystems. Univ. of Ga. College of Agric. Exp. Stations, Spec. Pub. 23, pp. 335-352.

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

Wright, D.L., J. Marois, T. Katsvairo, Pawel Wiatrak, and D. Hartzog. 2006. Perennial grasses- a key to improving conservation tillage. Proc. Southern Cons. Till. Conf. for Sustainable Agr. June 26-28, 2006. Amarillo, TX
http://www.ag.auburn.edu/auxiliary/nsdl/sctcsa/

GROWTH AND PHYSIOLOGICAL CHARACTERISTICS OF COVER CROP IN SOD-BASED PEANUT-COTTON CROPPING SYSTEMS

Duli Zhao, David Wright, Jim Marois, and Cheryl Mackowiak

IFAS-North Florida Research and Education Center
University of Florida, 155 Research Road, Quincy, Florida 32351
Email: dzhao@ufl.edu

ABSTRACT

It has been confirmed that sod-based peanut-cotton rotation systems can greatly improve soil health and increase crop yield and profitability in the southeastern USA. In the sod-based rotation systems the winter cover crop is an important component in conservation tillage. The objective of this study was to determine effects of summer crops, cotton and peanut on the growth, dry matter accumulation and physiology of an oat cover crop in both a conventional and sod-based peanut-cotton rotation system. Two cropping systems of Peanut-Cotton-Cotton (P-C1-C2, Conventional) and Bahia-Bahia-Peanut-Cotton (B1-B2-P-C, Sod) were established in an experimental field at the North Florida Research and Education Center, Quincy, FL in 2000. Oats were planted 8 December 2006 at a seeding rate of 64 lbs/A and 7 inches of row spacing after mowing down cotton stalks. Plant height, leaf chlorophyll, leaf sap NO_3-N concentration, and above-ground biomass were determined biweekly starting 49 days after planting. Both cropping system and previous crop impacted cover crop growth and physiological parameters measured. Oats grown in plots of the Sod system had higher leaf chlorophyll and NO_3-N concentrations and greater biomass compared with oat plants in the Conventional system. The peanut plots increased the cover crop plant N status and above-ground biomass, as compared to the cotton plots. Increases in cover crop plant growth and N status for the Sod cropping system may be associated with greater soil fertility and soil quality parameters. Information from this study provides growers options in N fertilizer management of cotton and peanuts in two different production systems. The data also serves those using cover crops for grazing livestock.

INTRODUCTION

Conserving cropland soil is a principal goal of sustainable agriculture, as is preservation of surface water and groundwater quality. Numerous studies have confirmed that a winter cover crop helps to conserve both soil and water quality while allowing row crops to be grown profitably. Adding a cover crop component to cropping systems can improve productivity and reduce environmental threats from erosion (Langdale et al., 1991) and nutrient runoff and leaching losses (Meisinger et al., 1991; Sharpley and Smith, 1991).The additional biomass enhances soil organic matter, improves soil-water dynamics, and soil quality (Horton et al., 1994). Unused soil nitrates at the end of the growing season tend to leach from the southeast sandy soils and may cause groundwater contamination. Certain cover crops tend to be very efficient at recycling or scavenging excess nutrients, especially soil nitrogen (N). Additionally, when the cover crop dies or is removed as forage, some of the N will be released and reused by future crops or utilized as protein in the animal feed (Horton et al., 1994).

Cover crops can either increase yield potential or reduce the amount of additional N fertilizer required by a succeeding crop, depending on the type of cover crop and rotation system (Reeves et al., 1995). Studies have also suggested that the sod-based peanut-cotton rotation systems in the southeast USA improve soil health and increase crop yield and profitability (Marois et al., 2002; Wright et al., 2004; Katsvairo et al., 2006; Katsvairo et al., 2007). Including a winter cover crop to a sod-based rotation of peanut and cotton improves the benefits of conservation tillage. To protect highly erodible soils, like those in the southeastern USA, emphasis has been placed on leaving as much residue as possible on the fields during the winter. Reduced tillage and conservation cropping systems have increased markedly in the region. As a result, most of Florida cropland, primarily peanuts, cotton, corn, and soybeans, has about 60% of its surface covered with residue. However, peanuts and soybeans produce a relatively low amount of residue that decomposes rapidly. Also, soil aggregates are less stable under these crops. Therefore, farmers in the region still face a high risk of soil erosion and soil nutrient leaching losses.

Climatic conditions (precipitation and warm weather) in the southeastern USA are favorable for winter cover crops. Horton et al. (1994) reported that an oat (*Avena sativa* L.) cover crop had a dramatic effect on soil erosion and runoff in the simulated rainfall tests with an 84% reduction in sediment loss, compared to non-oat cover crop plots. Cover crops are also attractive as a way of scavenging the soil profile for nitrate, thus lessening winter and spring leaching of nitrate and improving the N and organic matter status of the soil (Horton et al., 1994; Franzluebbers, 2007).

Several sod-based crop rotation systems with oat as a winter cover crop have been established at the University of Florida, North Florida Research and Education Center, Quincy, FL for many years for investigating long-term soil and crop responses to cropping systems and the resulting economic return. The primary goal of this study was to determine effects of summer crops on oat cover crop growth and several physiological parameters using two cropping systems, 1) Peanut-Cotton-Cotton (P-C1-C2 or Conventional System) and 2) Bahiagrass-Bahiagrass-Peanut-Cotton (B1-B2-P-C or Sod System). The specific objectives of this study were to: (1) determine plant growth and above-ground biomass of an oat cover crop and (2) determine oat shoot N concentration and N accumulation as affected by the summer crop and cropping system.

MATERIALS AND METHODS

Experimental location and treatments

The experiment was conducted at the North Florida Research and Education Center, University of Florida, Quincy, FL (84°33’ W, 30°36’ N). The soil type used in this study was a Dothan sandy loam (fine-loamy, kaolinitic, thermic Plinthic Kandiudult). Two cropping systems, 1) Peanut-Cotton-Cotton (P-C1-C2, Conventional system) and 2) Bahia-Bahia-Peanut-Cotton (B1-B2-P-C, Sod system) with an oat (*Avena sativa* L., Fla 501) as the winter cover crop were used. Treatments included two N fertilizer rates of 0 and 60 lbs N/acre in the preceding cotton crop. The experiment was a split-plot design with three replications. Cropping system was the main plot and N rate was the subplot. The subplot size was 68 ft by 30 ft and rows aligned east to west.

Measurements

Oat was seeded at a seeding rate of 64 lbs/acre and 7 inches of row spacing in all plots on 8 December 2006, after mowing down cotton stalks. Based on the regional cover crop management recommendation, 40 lbs N/acre as ammonium nitrate was broadcasted on 6 February 2007 [60 days after planting (DAP)]. Plant height, above-ground biomass, leaf chlorophyll, leaf sap NO_3-N concentration were determined biweekly starting at 49 DAP until pre-heading (101 DAP). Plant height was determined from ground surface to the last collared extended leaf held upright. Leaf chlorophyll measurements were taken on 10 upper most-fully expanded leaves randomly collected from 10 plants in each plot using a SPAD-502 chlorophyll meter (Minolta Co., LTD., Japan). At the same time, 20 leaves at the same position in each plot were sampled and the leaves were used to collect leaf sap for measuring NO_3-N concentration using a C-141 CARDY meter (Horiba, LTD., Kyoto, Japan). Oat above-ground biomass was estimated by cutting 3-foot row plants from ground surface in each plot at all sampling dates. Plant samples were dried in a forced air oven at 65°C for 48 hours and weighed. In order to estimate oat plant N uptake prior to killing cover crop with ROUNDUP herbicide for the following row crops, the dry oat plant samples collected pre-heading (101 DAP), were ground to determine tissue total N concentration and other mineral nutrient elements using a commercial analytic laboratory (Waters Agricultural Laboratories, Inc., Camilla, GA).

Data analysis

Since no statistical differences were detected in most measured parameters of oat cover crop between the 0 and 60 N treated cotton plots, data collected from the 0 N and 60 N treated cotton plots were averaged. The mean values are presented in this report. Analysis of variance was carried out using SAS PROC MIXED model to determine the cropping system and previous crop effects on winter cover crop oats. The least significant difference (LSD) tests were used to distinguish the treatment differences at $P = 0.05$ level.

RESULTS AND DISCUSSION

Plant height and above-ground biomass

Changes in oat plant height and above-ground biomass during growth were similar and followed a growth pattern typical of winter cover crops. In first 70 days, plant height and shoot biomass increased slowly. Thereafter, the two growth parameters increased more rapidly (Fig. 1). Both cropping system and summer crop significantly oat plant height ($P < 0.001$) and above-ground biomass ($P < 0.0001$). Plant height and biomass of oat in peanut plots were significantly greater than oat in cotton plots at all measurement dates (Fig. 1A). There were no differences in either plant height or above-ground biomass of oats gown in peanut plots of either of the two cropping systems. However, oats grew better (i.e. taller with more above-ground biomass) in the Sod system cotton plots (Fig. 1). At 101 DAP, oats in cotton plots of the Sod system had over 22% greater biomass ($P < 0.05$) as compared to oats in the cotton plots of the Conventional system (Fig. 1B). Improved growth in the Sod cropping system may be an indicator of improved soil properties, particularly soil available N, provided by bahiagrass (Reeves, 1997; Wright et al., 2004; Katsvairo et al., 2006 and 2007). In the southeastern USA, a cover crop can be used as pasture or hay or the crop can be returned to the soil to increase soil organic matter and fertility.

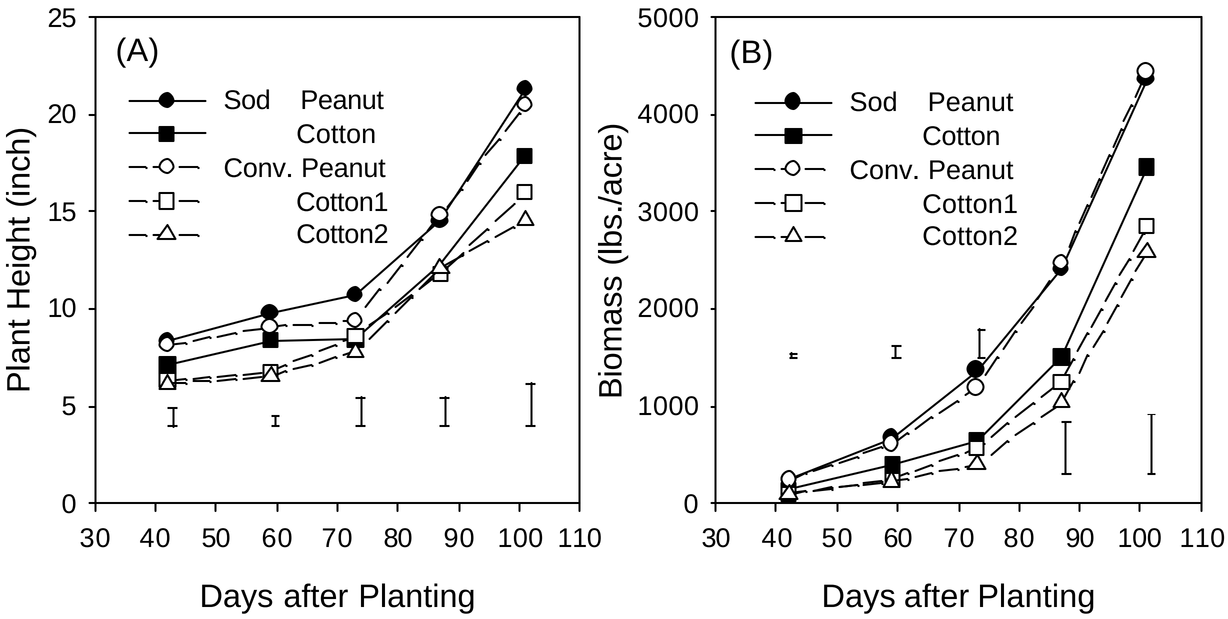


Fig. 1. (A) plant height and (B) above-ground biomass of winter cover crop oats and their responses to the Sod and Conventional cropping systems as well as previous crops of peanuts and cotton. Vertical bars present values of $LSD_{0.05}$.

Leaf chlorophyll and NO_3-N concentrations

Leaf chlorophyll increased between 42 and 73 DAP and then reached a plateau as plants aged (Fig. 2A). The summer crop significantly influenced oat leaf chlorophyll content ($P < 0.0001$). Oats grown in peanut plots had greater chlorophyll values as compared with oats grown in cotton plots over the first three sampling dates (Fig. 2A). Leaf chlorophyll values were not statistically different among treatments at 87 DAP. Cropping systems had no effect on leaf chlorophyll. Averaged across sampling dates, leaf chlorophyll values of oats grown in peanut and cotton plots of the Sod system were 41.6 and 37.6, respectively; while oats grown in peanut and cotton plots of the Conventional system were 42.6 and 36.5, respectively.

Leaf sap NO_3-N concentrations (Fig. 2B) response to cropping system and summer crop were similar to that of leaf chlorophyll (Fig. 2A). However, the variation of NO_3-N in leaves with sampling dates and among treatments was much greater than that of leaf chlorophyll. About 2 weeks after N fertilizer application (60 DAP), both leaf chlorophyll and NO_3-N peaked. Greater leaf chlorophyll and leaf sap NO_3-N concentrations from peanut plots was likely attributed to greater soil N content associated with the leguminous peanut crop, but soil mineral composition was not measured to verify this.

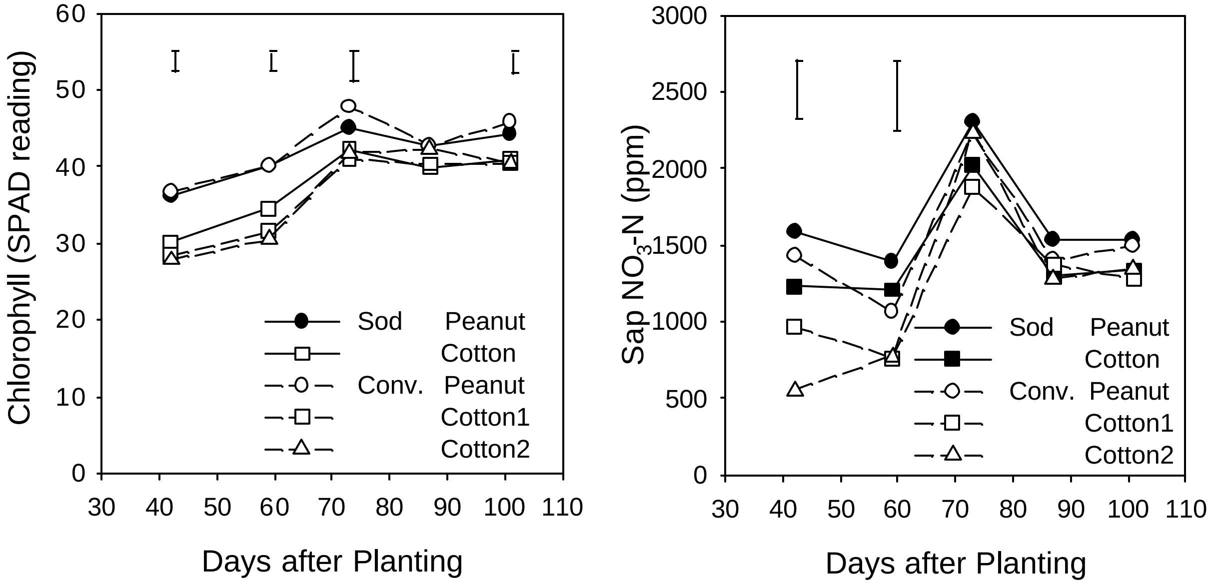


Fig. 2. Changes in (A) leaf chlorophyll and (B) leaf sap NO_3-N concentration of oats during growth and their responses to cropping systems (Sod and Convention) and previous crops (peanut and cotton). Vertical bars present values of $LSD_{0.05}$.

N concentration and N uptake of oat shoots

At 101 DAP, oats grown in peanut plots of the Sod system had greater tissue N concentrations, than oats grown in cotton plots of the Conventional system (Fig. 3A). It is hypothesized that higher soil fertility and better soil quality in peanut plots of the Sod system improved cover crop plant N status, stimulated plant growth, and increased above-ground biomass. The summer crop and cropping system significantly affected cover crop N recovery (Fig. 3B). At pre-heading (101 DAP), approximately 80 lbs N/acre was recovered in above-ground biomass of oats grown in peanut plots, 60 lbs N/acre was recovered from the cotton plots of the Sod system, and only 40 lbs N/acre was recovered from the cotton plots of the Conventional system (Fig. 3B). Therefore, N management will depend upon both, the cropping system and the previous summer crop.

CONCLUSIONS

Results from this study indicated that both, cropping system and the summer crop influenced oat cover crop above-ground biomass, plant N status and therefore, N recovery. Oats grown in plots of the Sod system had greater biomass, leaf chlorophyll and leaf sap NO_3-N concentrations as compared to oat grown in the Conventional system. Oat grown in peanut plots had much greater shoot biomass production and greater tissue N concentration than oats grown in cotton plots. The increases in cover crop plant growth and N status found in the Sod cropping system may be associated with improved soil physical property, soil fertility, and other soil quality parameters contributed by the bahiagrass sod. The data gathered from this study can help growers with their N fertilizer management of cotton and peanuts in either sod-based or conventional rotational cropping systems in the southeastern USA. Our data also may be useful for those producers who manage cover crops for livestock as pasture or hay.

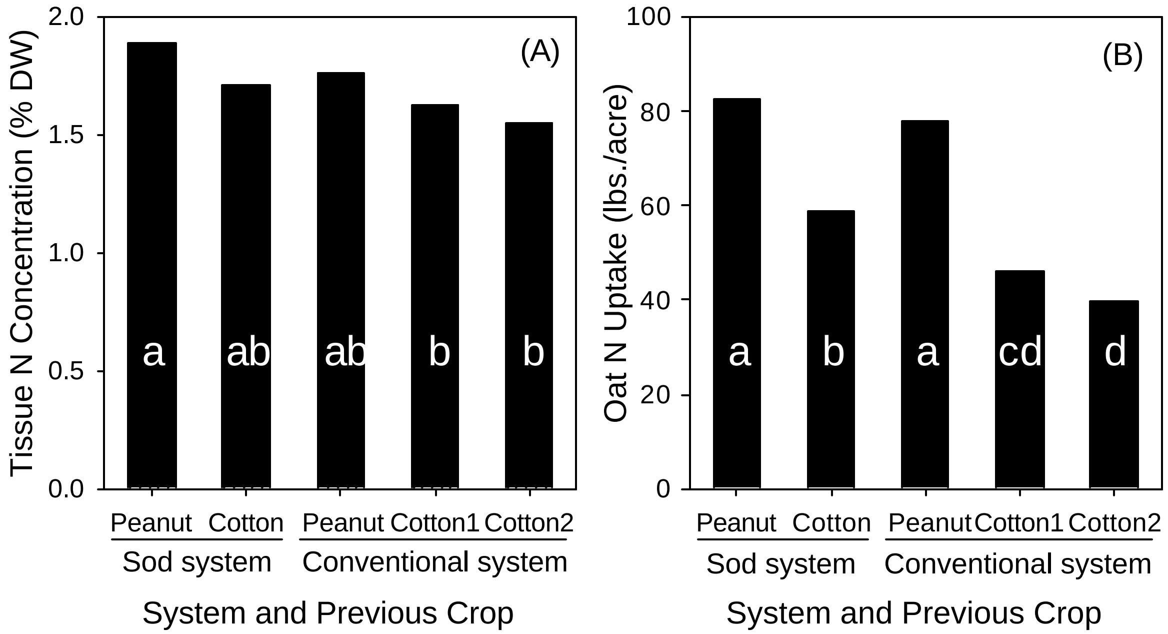


Fig. 3. (A) N concentration (% of dry matter) of oat shoots and (B) shoot N uptake at pre-heading (101 DAP), as affected by previous summer crop and cropping system. Bars with the same letter are not significant at P = 0.05 level.

REFERENCES

Franzluebbers, A. J. 2007. Integrated crop–livestock systems in the southeastern USA. Agron. J. 99:361-372.

Langdale, G.W., Blevins, R.L., Karlen, D.L., McCool, D.K., Nearing, M.A., Skidmore, E.L., Thomas, A.W., Tyler, D.D., and Williams, J.R. 1991. Cover crop effects on soil erosion by wind and water. p. 15–22. In W.L. Hargrove (ed.) Cover crops for clean water. Soil and Water Conserv. Soc., Ankeny, IA.

Horton, R., Kaspar, T.C., and Kohler, K.A. 1994. Fall-planted spring oats: A low-risk cover crop to reduce erosion following soybean. Leopold Center Progress Reports. Vol 3. 49-52.

Katsvairo, T.W., Wright, D.L., Marois, J.J., Hartzog, D.L., Rich, J.R., and Wiatrak, P.J. 2006. Sod–livestock integration into the peanut–cotton rotation: A systems farming approach. Agron. J. 98: 1156-1171.

Katsvairo, T.W., Wright, D.L., Marois, J.J., Hartzog, D.L., Balkcom, K.B., Wiatrak, P.P., and Rich, J.R. 2007. Cotton roots, earthworms, and infiltration characteristics in sod–peanut–cotton cropping systems. Agron. J. 99:390-398.

Marois, J.J., Wright, D.L., Baldwin, J.A., and Hartzog, D.L. 2002. A multi-state project to sustain peanut and cotton yields by incorporating cattle in a sod based rotation. p. 101–107. In E. van Santen (ed.) Proc. 25th Ann. South. Conserv. Tillage Conf. Sustain. Agric., Auburn, AL. 24–26 June 2002. Alabama Agric. Exp. Stn., and Auburn Univ.

Meisinger, J.J., Hargrove, W.L., Mikkelsen, R.L., Williams, J.R., and Benson, V.W. 1991. Effects of cover crops on groundwater quality. p. 57–68. In W.L. Hargrove (ed.) Cover crops for clean water. Soil and Water Conserv. Soc., Ankeny, IA.

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

Reeves, D.W., Tyler, D.D., and Hargrove, W.L. 1995.Winter cover crops. p. 27–30. In G.W. Langdale and W.C. Moldenhauer (ed.) Crop residue management to reduce erosion and improve soil quality: Southeast. Conserv. Res. Rep. 39. USDA-ARS, Washington, DC.

Sharpley, A.N., and Smith, S.J. 1991. Effects of cover crops on surface water quality. p. 41–49. In W.L. Hargrove (ed.) Cover crops for clean water. Soil and Water Conserv. Soc., Ankeny, IA.

Wright, D., Marois, J., Katsvairo, T., Wiatrak, P., and Rich, J. 2004. Value of perennial grasses in conservation cropping systems. Proc. 26th Southern Conserv. Tillage Conf. Sustain. Agric., Raleigh, NC, 8-9 June 2004. p. 135-142.

Breeding Tetraploid Bahiagrass for Traits Conducive to Sod-based Crop Rotations

C.A. Acuna, C.L. Mackowiak, A.R. Blount, K.H. Quesenberry, and J.R. Rich
University of Florida, 306 Newell Hall, Gainesville, Fl 32611
caalac@ufl.edu

INTRODUCTION

Bahiagrass, *Paspalum notatum* Flügge, is currently one of the most important pasture and utility turf species in Florida and the southern Coastal Plain region of the USA (Gates et al., 2004). It has been successfully utilized in sod-based crop rotations as a means of supporting livestock grazing and improving soil properties for successive crops (Katsvairo et al., 2006; Wright et al., 2004). Additionally, seed-propagated bahiagrass is a more economically viable alternative to vegetatively propagated sod in short (2-year) rotations.

Bahiagrass is a polymorphic species that contains races with different ploidy levels and linked reproductive characteristics. While diploids reproduce sexually (Burton, 1955), tetraploids reproduce asexually via apomixis (Burton, 1948). Apomixis is an asexual mode of reproduction where megasporogenesis and fertilization of the egg by a male gamete are bypassed, resulting in the production of clonal progeny. Apomixis therefore allows perpetuation of a fixed genotype, including complex, high yielding hybrids. This technique may provide a tremendous advantage in plant breeding and seed production (Grimanelli et al., 2001). All bahiagrass tetraploid cultivars released in the USA have been superior apomictic ecotypes selected from introduced germplasm, such as the cultivars 'Argentine' (PI 148996), 'Paraguay 22' (PI 158822), and 'Wilmington' (PI 434189) (Gates et al., 2004). However, a segregating population can be generated for breeding purposes or for genetic analyses by making crosses between sexual induced tetraploid plants and apomictic tetraploid plants.

Genotypic variability expresses itself in a myriad of traits; yield being the most notable. Traits favored in a bahiagrass breeding program may include cold tolerance, disease tolerance, forage quality, and nutrient utilization. Nutrient interception and uptake by plant roots, as in the case of nitrates, ensures that fertilizers applied to the soil are being removed effectively, resulting in potentially less run-off and leaching losses.

Nitrogen management in Florida is particularly important since nitrates can rapidly leach through the sandy soils and Karst geology of upper Florida, thereby impacting groundwater and spring ecology. High root densities, such as those associated with perennial forages, can remove over 80% of applied nitrogen. In comparison, row crops may remove less than 60% of applied nitrogen. A more effective root system can be particularly important for production systems located on the sandy southeast Coastal Plain soils since high rainfall events move nitrates rapidly from surface soil into the subsoil. Bahiagrass is a good candidate for N removal since it has nutrient storage capability in its stolons (Blue, 1972; Rodriguez et al., 1973) and posses a large, deep fibrous root system (Ball et al., 2002). Nitrogen removal can be increased by selecting cultivars with greater biomass production and/or greater tissue N content. Unlike yield, it is not well known how much genotypic variability exists among bahiagrass cultivars in terms of N capture and removal in low or high N input systems. Muchovej and Mullahey (2000) found approximately a 25% difference in seasonal yield and a 10% difference in seasonal forage N content among 5 commercially available cultivars grown under low N (50 lb/A/yr). It is possible that cultivar differences may be greater under higher N inputs. Since bahiagrass N content tends to be relatively low in comparison to other C_4 grasses (i.e. bermudagrass and limpograss), moderate increases in bahiagrass forage N accumulation might improve overall forage quality without reaching a point of excessive tissue nitrates.

Other traits, such as nematode resistance is especially beneficial when using bahiagrass in a crop rotation. Some of the positive effects associated with a bahiagrass rotation, such as yield increases by crops following the sod, have been attributed to nematode and disease suppression (Gates et al., 2004). The genotypic response to nematode pressure is only beginning to be evaluated in our bahiagrass research program.

The objectives of this research were 1) to characterize the bahiagrass tetraploid germplasm, 2) to generate a segregating population by hybridizing sexual and apomictic tetraploid genotypes, and 3) to initiate screening of selected apomictic progeny for forage production, nitrogen accumulation, and nematode resistance.

MATERIALS AND METHODS

Germplasm Characterization

Twenty of the most vigorous plants from a population of 300 artificially induced tetraploids (Quesenberry and Smith, 2003) were grown in the field and greenhouse from summer 2004 to the end of summer 2005. Two sexual tetraploid lines, Q4188 and Q4205 (Quarin et al., 2003), the cultivars Argentine (PI 148996) and Wilmington (PI 434189), and the experimental hybrid Tifton-7 (Burton, 1992) were also grown in a greenhouse and field during this time period. The ploidy level of these genotypes was confirmed by flow cytometry, and their mode of reproduction was determined by embryo sac observations as described by Acuna, 2006. A segregating population containing 600 hybrids was generated by crossing the best 6 sexual plants as female parents and Argentine and Tifton 7 as male parents.

Progeny Evaluation

Entire progeny (Phase 1)

The progeny obtained by hybridization of sexual and apomictic genotypes were transplanted into the field in May 2005. Initial assessments were based on plant diameter, plant height, recovery (regrowth) from clipping in fall and spring and frost resistance. Plant diameter was estimated using the average between the longest and the shortest diameters of a given plant. Plant height was measured from the base of the plant to the top of the standing canopy. Starting on 20 July (50 days after transplanting or DAT), plant diameter and height were taken at 4 wk intervals. On 21 September all plants were defoliated to approximately 3 inches above the soil level. Regrowth was visually rated on 28 October, and 24 May of the following growing season using a 1 to 5 scale, where 1 equaled plants with the lowest amount of forage and 5 equaled plants with the greatest amount of forage. Frost resistance was visually estimated on 28 December after two consecutive frost events on 23 and 24 December, with temperatures of 28 and 30 °F respectively, using a 1 to 5 scale, where 1 equaled the least frost resistant, and 5 equaled the most frost resistant plant. In an attempt to estimate the segregation for apomixis and to collect seed before the field evaluations were completed, a group of 71 plants was selected on 19 August, 2005. These plants were classified as sexual, apomictic, and facultative apomictic based on mature embryo sac observations.

Selected apomictic hybrids (Phase 2)

Small plots (65 ft^2) with 7 of the most promising apomictic hybrids were established in Gainesville in 2006. Two other apomictic hybrids, and cultivars Argentine and the experimental hybrid Tifton-7 were also included. These plots were fertilized at the beginning of the growing season with 16-4-8 at 445 lb/A. Plots were harvested on October 31 and forage mass and N concentration were determined. Plots were sampled again in April 2007 for forage and stolon/root mass.

RESULTS AND DISCUSSION

Germplasm Characterization

Cultivars

Flow cytometric analysis confirmed that the cultivars Argentine, Wilmington, and the experimental hybrid Tifton-7 were all tetraploid. Embryo sac observations indicated that the cultivars Argentine and Wilmington were highly apomictic plants. Ninety five percent of the analyzed ovules had multiple apomictic sacs for both cultivars; while the other 5% had multiple apomictic sacs in addition to one meiotic sac. The experimental hybrid, known as Tifton-7, was generated throughout a long and intricate breeding approach (Burton, 1992). Although this hybrid has been shown to be significantly more productive than Argentine, it has remained as an experimental hybrid due to concerns regarding seed production. It was also highly apomictic with 95% of its ovules containing only apomictic embryo sacs, and 5% containing both apomictic and meiotic sacs sharing the same ovule. Although Burton (1992) stated that Tifton-7 was significantly more fertile than Argentine, our results showed no significant differences in self- and cross-fertility between these two genotypes. They produced 31% of seed when self-pollinated and 36% when open-pollinated. Thus, the previously reported differences in seed production might be related to number of inflorescences per unit area.

Induced tetraploids

Flow cytometric analysis confirmed that the 20 genotypes from the artificially induced population were all tetraploid. In addition, all of them were determined by mature embryo sac observations to reproduce sexually. Although large variability in terms of sexual expression was recorded for naturally occurring tetraploids (Martínez et al., 2001), highly sexual plants have not been found in natural populations.

In addition to being the most vigorous plants in a large population these 20 genotypes were reasonably cross-fertile, and self-sterile. They produce 2 % of seed when self-pollinated and 22 % of seed when cross-pollinated. Thus, results indicated that these 20 sexual tetraploids should be considered as good female counterparts for breeding tetraploid bahiagrass.

Progeny Evaluation

Entire progeny

Plant diameter and plant height were measured in order to characterize the growth habit of the progeny. Progeny showed significant differences for both variables during the entire growing season indicating a marked variability in terms of growth habit. On 20 July, 50 days after transplanting, progeny were ranked based on their diameter. A range from 5 to 11 inches in diameter was observed for the first measurement. The progeny showed an additional spread of between 2 to 6 inches after an additional month and between 4 to 9 inches two months later. The rate of spread between the first and the second measurements was higher than between the second and the third measurements. This difference could be related with the daylength for each period. The average daylength between the first and the second measurements (13 h 30 min) was 50 min longer than the average daylength between the second and the third measurements (12 h 40 min).

Plant height for a given progeny did not vary significantly among the three measurement periods, indicating that the progeny did not increase in height from 20 July until the end of the growing season. These results indicate that increases in canopy height occurred early and reached maximum height soon after transplanting. Some progeny showed a marked vertical or upright growth habit while other progeny showed a marked horizontal or prostrate growth. The most successful forage grasses for Florida pastures have tended to have exhibited marked prostrate growth resulting in persistence under grazing, and they have the capability to spread and colonize new areas quickly. For example, our Fl-4-36-1 x Argentine, Fl-2-2-7 x Tifton-7, Fl-71 x Argentine, and Fl-106 x Tifton-7 hybrids may potentially be good choices for pastures since they have a more prostrate growth habit.

The progeny were determined to be significantly different in terms of plant regrowth during fall 2005 and spring 2006. The top four populations, Fl-4-36-1 x Argentine, Fl-106 x Tifton-7, Fl-2-2-7 x Tifton-7, and Fl-71 x Argentine were determined to be the most suitable combinations for extending the growing season. Interestingly, the four populations that spread fastest between 1 June and 21 September showed better plant regrowth either before or after the winter. Additionally, these four populations had a better general vegetative vigor throughout the initial growing season.

Large variability was also observed among the progeny in terms of frost resistance. The four progeny that showed superior vegetative vigor also were among the most frost resistant, populations. Among the best performers in this category was Fl-106 x Tifton-7 progeny.

To gain time and realize genetic advance in the evaluation process, a group of 71 plants was phenotypically selected on 19 August 2005. Both inflorescences at anthesis and seed were collected from all plants. The plants were classified as sexual, apomictic, and facultative apomictic based on embryo sac observations. Eight of them were classified as apomictic because more than 90 % of their ovules contained apomictic embryo sacs. Twelve plants were classified as facultative apomictic because a low percentage (less than 40 %) of their ovules showed apomictic embryo sacs while the rest of their ovules showed sexual embryo sacs. The remaining 51 plants were classified as highly sexual because all of their ovules contained only a single sexual embryo sac. By grouping both apomictic and facultative apomictic plants, it is estimated that 28 % of the plants from this sample inherited the gene(s) for apomixis.

Selected apomictic hybrids

High variability was observed for forage mass among these hybrids. The average forage mass was 3110 lb/A varying from 1550 lb/A to 4570 lb/A (Fig. 1). Cultivar Argentine produced 2130 lb/A while Tifton-7 produced 3210 lb/A. For comparison, Tifton-7 yields in our trials have been comparable to the diploid, Tifton-9 yields. Five novel hybrids (3 from Argentina and 2 from the UF program) produced more forage mass than Tifton-7. However, these results are preliminary and further evaluation is required. An initial spring 2007 sampling of stolons + roots resulted in a 3-fold difference in stolon/root dry mass among hybrids (Fig. 2). In general, there appears to be a moderate correlation between above-ground and stolon/root biomass ($r^2 > 0.50$). Even so, enough variation among hybrids may exist to use stolon/root mass as a selection criterion for specific forage systems. Additional measurements in 2007 and 2008 will determine if this is the case.

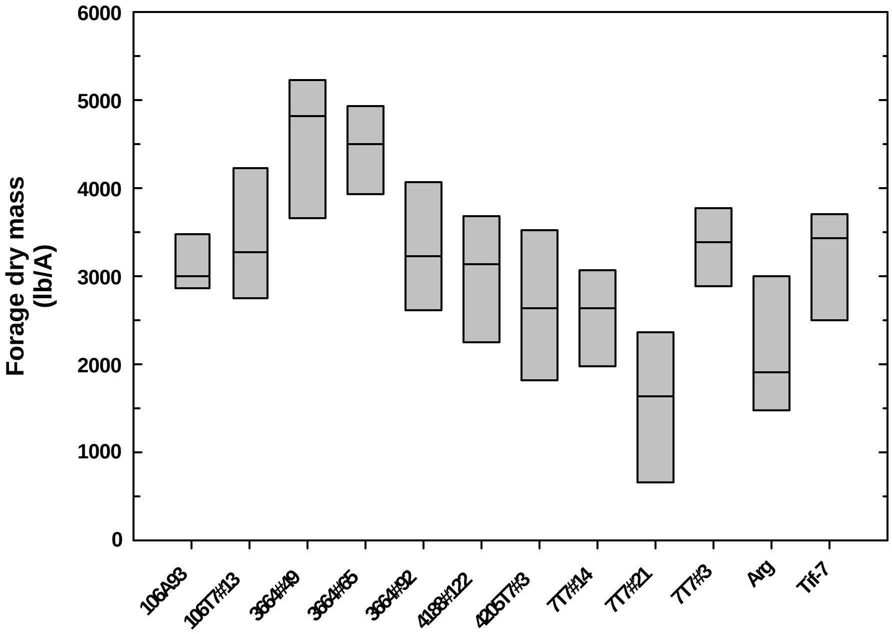


Fig. 1. Box plot of fall 2006 forage field harvest of selected apomictic hybrids compared with Argentine (Arg) and Tifton-7 (Tif-7). Bar length equates to value range and median is represented by horizontal line (n = 4).

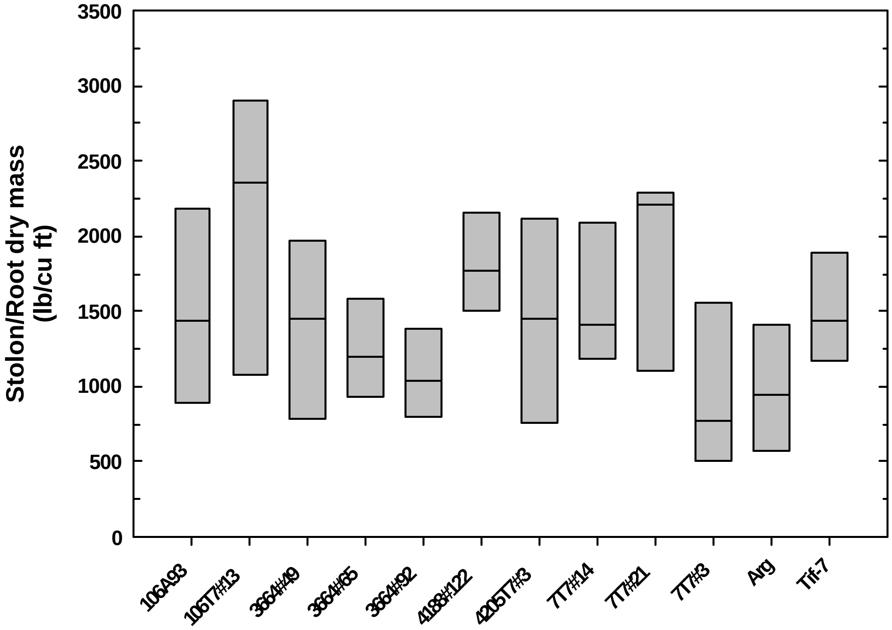


Fig. 2. Box plot of spring 2007, stolon + root harvest from selected apomictic hybrids as compared with Argentine (Arg) and Tifton-7 (Tif-7). Each 16 cu inch soil core was taken below an established plant. Bar length equates to value range and median is represented by horizontal line (n = 4).

Some hybrid variability was observed for leaf nitrogen concentration in the fall sampling. The average nitrogen concentration varied from 0.9 to 1.2 % (Fig. 3). The generally low nitrogen concentration in all the harvested forages was likely related to its maturity (first and only cutting) at the time it was collected (Fall, 2006). Based on the preliminary data, variability observed with nitrogen accumulation was primarily defined by genotypic differences on forage production but not in all cases. For example, hybrid 106T7#13 removed as much N as the highest yielding hybrids containing lower tissue N (Fig. 4). Total N removal by biomass ranged from 21 lb/A to 54 lb/A with an overall average of 37 lb/A. Sampling will continue in 2007 to determine cultivar variability in N content and removal over an entire growing season using a low and high N application rate.

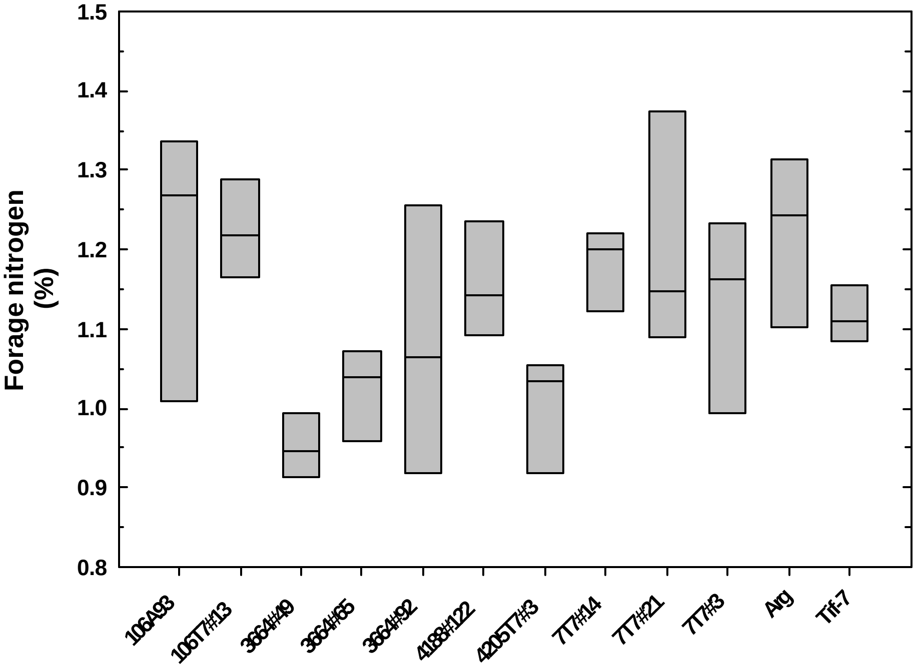


Fig. 3. Box plot of fall 2006 forage nitrogen content of selected apomictic hybrids compared with Argentine (Arg) and Tifton-7 (Tif-7). Bar length equates to value range and median is represented by horizontal line (n = 4).

Although still in its initial testing phase, it becomes clear that given enough genotypic variability among progeny, customized bahiagrass cultivars may be used in specific systems. For example, one bahiagrass cultivar might be most appropriate for a hay system, another for a pasture system and then another for a sod-based crop rotation. Table 1 provides examples of how system attributes may differ and which of our tetraploid evaluations might fit into the various systems. Hay production would require good yield and stolon/roots to protect against drought or other stresses. Good N recovery means less fertilizer inputs. In a pasture system, greater crude protein, particularly under low N input (typical of many pastures in Florida) and greater stolon/root mass would be desirable. Greater forage yield may not be as important, particularly since summer production can get ahead of grazing pressure with many of the currently available cultivars. Sod-based rotation requirements may be similar to pasture requirements, with the exception that a lower stolon/root producer may be easier to manage when it comes to rotating in with the succeeding row crop.

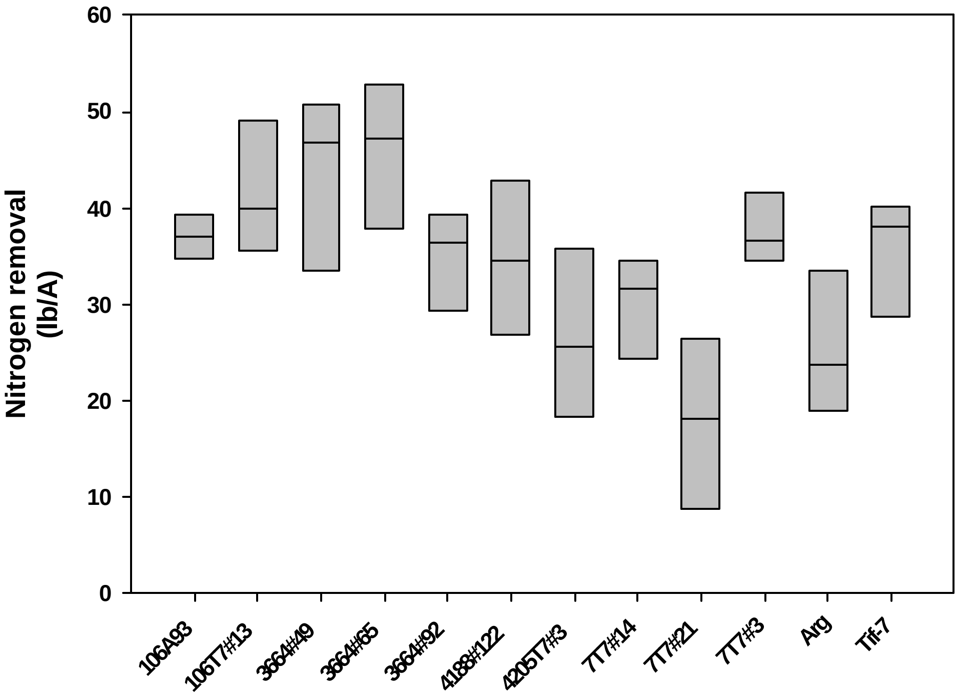


Fig. 4. Box plot of fall 2006 forage nitrogen removal in biomass of selected apomictic hybrids compared with Argentine (Arg) and Tifton-7 (Tif-7). Bar length equates to value range and median is represented by horizontal line (n = 4).

Table 1. Attributes and bahiagrass genotypes conducive to sustainable agricultural systems.

System	**Desirable Attributes**	**Potential Tetraploids**
Hay Production	greater yield greater stolon and root mass greater N recovery	106T7 #13 3664 #49
Pasture	greater crude protein greater stolon and root mass	Argentine Tifton-7 106 x A #93 7 x T7 #21 106 T7 #13
Sod-based Crop Rotations	greater crude protein (grazing) greater N recovery less stolon and root mass	3664 #92 7T7 #3

Nematode resistance/tolerance was not listed under the Table 1 attributes but it is a trait that is highly desirable for use in a sod-based crop rotation. Greenhouse screening for root-knot nematode resistance or susceptibility was initiated in spring, 2007, using novel tetraploid hybrids and commercially available tetraploid and diploid cultivars. Data collection will begin in early summer, 2007. Chances are good that some genotypic variability exists among bahiagrass cultivars since variability has been observed for many other traits. For example, genotypic variability exists for biomass and N content (Muchovej and Mullahey, 2000) and even herbicide tolerance (Bunnell et al., 2003). Additionally, large genotypic variability to root-knot nematode resistance was found in Italian and perennial ryegrasses (York and Cook, 1988).

Conclusions

Bahiagrass tetraploid hybrids were successfully created by crossing the best sexual and apomictic genotypes, resulting in a ratio of 3 sexual to 1 apomictic hybrids. Screening was initiated in the field and greenhouse to evaluate the new genotypes for forage production, nitrogen utilization and nematode resistance. There were clear genotypic differences for forage production and N removal, where total N removal was primarily dictated by forage yield under low N inputs (50 lb/A). Other traits, such as stolon/root mass and forage N concentration were not as highly variable but additional sampling under greater N application rates need further testing. Work will also continue to determine N uptake with soil depth and nematode resistance of the different promising genotypes.

References

Acuna, C.A. 2006. Bahiagrass Germplasm Characterization and Breeding at the Tetraploid Level. Master of Science thesis, University of Florida.

Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 2002. Southern Forages (3rd ed). Potash and Phosphate Inst., Norcross, GA. pp. 322.

Blue, W.G. 1972. Role of Pensacola bahiagrass stolon-root systems in fertilizer nitrogen utilization on Leon fine sand. Agron. J. 65:88-91.

Bunnell, B.T., R.D. Baker, L.B. McCarty, D.W. Hall, and D.L. Colvin. 2003. Differential response of five bahiagrass (*Paspalum notatum*) cultivars to metasulfuron. Weed Tech. 17:550-553.

Burton, G.W. 1948. The method of reproduction in common bahiagrass, Paspalum notatum. J. Am. Soc. Agron. 40:443-452.

Burton, G.W. 1955. Breeding Pensacola bahiagrass, Paspalum notatum: I. Method of reproduction. Agron. J. 47:311-314.

Burton, G.W. 1992. Manipulating apomixis in Paspalum. Proceedings of the Apomixis Workshop, February 11-12, Atlanta, Georgia. p. 16-19.

Gates, R.N., C.L. Quarin, and C.G.S. Pedreira. 2004. Bahiagrass. p. 651-680. In: L.E. Moser, B.L. Burson, and L.E. Sollenberger (eds.), Warm-Season (C4) Grasses, ASA, CSSA, SSSA, Madison, WI, USA.

Grimanelli, D., O. Leblank, E. Perotti, and U. Grossniklaus. 2001. Developmental genetics of gametophytic apomixis. Trens Genet. 17:597-604.

Katsvairo, T.W., Wright, D.L., Marois, J.J., Hartzog, D.L., Rich, J.R., and Wiatrak, P.J. 2006. Sod–livestock integration into the peanut–cotton rotation: A systems farming approach. Agron. J. 98:1156-1171.

Martínez, E.J, M.H. Urbani, C.L. Quarin, and J.P.A. Ortiz. 2001. Inheritance of apospory in bahiagrass, Paspalum notatum. Hereditas 135:19-25.

Muchovej, R.M. and J.J. Mullahey. 2000. Yield and quality of five bahiagrass cultivars in southwest Florida. Soil and Crop Sci. Soc. Florida. 59:82-84.

Quarin C.L., M.H. Urbani, A.R. Blount, E.J. Martínez, C.M. Hack, G.W. Burton, and K.H. Quesenberry. 2003. Registration of Q4188 and Q4205, sexual tetraploid germplasm lines of bahiagrass. Crop Sci. 43:745-746.

Quesenberry, K.H. and R. Smith. 2003. Production of sexual tetraploid bahiagrass using in vitro chromosome doubling agents. Molecular breeding of forage and turf, Third International Symposium, May 18-22, Dallas Texas, USA.

Rodriguez, M. W.G. Blue, and J.E. Moore. 1973. Nutritive value of Pensacola bahiagrass stolons. Agron. J. 65:786-788.

Wright, D., Marois, J., Katsvairo, T., Wiatrak, P., and Rich, J. 2004. Value of perennial grasses in conservation cropping systems. Proc. 26th Southern Conserv. Tillage Conf. Sustain. Agric., Raleigh, NC, 8-9 June 2004. p. 135-142.

York, P.A. and R. Cook. 1988. Variation in forage grasses as hosts of the root-knot nematode Meloidogyn naasi (Franklin) and selection for resistance in ryegrass. Euphytica 43:135-141.

A Conservation Tillage Profitability Learning Tool: Version 2[1]

Jason Bergtold
USDA-ARS-NSDL
411 S. Donahue Dr.
Auburn, AL 36832
Phone: (334) 844-4741
Fax: (334) 887-8597

Abstract

Many studies have examined the agronomic and economic impact of conservation tillage systems on the primary cash crops in Alabama and Georgia (e.g. corn, cotton, peanuts and soybeans) with mixed results. While some studies purport that conservation tillage systems are agronomically and economically beneficial, others have shown that conservation tillage systems under various circumstances can be detrimental and actually hurt crop yields and lower farm profits. To date, only a limited number of studies have tried to bring much of these results together to examine the impact of conservation tillage systems on corn, cotton, peanuts and soybeans across the Southeast. In an effort to bring the results of past and present agronomic and economic studies together into a decision support tool, the purpose of this project is to construct a conservation tillage profitability learning tool that allows end-users to assess the economic impact of alternative conservation tillage technologies, including cover crops, on different cropping systems in their geographic region of the Southeast. The second version of the learning tool includes a net returns calculator that allows the user to examine the profitability of adopting conservation tillage technologies with or without a cover crop in Alabama and Georgia. Data used to construct the tool came from studies published in agronomic and economic journals, as well as research experiments being conducted in both states. A second decision tool, a cover crop biomass economic decision aide, allows the user to examine the potential of using winter cover crops prior to corn and cotton and provides a detailed economic analysis of the optimal level of biomass to ensure profitability (i.e. that increase in crop yield compensate for the cost of the cover crop). The decision aide has been remodeled to be more user friendly and to run as a stand alone application on Windows based operating systems.

[1] Authors Jason Bergtold, Trent Morton, Francisco Arriaga, Kipling Balkcom, Ted Kornecki, Andrew Price, Randy Raper Affiliation: Soil Dynamics Research Unit, USDA-ARS, 411 S. Donahue, Auburn, AL 36832

ASSESSMENT OF SOIL PHYSICAL PROPERTIES ON DIFFERENT MANAGEMENT PRACTICES AND LANDSCAPE POSITIONS

Andre S. Biscaro*[1], Francisco J. Arriaga[2], Kipling S. Balkcom[2], Joey N. Shaw[1], Edzard van Santen[1], Jason S. Bergtold[2], Randy L. Raper[2] and D. Wayne Reeves[3]
[1]Dept. of Agronomy and Soils, Auburn University, 201 Funchess Hall, Auburn, AL 36849.
[2]USDA-ARS, National Soil Dynamics Laboratory, 411 S Donahue Drive, Auburn, AL 36832.
[3]USDA-ARS, J. Phil Campbell Sr. Natural Resource Conservation Center, 1420 Experiment Station Rd, Watkinsville, Georgia 30677.
*biscaas@auburn.edu

ABSTRACT

Crop production has become more costly every year, and improving recommendations and implementation of site-specific crop management can help farmers achieve input optimization and consequent savings. The use of precision agriculture techniques is completely dependent on understanding the spatial variability of soil physical properties. In order to assess management practices and landscape variability effects on soil physical properties, infiltration, aggregate stability and total carbon (C) were measured in a 22 acre field in the central Alabama Coastal Plain. Based on the local soil properties, the field was separated into three zones - summit, backslope and accumulation. Four tillage systems treatments - conventional system with (CT+M) or without (CT) dairy manure, and conservation system with (NT+M) or without (NT) dairy manure - and corn-cotton rotation have been established in the study area since 2001. Overall, infiltration, aggregate stability and C content were lower in CT. The C content was significantly higher ($P = 0.001$) for treatments with manure, where CT+M was 62% greater than CT, and NT+M was 39% greater than NT. Infiltration was highest on the summit (5.7 in/h), followed by backslope and accumulation zones (3.4 and 2.8 in/h, respectively). No significant difference ($P = 0.69$ and 0.39, respectively) was found for aggregate stability and carbon among the zones. Conservation tillage for 6 crop years thus far has improved infiltration and increased soil C content, whereas manure has only increased soil C content.

INTRODUCTION

The movement of water and chemicals is greatly affected by soil physical properties, which in turn have a great impact on crop productivity. The physical properties of soil can vary significantly within a field. Soil spatial variability is often related to changes in landscape position, and is usually the major cause of spatial variability in crop yields (Terra et al., 2005). As a soil-forming factor, topography leads to differentiation in soils (Jenny, 1941). Steep slopes associated with conventional tillage practices may lead to erosion and soil deterioration. Nutrient distribution within a soil profile can change with landscape position (Balkcom et al., 2005). Soil C can significantly affect soil chemical and physical properties, and landscape position plays an important role in C sequestration (Terra et al., 2005). Further, conservation tillage systems, such as non-inversion tillage practices like strip-tilling, can benefit production systems of southeastern U.S. The use of conservation systems benefits soils by increasing organic C content and providing protective crop residue on the soil surface, which is a prominent issue for these soils. Therefore, the objective of this work is to assess the effect of management practices and landscape variability on selected soil physical properties.

MATERIALS AND METHODS

The study site is located at the Alabama Agricultural Experiment Station's E.V. Smith Research Center, near Shorter. Four management treatments were established in late summer of 2000 on a corn and cotton rotation that has both crops present each year. The management systems included a conventional tillage system (chisel- followed by disc-plow) with (CT+M) and without (CT) manure, and a conservation tillage system (non-inversion tillage) that incorporated the use of winter cover crops with (NT+M) and without manure (NT). A mixture of rye (*Secale cereale* L.) with black oat (*Avena strigosa* Schreb.), and a mixture of crimson clover (*Trifolium incarnatum* L.) with white lupin (*Lupinus albus* L.) and fodder radish (*Raphanus sativus* L.) were typically used as winter cover before cotton (*Gossypium hirsutum* L.) and corn (*Zea mays* L.), respectively. Four strips with an average length of 800 ft were established across the landscape to represent the four management systems for each crop per each replication. Each strip was further divided into cells to simplify sampling and field measurements. A total of six replications were established on the 22 ac field. Maximum slope is 8% and 9 soil map units are contained within this landscape.

Prior research work at the same field site delineated four distinct zones using a digital elevation map, electrical conductivity survey, and traditional soil mapping techniques. For this study, three of these zones were selected and recognized as summit, backslope, and accumulation zones in the landscape. Two cells per management and zone were selected to conduct soil physical properties characterization (Fig. 1). Soil properties studied included total soil C by dry combustion at three depths, water infiltration with a mini-disk infiltrometer (Decagon Devices Inc., Pullman, WA)[1], and water stable aggregates (Nimmo and Perkings, 2002). Other data was

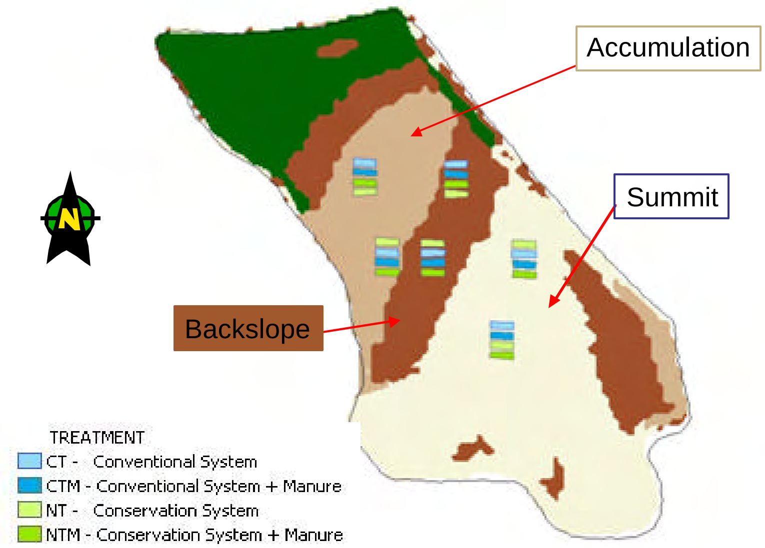


Figure 1. Location of sampling cells for each of the three landscape zones used in this study. The green region in the northern section of the field is an intermediate zone not included in this research.

---

[1] Mention of a company name or trademark does not constitute endorsement by Auburn University and/or USDA-Agricultural Research Service to the exclusion of others.

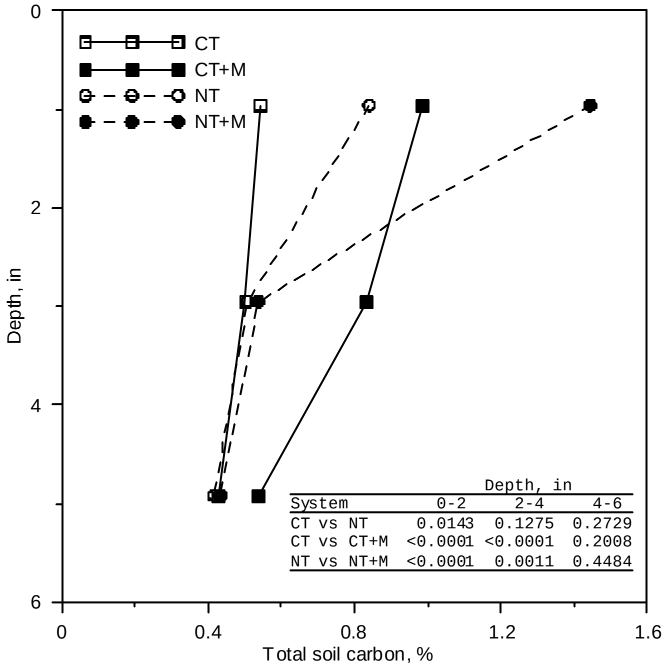
collected, including soil bulk density, water retention, and crop yields, but will not be presented here.

Data were analyzed with the MIXED model procedure in SAS (SAS Institute Inc., Cary, NC). Management system, landscape position, depth, and their interactions were considered as fixed effects.

RESULTS AND DISCUSSION

On the surface 2 inches of soil, total C was greatest in the NT+M followed by CT+M, NT, and CT (Fig. 2). Differences in C content between CT and NT were significant at the 0-2 inches of depth only. Non-inversion tillage increased C content by 54.7% on the surface soil, and by 1.3% from 2-4 inches of depth. However, C content was 2.5% lower in the NT than in the CT at the 4-6 inch depth. This lower C content can be attributed to the lack of soil mixing in the NT system. Nevertheless, soil C accumulation is greater with NT since C is broken down by increased soil respiration from CT operations. Small differences in C were observed with depth in CT, with C content ranging from 0.54 to 0.43%. All management systems had significant interaction (P = 0.001) with depth, except CT. The lack of difference in soil C content with depth in CT can be attributed to low C additions, greater C breakdown, and mixing of the surface soil (Fig. 2).

Manure application significantly increased C content for CT+M and NT+M when compared to CT and NT on the top 4 inches of soil (Fig. 2). Carbon content was increased by 81.9, 65.7, and 26.2% from 0-2, 2-4, and 4-6 inches of depth, respectively, when comparing CT and CT+M. A similar trend was observed for NT and NT+M, with C content increasing by 71.8, 5.7, and 4.2% for 0-2, 2-4, and 4-6 inches of depth, respectively. Landscape position had no significant effect (P = 0.39) on soil C content (Fig. 3).



	Depth, in		
System	0-2	2-4	4-6
CT vs NT	0.0143	0.1275	0.2729
CT vs CT+M	<0.0001	<0.0001	0.2008
NT vs NT+M	<0.0001	0.0011	0.4484

Figure 2. Total soil C content for the conventional (CT), conventional with manure (CT+M), no-till (NT), and no-till with manure (NT+M) management systems. Statistical significance between management systems of interest at a given depth is depicted in the table insert.

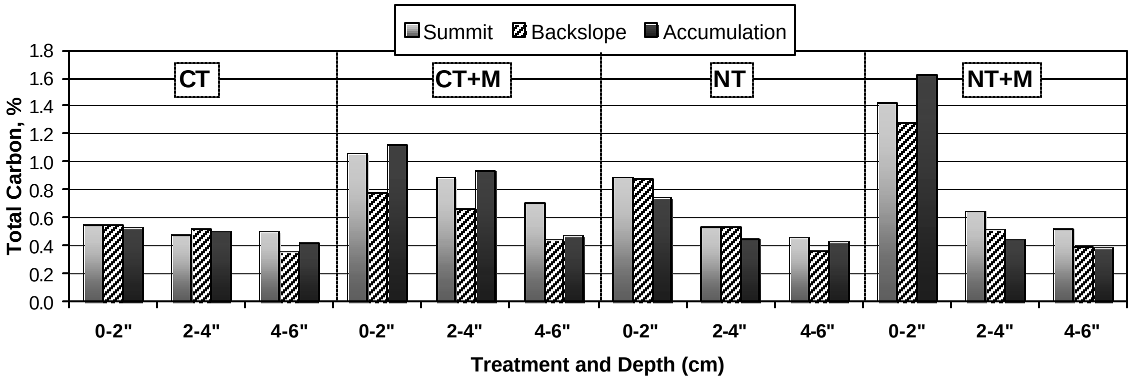


Figure 3. Total soil carbon content by landscape position, depth and management system (CT - conventional; CT+M - conventional with manure; NT - no-till; NT+M - no-till with manure).

Overall, non-inversion tillage increased infiltration in all zones (Fig. 4). The NT system had greater infiltration in the summit and accumulation zones than in the backslope. A similar trend was noted with NT+M. The backslope position is a transitional zone where C deposition and accumulation is less likely to occur. Infiltration in the summit for the CT treatment was greater than in the accumulation and backslope zones (Fig. 4). Manure application did not improve infiltration in the study area. No main effect for treatment (P = 0.51) and zone (P = 0.27) was observed for aggregate stability (Fig. 5). This may be attributed to the large variability in aggregate stability measurements.

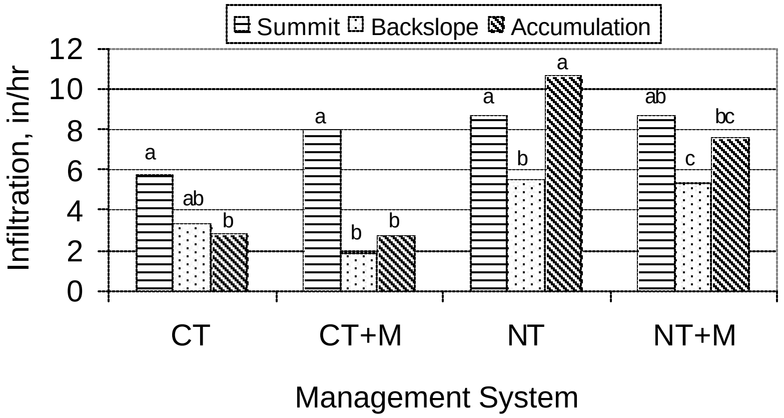


Figure 4. Infiltration rate for four management systems (CT – conventional; CT+M – conventional with manure; NT - no-till; NT+M – no-till with manure) and landscape position. Different letters denote a significant difference between landscape positions within the same management system.

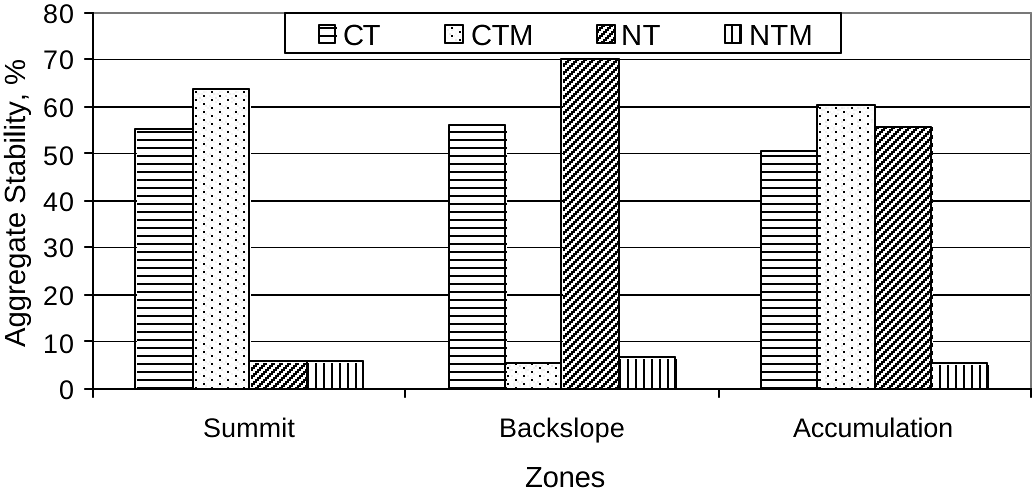


Figure 5. Water stable aggregates for four management systems (CT – conventional; CT+M – conventional with manure; NT - no-till; NT+M – no-till with manure) and landscape position.

CONCLUSIONS

Manure significantly increased C content in CT and NT treatments, especially in the 0-2 inches of depth. However, it did not improve infiltration or aggregate stability. There were no significant differences between treatments and zones in aggregate stability. Infiltration tended to be higher in the summit position for all the treatments, with the exception of NT. Overall, conservation systems have improved C contents and infiltration of this landscape. It is expected that by the end of this experiment a more representative set of data will better characterize soil physical properties for the treatments and landscape positions of this research field.

REFERENCES

Balkcom, K.S., J.A. Terra, J.N. Shaw, D.W. Reeves, and R.L. Raper. 2005. Soil management system and landscape position interactions on nutrient distribution in a coastal plain field. J. Soil & Water Cons. 60(6):431-437.

Nimmo J.R., and K.S. Perkings. 2002. Wet-aggregate stability. p. 321–323. *In* J.H. Dane and G.C. Topp (ed.) Methods of soil analysis: Physical methods. SSSA, Madison, WI.

Jenny, Hans. 1941. Factors of soil formation: A system of quantitative pedology. McGraw Hill Book Company, New York, NY.

Terra, J.A., J.N. Shaw, D.W. Reeves, R.L. Raper, E. van Santen, E.B. Schwab and P.L. Mask. 2005. Soil management and landscape variability affects field-scale cotton productivity. Soil Sci. Soc. Am. J. 70: 98-107.

Bahiagrass Breeding at the University of Florida

Ann Blount[1], Paul Mislevy[2], Ken Quesenberry[3], Tom Sinclair[3], Cheryl Mackowiak[1], Bob Myer[1], and Richard Sprenkel[1]

1. Univ. of Florida, North Florida Research and Education Center, Marianna and Quincy, FL
2. Univ. of Florida, Range Cattle Research and Education Center, Ona, FL
3. Univ. of Florida, Agronomy Dept., Gainesville, FL

Background

Bahiagrass breeding is a multi-disciplinary and multi-state effort between faculty at the University of Florida and USDA-ARS scientists in Georgia and Florida. Bahiagrass is a perennial grass species, and improvements through plant breeding have been multi-disciplinary. Faculty involved in breeding bahiagrass includes forage breeders, animal nutritionists, forage management specialists, soil scientists, and crop physiologists.

Bahiagrass is one of the predominant pasture grasses utilized by the beef cattle industry in southern Georgia, southern Alabama, and throughout Florida. Its popularity is attributed to its tolerance of low soil fertility, establishment by seed, persistence under grazing, long-lived stands, disease and nematode suppressing ability in crop rotations, and use as a pasture, hay, or sod crop. Although bahiagrass is native to South America, it has proved to be remarkably adapted to the southern Coastal Plain and, particularly, to our Florida environment. This species is estimated to cover at least 6.0 million acres throughout the southeastern United States (Burton et al., 1997). Strong support from the beef industry sector in the southeast has prompted a multi-state emphasis on bahiagrass variety development. The focus of the breeding program has emphasized plant improvement in seedling vigor and establishment, cold tolerance, photoperiod response, seasonal distribution of forage production, forage quality, rooting, and insect, nematode and disease resistance.

‘Pensacola’ bahiagrass dominates the bahiagrass acreage in the southeastern U.S. In Florida, an estimated 60% of the bahiagrass acreage is planted in Pensacola, about 25% in ‘Argentine’, 10% in ‘Tifton 9’, and 5% in ‘Paraguay 22’ (Carrol Chambliss, University of Florida State Extension Forage Specialist, 2002). The bahiagrass cultivar ‘AU Sand Mountain’ was recently released from Auburn University. In the northern parts of Alabama and Georgia, this new variety has out-yielded Tifton 9. AU Sand Mountain is not expected to greatly impact bahiagrass acreage in southern Alabama, southern Georgia, or Florida, however it may be very successful further north.

Dr. Glenn Burton, at the USDA-ARS Crop Genetics and Breeding Research Unit at Tifton, GA, began a bahiagrass breeding program there in the early 1960s (Burton, 1982). He used a selected procedure called Recurrent Restricted Phenotypic Selection (RRPS). Applying this procedure to Pensacola bahiagrass, he selected for increased above-ground yield for nine cycles, which led to the development of Tifton 9. Twenty-three cycles of RRPS selection were eventually conducted at Tifton, and seed has been maintained from each population. Efforts at Tifton, Ona, Brooksville and Marianna utilize this existing germplasm to select for such attributes as increased forage production, improved digestibility and rapid stand establishment.

Bahiagrass, as is typical of most warm-season grasses, has lower forage quality (protein and digestibility) than cool-season grasses such as ryegrass and tall fescue. Bahiagrass forage quality is particularly low in late summer. Frequent cutting does not increase digestibility appreciably (Gates et al., 1999). Selections have recently been made at Tifton for individual plants with superior forage quality. Eight cycles of selection for higher digestibility have resulted in small, but significant progress in improved digestibility that will hopefully be incorporated into the breeding program. Also, low seedling germination and poor stand has been a common problem with pasture establishment. As part of the breeding selection, seed from each new cycle are germinated in the greenhouse and plants are selected based on rapid emergence and early seedling vigor, in an effort to improve seedling establishment.

Ploidy and Diploid Cultivar Development

Many bahiagrass cultivars are tetraploid (2n=40) and apomictic; however Pensacola bahiagrass is diploid (2n=20) and sexual. Individual plants within this heterogeneous population vary for many agronomic traits, like crown growth, plant height and foliage yield. A system of recurrent restricted phenotypic selection (RRPS) was used to increase forage yields in Pensacola bahiagrass, which is heterogeneous for forage production (Werner and Burton, 1991). Selections cycles were developed at the Coastal Plain Experiment Station based on selection for a single trait, forage yield, in spaced-plant bahiagrass tests for a number of years, beginning in 1960.
Burton selected for a single trait, above-ground forage yield using the RRPS procedure (G.W. Burton, personal communication, 1999). While each annual cycle improved forage yield, the morphology of the plants comprising each cycle was altered toward a more upright growth habit with a smaller basal diameter (Werner and Burton, 1991).

The release of Tifton 9 bahiagrass resulted from the ninth cycle of breeding for forage improvement in Pensacola, and is the only cultivar that has made a significant impact on newly established acreage in the southeastern US (Burton, 1989).

Bahiagrass growth essentially ceases during the fall and winter months, which has a negative impact on livestock production (Blount, 2000). Cessation of growth may be a response to several environmental limitations, including solar radiation, temperature and rainfall. In Florida, simulated forage yields with bahiagrass resulted in winter harvests yielding slightly more than half the peak yield harvested in early summer (Sinclair et al., 1997). This was attributed to reduced solar radiation in the fall and winter months. Observed winter yields, however, are only a very small fraction of summer yields (Mislevy and Everett, 1981). One possible explanation for this dramatic decrease during the winter is plant response to the short daylength. While shortening daylength has been shown to be associated with induced dormancy in floral initiation and vegetative growth behavior in many plants (Aamlid, 1992; Damann and Lyons, 1993; Ellis, et al., 1997; Marousky, et al., 1991; Wallace, et al., 1993), its affect on vegetative growth of tropical and subtropical grasses has not been well documented.

A recent study, conducted at the Range Cattle Research and Education Center (RCREC) at Ona, FL, determined that daylength in the winter months influenced the vegetative behavior of bahiagrass and bermudagrass (Sinclair et al., 2001). A field study was designed to compare the winter growth of these two subtropical genera under a light regime mimicking summer daylength (15 h) and normal (shortening) daylength. The study resulted in a greater than 6-fold increase for bahiagrass exposed to the supplemental light under the shortest daylength, compared to the growth of the same grass under normal (short-day) conditions. This finding may be significant for bahiagrass improvement, if genetic diversity for photoperiod response was found in diploid bahiagrass. Genotypes identified for insensitivity to shortening daylength could provide the genetic base in developing bahiagrass with improved fall/winter growth.

Based on the RCREC-Ona findings with bahiagrass, another experiment, conducted at the North Florida Research and Education Center (NFREC) at Quincy, FL from 1999-2001, looked at genetic differences for photoperiod among bahiagrass selection cycles (Blount et al., 2001). Photoperiod response influenced the growth and development of ‘Pensacola' derived bahiagrass in four selection cycles [C0 (Pensacola), C4, C9 (Tifton 9) and C23. Field grown plants representing these four cycles were exposed to two daylength treatments. One treatment used natural light and the other imposed a 15 h extended daylength using quartz-halogen lamps. Foliage growth of individual plants was harvested and plant height was recorded from 1999 through 2001. Crown area was measured in mid February 2000 and 2001. Increasing daylength exposure to 15 h after August on all bahiagrass cycles was found to dramatically increase the foliage and height of bahiagrass, while reducing crown area, at nearly all dates where foliage harvests or plant heights were recorded. By October 1999, extended light significantly ($P < 0.05$) increased foliage yield by 69%, 76%, 47%, and 9% for C0, C4, C9, and C23, respectively, compared to yields of those under natural light (Fig. 1). Similar differences were reported at other harvest dates. Plant height was also greatly increased under the extended light treatment for nearly all cycles, at all dates. For example, October 1999 plant heights are shown in Fig. 2. Extended daylength reduced crown area by nearly half that of the plants grown under normal daylength conditions in winter 2000 (Fig. 3). While not as dramatic, similar behavior was observed in 2001. Overall, C9 and C23 appeared to be somewhat less sensitive to daylength, than C0 and C4. Results from that experiment demonstrated a high sensitivity in growth and development of Pensacola-derived bahiagrass to daylength, and implicated photoperiod as a major influence on plant development. The study also identified plants that exhibited a day-neutral (no or little influence from the daily duration of sunlight exposure) response, which should be valuable in cultivar development.

Diploid Breeding

As we develop late season forage types, cold tolerance in the population will allow the forage to withstand cold fronts that often occur in Florida in the late fall, winter, and early spring seasons. The current status of bahiagrass cultivar development is based on recurrent selection for cold tolerance, late-season forage growth, and ample stolon development within the original Pensacola germplasm. Utilizing plants selected from the NFREC-Quincy photoperiod study, and the breeding nursery at Quincy, selections were made in winter 1999 for high levels of cold tolerance and excellent crown and top growth. Vegetative cuttings from these selections were crossed in the greenhouse at NFREC-Quincy and seed from this cycle (FL PCA Cycle 1) was then germinated in the greenhouse at Quincy in late spring. Seedlings were selected for rapid seedling emergence and vigor in the greenhouse, and inferior seedlings were eliminated from the program. Selected seedlings were then planted at the NFREC-Marianna Beef Unit in late summer 1999. Plant selections for fall forage growth and cold tolerance were made in late fall 1999 and winter 1999-2000. Vegetative cuttings from these selections were crossed in early spring in the greenhouse at NFREC- Quincy. The seed (FL PCA Cycle 2) was germinated in the greenhouse and resulting seedlings were transplanted at the Range Cattle Research and Education Center (RCREC) at Ona, FL in summer 2000. After rigorous culling of the selections in March 2001 at RCREC-Ona, vegetative cuttings were taken from superior plants selected for better photoperiod insensitivity, cold tolerance and general appearance. These cuttings were brought back to NFREC-Marianna and were crossed in the greenhouse at NFREC-Marianna in late spring and early summer 2001. Seed (FL PCA Cycle 3) from this cross was tested for rapid seedling emergence and seedling vigor at Tifton, GA. Plants selected from that cycle were planted at the RCREC-Ona in fall 2001. Again, superior plants in the population at the RCREC-Ona were selected in spring 2002. Selected plants were crossed at the NFREC-Marianna in summer 2002 and seed (FL PCA Cycle 4) resulting from that cross was germinated. The resulting seedlings were selected for rapid seedling emergence and seedling vigor at Quincy-NFREC in late Summer 2002. The seedlings or Cycle 4 plants are now presently growing at the RCREC Ona in a spaced-plant nursery and a breeder's seed increase was established at Marianna in 2005. While cultivar development is a long term project, we have accomplished four selection cycles in rapid succession, as a result of an integrated team effort.

FL PCA Cycle 5 is the next cycle of selection that was developed from FL PCA Cycle 4 through an elite polycross of selected genotypes that had deep rooting characteristics along with improved dollar spot resistance, forage yield and improved digestibility. A breeder's seed increase of FL PCA Cycle 5 was established at Marianna in 2006.

One other population of diploid bahiagrass was developed from advanced cycles of selection form Dr. Burton's RRPS breeding program and was designated as FL Hay. This experimental line was designed for sod-based rotation systems where less dense sod would be desirable along with improvements in forage yield and quality, plant persistence and pest resistance. At present we are testing FL Hay in sod systems for short-term rotation with peanuts and cotton.

Preliminary variety trials indicate excellent seedling vigor and early-season forage production on FL PCA 4, FL PCA 5 and FL Hay. Variety trials that include these lines are a multi-location and multi-year efforts. This is necessary to adequately test these experimental diploid lines prior to releasing of a commercial cultivar.

References:

Aamlid, T.S. 1992. Effects of temperature and photoperiod on growth and development of tillers and rhizomes in *Poa pratensis* L. Ann. Bot. 69(4):289-296.

Blount, A.R. 2000. Production in the southern Coastal Plain. Univ. of Fla. Agri. Exp. Sta. EDIS SS-AGR-81.

Blount, A.R. T.R. Sinclair, R.N. Gates, K.H. Quesenberry, P. Mislevy and R. Littell. 2001. Photoperiod response in 'Pensacola' Bahiagrass. p. 487-88. *In*: Proc. International Grassl. Congr. XIX, Sao Paulo, Brazil.

Burton, G.W. 1982. Improved recurrent restricted phenotypic selection increases bahiagrass forage yields. Crop Sci. 22:1058-1061.

Burton, G.W. 1989. Registration of ‘Tifton 9’ Pensacola Bahiagrass. Crop Sci. 29:1326.

Burton, G.W., R.N. Gates, and G.J. Gasho. 1997. Response of Pensacola bahiagrass to rates of nitrogen, phosphorus and potassium fertilizers. Soil Crop Sci. Soc. Florida Proc. 56:31-35.

Damann, M.P., and R.E. Lyons. 1993. Juvenility, flowering, and the effects of a limited inductive photoperiod in *Coreopsis grandiflora* and *C. laneceolata.* J. Amer. Soc. Hort. Sci. 118(4):513-518.

Ellis, R.H., A. Qi, P.Q. Craufurd, R.J. Summerfield, and E.H. Roberts. 1997. Effects of photoperiod, temperature and asynchrony between thermoperiod and photoperiod on development to panicle initiation in sorghum. Ann. Bot. 79(2)169-178.

Gates, R.N., G.M. Hill and G.W. Burton. 1999. Response of selected and unselected bahiagrass populations to defoliation. Agron. J. 91:787-795.

Marousky, F.J., R.C. Ploetz, D.C. Clayton, and C.G. Chambliss. 1991. Flowering response of Pensacola and Tifton 9 bahiagrass grown at different latitudes. Soil and Crop Sci. Soc. Fla. Proc. 50:65-69.

Mislevy, P., and P.H. Everett. 1981. Subtropical grass species response to different irrigation and harvest regimes. Agron. J. 73:601-604.

Sinclair, T.R., J.M. Bennett, and J.D. Ray. 1997. Environmental limitations to potential forage production during winter in Florida. Soil and Crop Sci. Soc. Fla. Proc. 56:58-63.

Sinclair, T.R., P. Mislevy, and J.D. Ray. 2001. Short photoperiod inhibits winter growth of subtropical grasses. Planta 213:488-491.

Wallace, D.H., K.S. Yourstone, P.N. Masaya, and R.W. Zobel. 1993. Photoperiod gene control over partitioning between reproductive and vegetative growth. Theor. Appl. Gen. 86(1):6-16.

Werner, B.K., and G.W. Burton. 1991. Recurrent restricted phenotypic selection for yield alters morphology and yield of Pensacola bahiagrass. Crop Sci. 31(1):48-50.

Fig. 1. Mean foliage yield of bahiagrass cycles grown under natural light (MN) and extended light (ME) treatments on 22 Oct. 1999.

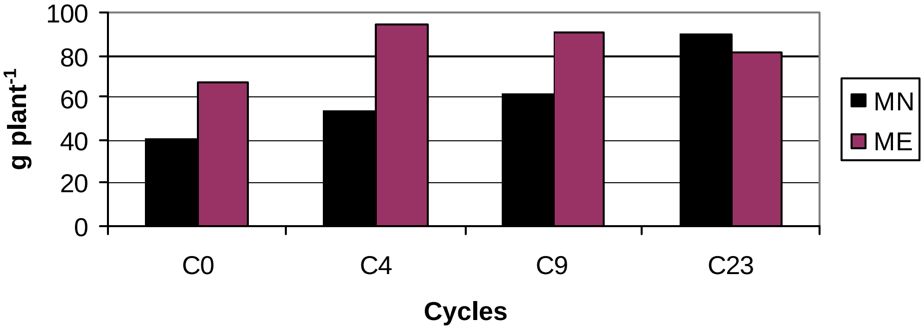


Fig. 2. Mean foliage height of bahiagrass cycles grown under natural light (MN) and extended light (ME) treatments on 20 Oct. 1999.

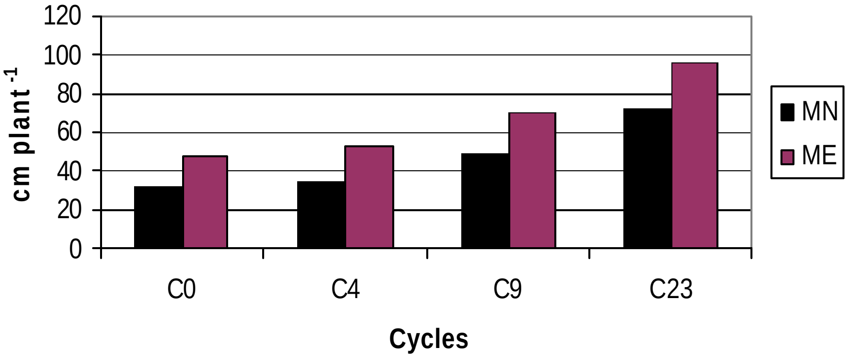
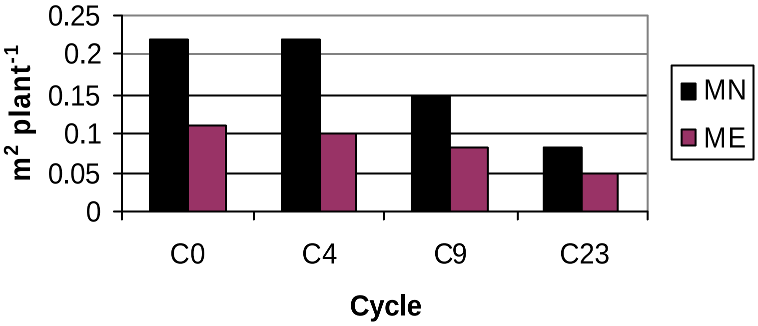


Fig. 3. Mean crown area of bahiagrass plants grown under natural light (MN) and extended light (ME) treatments recorded on 15 Feb. 2000.



RUSLE2 SOIL EROSION CALCULATIONS ON CONSERVATION TILLAGE SYSTEMS

Steve Boetger
USDA-NRCS
2614 NW 43rd St.
Gainesville, FL. 32606
Steve.Boetger@fl.usda.gov

INTRODUCTION

The Revised Universal Soil Loss Equation, Version 2 (RUSLE2) is an upgrade of the text-based RUSLE DOS version 1. It is a computer model containing both empirical and process-based science in a Windows environment that predicts rill and interrill erosion by rainfall and runoff. RUSLE2 was developed primarily to guide conservation planning, inventory erosion rates and estimate sediment delivery. Values computed by RUSLE2 are supported by accepted scientific knowledge and technical judgment, are consistent with sound principles of conservation planning, and result in good conservation plans.

MATERIALS AND METHODS

Using RUSLE2 Version 1.26.6.4, release date November 13, 2006. Climate data from Jackson County, Florida, soil data is the Dothan loamy sand map unit from the Jackson County Soil Survey, slope length was 100 feet and the percent slope was 4 percent. Crops evaluated were peanuts and cotton using three different management scenarios. The managements used for peanuts were: 1. spring disk, residue left 2. strip till into rye cover crop, residue left, and rye is no till 3. no till into rye cover crop, residue left, and rye is no till. Managements for the cotton were: 1. spring disk 2. strip till into rye cover crop, rye is no till 3. no till into rye cover crop, rye is no till. Erosion rates were evaluated on each management. The soil conditioning index, which is a prediction tool that is used to estimate whether applied conservation practices will result in maintained or increased levels of soil organic matter, was evaluated to determine if there was an improving trend with the use of conservation tillage. Another indicator that was evaluated was the soil tillage intensity rating. This indicator is based on the amount of tillage and how that tillage disturbs the soil surface. Fuel usage and cost were evaluated based on all operations using diesel as the fuel type.

RESULTS AND DISCUSSION

Using the RUSLE2 worksheet erosion calculation I evaluated the three managements on peanuts. See Table 1 for the results of these managements on erosion rate, soil conditioning index, soil tillage intensity rating, fuel usage, and fuel cost.

Table 1

Management on Peanuts	Erosion rate(tons/ac/yr)	Soil Conditioning Index	Soil Tillage Intensity Rating	Fuel Usage (gal./ac)	Fuel Cost ($/ac)
Spring disk, residue left	15	-1.4	142	3.9	$9.775
Strip till into no till rye cover crop with residue left	4.9	-0.050	35.7	3.8	$9.456
No till into no till rye cover crop with residue left	4.7	-0.013	30.7	2.3	$5.823

In evaluating the results of the three different managements on peanuts for erosion rate shows that the most erosive is the spring disk. There is a significant decline when strip tillage with a no till rye cover crop is used. The drop in the erosion level is due to more residue being left on the soil surface, because the only soil disturbance is in the strip area. There is a lesser reduction in erosion when using no till instead of strip till. The soil conditioning index shows a negative number in all three managements, which indicates a decreasing trend in soil organic matter. In the strip till and no till managements the negative number is closer to zero than the conventional tillage, which is a better trend. The number is negative due to the drilling of the rye cover crop. The soil tillage intensity rating is worst when the number is large, which indicates a large amount of tillage disturbing the soil surface. This is the case with the spring disk in the first management. The number is much lower for both the strip till and no till managements, since there is a limited area on the soil surface that is being tilled. Fuel usage for the spring disk and strip till managements are quite close in number due to the amount of tillage to be done in preparing the seed bed and planting of the crop. In the no till management there is a significant reduction in fuel use due to the fact of no tillage. The fuel cost mirrors the fuel usage in the three managements with the spring disk and strip till being more than the no till.

Using the RUSLE2 worksheet erosion calculation I evaluated the three managements on cotton. See Table 2 for the results of these managements on erosion rate, soil conditioning index, soil tillage intensity rating, fuel usage, and fuel cost.

Table 2

Management on Cotton	Erosion rate (tons/ac/yr)	Soil Conditioning Index	Soil Tillage Intensity Rating	Fuel Usage (gal./ac)	Fuel Cost ($/ac)
Spring disk	19	-1.8	149	5.2	$12.96
Strip till into no till rye cover crop	3.2	0.18	8.59	4.2	$10.48
No till into no till rye cover crop	1.6	0.34	3.55	2.7	$6.843

In evaluating the results of the three different managements on cotton for erosion rate shows that the most erosive is the spring disk. There is a significant decline when strip tillage with a no till rye cover crop is used. The drop in the erosion rate is due to more residue being left on the soil surface, because the only soil disturbance is in the strip area. There is a continued reduction in erosion (by half the amount) when using no till instead of strip till. The soil conditioning index shows a negative number in the spring disk management, which indicates a decreasing trend in soil organic matter. In the strip till and no till managements the number is positive, which indicates an increasing trend in soil organic matter. The soil tillage intensity rating is worst when the number is large, which indicates a large amount of tillage disturbing the soil surface. This is the case with the spring disk in the first management. The number is tremendously lower for both the strip till and no till practices, since there is a limited area on the soil surface that is being tilled. Fuel usage for the spring disk and strip till practices are not quite as close in number as in the peanut crop above, but still due to the amount of tillage to be done in preparing the seed bed and planting of the crop. In the no till operation there is a significant reduction in fuel use due to the fact of no tillage being done. The fuel cost mirrors the fuel usage in the three managements with the spring disk and strip till being more than the no till.

CONCLUSION

In conclusion, these three managements on peanuts shows that conventional tillage with a disk even with residue left still causes the most soil erosion rate, has the highest negative numbers for the soil conditioning index, the highest soil tillage intensity rating and the most fuel usage and cost when compared to the two conservation tillage managements. In comparing the conservation tillage managements, the strip till in peanuts has a slightly higher erosion rate, a higher and negative number for the soil conditioning index, a higher soil tillage intensity rating, and higher fuel use than the no till management, but the fuel use was slightly lower than the spring disk. In cotton the same conclusion can be drawn as in peanuts with the conventional tillage, but when comparing the two conservation tillage managements it clearly shows the no till management is superior to the strip till. This superiority is shown in half the reduction in soil erosion rate and both managements show a positive soil conditioning index, but the no till is twice as much in number as the strip till. This also relates to fuel usage, which is half the amount of strip till. So, in the big picture if a producer has the equipment or the means to rent or buy the equipment to convert to either strip till or no till, then they can save money in fuel, lower their soil erosion rate, add more organic matter to the soil which improves soil quality and this will increase their yields and their profits.

REFERENCES

RUSLE2 Web-site. 13 July 2004. Revised Universal Soil Loss Equation, Version 2. 17 May 2007. <http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm>

CORN PRODUCTION IN NO-TILL AND CONVENTIONAL TILLAGE WITH POULTRY LITTER: A 5-YR DATA

Dinku M. Endale[1]*, Harry H. Schomberg[1], Michael B. Jenkins[1], Miguel L. Cabrera[2],
[1] USDA-ARS J. Phil Campbell Sr. Natural Resource Cons. Center, Watkinsville, GA 30677
[2] Crop and Soil Sciences Dept., University of Georgia, Athens, GA 30602
*Corresponding author's email Dinku.Endale@ars.usda.gov

INTRODUCTION

Corn production in the Southeast is erratic due to intermittent droughts and hot weather during the growing season. Producers must relay upon irrigation for sustained yield. However, low prices along with costs of irrigation made corn production economically risky. Many producers opted to avoid the risk of financial loss by avoiding corn production thus turning the region into one of corn-deficit. Corn production declined from 1.64 million acres in the 1970s to less than 300,000 acres in 2006 in Georgia, for example, with significant declines occurring in the 1980s (Lee, 2007). The newly emerging potential for large-scale renewable bio-energy production has increased the price of corn dramatically as demand for corn-based ethanol, a well-established bio-fuel, is expected to rise sharply supported by the US legislature (Planet Ark, 2005).

Corn producers in the Southeast have potential to compete for this market share but still need to overcome traditional weather and production limitations. Many soils in the Southeast have low water holding capacity and/or root restrictive layers. Crusting is a problem in soils with low organic matter, which encourages runoff from fields. Conventional tillage methods, such as disking and harrowing, encourage development of these adverse soil conditions. No-till systems reduce runoff and soil loss, and increase infiltration as compared to conventional tillage (Bradley, 1995; Endale et al., 2002; Fawcett et al., 1994; Golabi et al., 1995; Radcliffe et al., 1988). No-till systems increase soil water availability, which can partly offset water stress arising due to frequent summer droughts.

Poultry production is a significant source of income for many row crop and cattle producers. In 2005, 8.9 billion broilers were raised in the U.S. with a value of $20.9 billion (NAAS, 2007). Four southeastern states (AL, AR, GA and NC) produced about 50% of these broilers. In the process, almost 14 million tons (2000 lb units) of poultry litter was produced. Poultry litter can be a valuable resource, which provides a wide range of nutrients and organic matter (Moore et al., 1995). It is often an economical alternative to inorganic fertilizers.

Research is required that would quantify yield differentials arising from different choices of tillage and fertilizer sources to help producers make informed decisions. The objective of this research was to quantify the agronomic benefits of no-till and poultry litter in a corn-rye cropping system in comparison to conventional tillage and conventional fertilizer.

MATERIALS AND METHODS

The research was conducted from 2001 to 2005 at the USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville, GA (83°24' W and 33°54' N) on 12 large (30 x 100 ft) nearly level (<2% slope) plots with drainage tiles. The soil is Cecil sandy loam (fine, kaolinitic thermic Typic Kanhapludult). Cecil and closely related soils occupy over half the area of the Southern Piedmont (Langdale et al., 1992). These soils are deep, well drained and moderately permeable. The pH decreases with depth. The soil at the research site has about 8 inches thick Ap-horizon of brown sandy loam, underlain by 2 to 4 inches thick BA-horizon of red sandy clay loam to clay loam texture (Bruce et al., 1983). This is followed by about 40 inches thick red clay Bt-horizon underlain by about 12 inches thick red loam to clay loam BC-horizon. The C-horizon is a loamy saprolite. Total available water in the top 40 inches of soil is approximately 4 inches, not taking changes due to long-term tillage manipulations into account. Long-term average daily air temperature in summer ranges from 75 to 80 °F at the site. Mean annual rainfall is 48.9 inches. Monthly rainfall distribution varies from 3 inches in October to 5.3 inches in March. The spring rainfall varies 3.7 to 5.3 inches monthly, while that of summer varies 3.8 to 4.8 inches. Short-term summer droughts are frequent in spring and summer with serious consequences on crop yield.

The experiment was laid out as a randomized complete block split plot design with three replications. Conventional tillage (CT) and no-till (NT) were main plots. Fertilizer subplots consisted of ammonium nitrate or sulfate as conventional fertilizer (CF), or poultry litter (PL). The CT consisted of a 12 inches deep chisel plowing followed by one to two diskings to a depth 8 inches and a subsequent disking to 3 inches to smooth the seed bed. The only soil disturbance in NT was a coulter disk for planting. NT treatments have continued on the same plots since the fall of 1991. The combined tillage and fertilizer treatments thus were CT-CF, CT-PL, NT-CF, and NT-PL.

The cropping system consisted of cereal rye (*Secale cereale* L., cv. Hy-Gainer) grown in the late-fall to early spring followed by corn (*Zea Mays*, cv. Pioneer 3223) from mid-spring to mid-fall. Planting and harvest dates consecutively from 2001 were: 05/24 & 10/09; 05/22 & 10/04; 05/29 & 10/22; 04/12 & 09/13; and 05/11 & 10/20. Nitrogen fertilization for corn was at a rate of 150 lbs N acre^{-1} in all but the third year. This meant an application of 5 tons acre^{-1} (30% moisture) for PL. The PL source was from local growers, who usually generate three flocks per cleaning on concrete floors covered with sawdust and shavings. Each flock takes 6-8 weeks to mature. Mineralization of N in PL was assumed to be 50% (Vest et al., 1994) during the corn season. Conventional fertilizer was put out in split applications, one-third a day or two before planting, and two-thirds about 33 days later. The N application rate was doubled to 300 lbs N acre^{-1} in the third year because of interest for detecting potential levels of the hormones estradiol and testosterone coming off the field in runoff or drainage. Amount of these hormones in runoff or drainage had remained at background levels at the application rates of the first two years. The rye cover crop was fertilized with ammonium nitrate at 100 to120 lbs N acre^{-1}. Soil analysis was used to determine P and K needs. All N, P and K fertilizers were applied to the surface of plots one to two days before planting, and incorporated in CT plots only. In addition, a mix of atrazine (1.5 qt acre^{-1}), and dual (1 qt acre^{-1}) was applied before planting and incorporated into soil in CT but not NT plots.

Corn yield was determined by hand harvesting and weighing all whole corn ears from each plot. Twenty to thirty ears were randomly picked from each plot to determine shelled corn weight. The kernel yield was determined in proportion to the whole ear yield of each plot and expressed at 15% moisture equivalent. Statistical analysis was carried out as repeated measures using the MIXED procedure of SAS (Littell et al., 1996; SAS Inst. 1990) with years used as the repeated measure and the experimental blocks used as a random variable. Unless otherwise indicated, all significant differences are given at P = 0.05.

RESULTS AND DISCUSSION

Annual Corn Yield

There were substantial differences in yield between years (Fig. 1; $P < 0.0001$ for year). Mean yield among years ranked in the order 2002<2003<2001<2004<2005 for CT-CF, CT-PL, and NT-PL. The 2001 and 2004 rankings were reversed for NT-CF. The lowest yields in 2002 varied from 1587 lbs acre^{-1} (28.9 bushels acre^{-1}) for CT-PL to 2342 lbs acre^{-1} (42.6 bushels acre^{-1}) for NT-CF. The highest yields in 2005 varied from 8321 lbs acre^{-1} (151.3 bushels acre^{-1}) for NT-CF to 11934 lbs acre^{-1} (217.0 bushels acre^{-1}) for NT-PL. The average yield over five years varied from 5607 lbs acre^{-1} (102 bushels acre^{-1}) for CT-CF to 7366 lbs acre^{-1} (134 bushels acre^{-1}) for NT-PL.

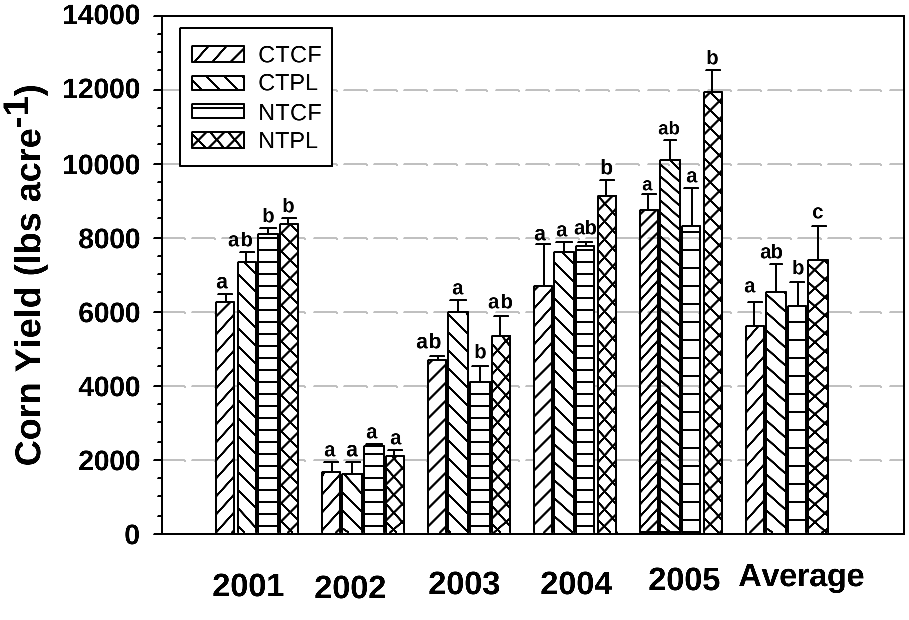


Fig. 1. Corn kernel yield from 2001 to 2005. Within each year, any two treatments sharing similar letters above the error bars are not significantly different from each other at P=0.05.

Several reasons contributed to the yield differential among years, besides treatments, the most prominent of which was variability in precipitation during critical periods (Fig. 2). Conditions for seed germination and early development were particularly unfavorable in 2002 and the plots were irrigated in the amount of 2.2 and 2.6 inches on days 13 and 14, respectively, after planting. The need to induce runoff to monitor hormone levels contributed to the high level of irrigation. Yield was best correlated with total precipitation during weeks 6 to 13 (days 35 to 91 after planting) inclusive. This period closely coincided with the reproductive stages including flowering, pollination, kernel development and grain filling. For the CT the coefficient of determination R^2 was 0.90 with CF and 0.93 with PL. This reduced for NT to 0.61 with CF and 0.77 with PL. Precipitation during this period was 3.9, 9.9, 10.2, 10.3 and 15.5 inches, respectively, in 2002, 2004, 2003, 2001 and 2005. The lowest and highest yields coincided well with the lowest and highest precipitations in all the treatments (Fig. 1). Yield was similar among treatments in 2001 and 2004, which appears to reflect the closeness of the 9.9 and 10.3 inches precipitations of weeks 6 to 13. The yield in 2003 was, however, the second lowest of the five years for about the same precipitation as those of 2001 and 2004. Insect damage was a primary cause of loss of yield in 2003.

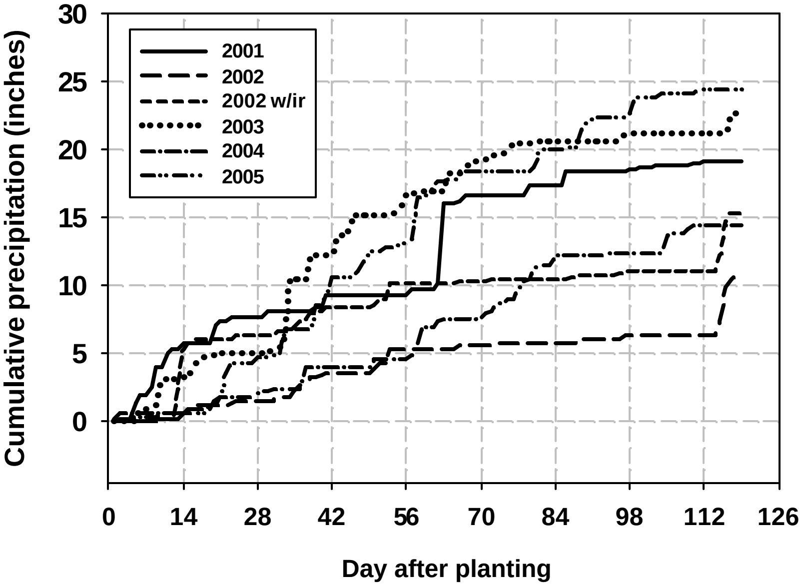


Fig. 2. Cumulative precipitation for the first 120 days during the 2001-2005 corn season

Four of the six NT plots had severe damage to the young shoots in several rows soon after germination, possibly by corn rootworm attack. Replanting became necessary in these rows, which resulted in low yields on these plots. In addition, growth in several NT plots was visibly reduced for a portion of the plot possibly due to insect damage, which resulted in reduced yield. The reasons are not clear, but there was an infestation of corn borer early in 2003 and we sprayed all the plots with Sevin (carbaryl).

In addition to precipitation and insect influences there was likely temperature influences on yield (Fig 3.). In 2002, average weekly maximum temperature was above 90°F and the minimum close to 70°f during the reproductive growth stage. These temperatures were causes of stress in the 2002 corn.

Tillage Effect on Corn Yield

The tillage effect varied from year to year (Fig. 1; P = 0.0319 for tillage; P = 0.0142 for tillage*year; Fig. 1). In CF plots, corn yield with NT significantly exceeded that with CT in 2001 (29%). Yield differences were neither consistent nor significant in the other years. In 2003 NT plots experienced proportionately more insect damage. In PL plots, corn yield with NT significantly exceeded that with CT in 2004 (20.4%). In the other years differences were neither consistent nor significant. Over the five years, average corn yield in NT plots significantly exceeded that in CT plots by 9.2% in plots receiving CF and 13.2% in plots receiving PL. Generally, no-till had greater yield enhancing influence in plots receiving CF in 2001 and 2002 and in plots receiving PL in 2003 to 2005 than corresponding fertilizer treatments.

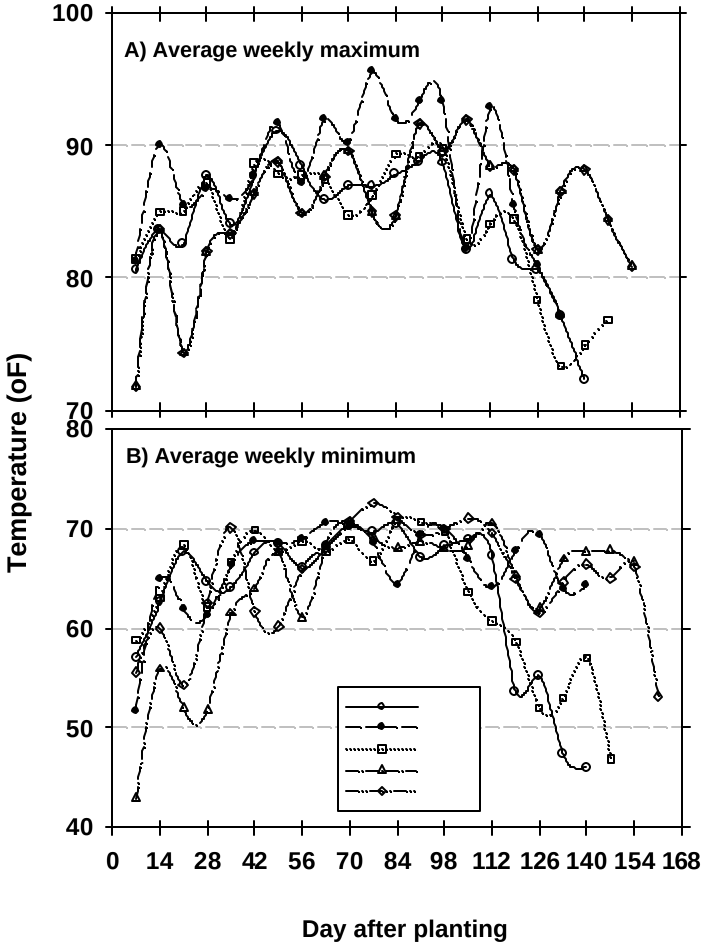


Fig. 3. Average weekly maximum (A) and minimum (B) temperatures during the 2001-2005 corn season

Fertilizer Effect on Corn Yield

The fertilizer effect on corn yield was also variable from year to year (P = 0.0019 for fertilizer; P = 0.0142 for fertilizer*year; Fig. 1). In CT plots those receiving PL had significantly greater yields over 5 years only (16%) despite yearly 15 to 27% differences than those receiving CF. Variability within treatments led to the lack of significance. Results were similar for fertilizer response in NT plots except that differences were significant in 2005 (43%) and over five years (20.3%) (Fig.1). Generally, poultry litter had greater yield enhancing influence in NT than CT plots in 2003-2005.

Combined Tillage and Fertilizer Effect on Corn Yield

The combined no-till and poultry litter treatment effect significantly increased yield by 33 to 36% in 2001, 2004 and 2005, and 31.4% over five years.

CONCLUSIONS

In order for corn growers in the Southeast to maximize benefits from recent increases in corn prices and the bio-fuel based increasing demand, growers need to overcome traditional weather and production related limitations. Together no-till and poultry litter can increase corn production compared to conventional tillage with conventional fertilizer. In conventionally fertilized plots, no-till enhanced yield 9.2% while in plots fertilized with poultry litter it enhanced yield by 13.2% over conventional tillage over five years. Yield pooled across fertilizer treatments was enhanced by 11.4% by no-till. Poultry litter enhanced yield by 16% in conventional tillage plots and by 20.3% in no-till compared to conventional fertilizer over five years. Pooled across the two tillage treatments, poultry litter enhanced yield by 18.2%. No-till and poultry litter combined enhance yield by 31.4% over five years compared to conventionally tilled and fertilized corn. Environmental and management factors can lead to substantial yield variability from year to year across all treatments. Severe water and/or temperature stress and pest pressure can reduce these yield enhancing advantages of no-till and poultry litter. Further research will be needed to determine the threshold of poultry litter application rates that might compromise soil and water quality.

ACKNOWLEDGMENTS

This research was supported in part by a grant from USDA-CSREES NRI and US Egg and Poultry Association. We thank Stephen Norris, Robin Woodroof and other technicians for their expert assistance. We appreciate assistance of Dwight Seman with statistical analysis.

REFERENCES

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

Bruce, R.R., J.H. Dane, V.L. Quisenberry, N.L. Powell, and A.W. Thomas. 1983. Physical characterization of soils in the southern region: Cecil. Southern Coop. Series Bull. No. 267. University of Georgia, Athens, GA.

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

Fawcett, R.S., B.R. Christensen, and D.P. Tierney. 1994. The impact of conservation tillage on pesticide runoff into surface water: A review and analysis. J. Soil and Water Cons. 49(2):126-135.

Golabi, M.H., D.E. Radcliffe, W.L. Hargrove, and E.W.Tollner. 1995. Macropore effects in conventional-till and no-tillage soils. J. Soil and Water Cons. 50 (2):205-210.

Langdale, G.W., L.T. West, R.R. Bruce, W.P. Miller, and A.W. Thomas. 1992. Restoration of eroded soil with conservation tillage. Soil Technology. 5(1): 81-90.

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

Littell, R. C., G.A. Milliken, W.W. Stroup, and W.R. Wolfinger. 1996. SAS Systems for Mixed Models. SAS Inst., Inc. Cary, NC.

Moore Jr., P.A., T.C. Daniel, A.N. Sharpley, and C.W. Wood. 1995. Poultry manure management: Environmentally sound options. J. Soil and Water Cons. 50(3): 321-327.

NASS. 2007. Poultry – Production and Value 2006 Summary. National Agricultural Statistics Service, Agricultural Statistics Board, U.S. Department of Agriculture.

Planet Ark. 2005. World Environment News. FACTBOX – Biofules take off in some countries. http://www.planetark.com/dailynewsstory.cfm/newsid/31182/story.htm Accessed 5-8-2007.

Radcliffe, D.E., E.W. Tollner, W.L. Hargrove, R.L. Clark, and M.H. Golabi. 1988. Effect of tillage practices on infiltration and soil strength of a Typic Hapludult soil after ten years. Soil Sci. Soc. Am. J. 52 (3):798-804.

SAS Institute, Inc. 1990. SAS/STAT User's Guide, Ver. 6. 4th ed. SAS Institute Inc. Cary, NC:

Vest, L., B. Merka, and W.I. Segars. 1994. Poultry waste: Georgia's 50 million dollar forgotten crop. Leaflet 206/July, 1994. Georgia Cooperative Extension Service, College of Agricultural and Environmental Sciences, University of Georgia. Athens, GA. At http://www.ces.uga.edu/pubcd/L206-w.html. Verified 27 Dec. 2003.

Pearl Millet Production Potential with No-till and Conventional Tillage on Cecil Soil in the Southeast

Dinku Endale
USDA-ARS
1420 Experiment Station Rd.
Watkinsville, GA 30677
Phone: (706) 769-5631

Abstract

Importing grains from the Midwest to the Southeast for poultry rations results in a net regional accumulation of phosphorus which potentially threatens environmental quality. Regionally grown grains would help reduce the imbalance of phosphorus importation. Pearl millet is well adapted to the region and produces live weight gains in poultry equal to or superior to those of rations with corn. However, very few of the 2.5 million acres of pearl Millet grown in the USA are in the southeast. In 2006, we evaluated the viability and productivity of 9 pearl millet varieties at Watkinsville, GA on Cecil soil with 2 different tillage treatments, conventional and no-till, and application of inorganic fertilizer. Prior to 2006, fertilization of the research plots was with poultry litter or inorganic fertilizer in a corn-related research. The pearl millet variety evaluation was planted in 14 inch row spacing. An additional test evaluated 7, 14 and 21 inch row spacing for two of the varieties. Yields ranged from 1998 lbs/acre to 4869 lbs/acre. Average yields were higher in the historically poultry litter plots for both conventional and no-tillage treatments. The study will continue in the Summer of 2007.

Tillage and Irrigation Effects on Plant Available Nutrients in Peanut-Based Cropping Systems

W. H. FAIRCLOTH and D. L. ROWLAND; USDA/ARS
National Peanut Research Laboratory
Dawson, GA 39842.

Abstract

Much research has demonstrated the extent to which conservation tillage improves soil characteristics such as increased plant available water, increased carbon, decreased runoff, and increased infiltration to name a few. However, little work has examined the effect of tillage on nutrients in the soil, particularly plant available nutrients in a peanut-based cropping system. Ion exchange resin membranes, specifically Plant Root Simulator® (PRS) probes, (Western Ag Innovations, Saskatchewan, Canada) have been shown to be excellent indicators of the relative differences in plant available nutrients in a wide range of soils and environmental conditions. Four probes, 2 each cation and anion, were buried in the soil within a root exclusion cylinder for a predetermined length of time to measure nutrient flux as available to the crop. This sampling method was utilized in an existing study located near Dawson, GA during 2006. The study investigates the interaction of tillage (conventional, strip, none) with irrigation level (100, 66, 33, 0% of a recommended amount) in a peanut-cotton-corn rotation, with each crop present each year in three replicates. PRS probes were placed in each plot during May (corn), June (corn), and August (cotton) for a 14 d burial. Mixed Models ANOVA indicated a significant ($P=0.05$) main effect of tillage for Ca, K, P, Zn, and S. Irrigation was significant for each burial time for the following plant nutrients: total N, NO_3-N, NH_4-N, Mg, Fe, Mn, Cu, B, Pb, and Al. The interaction of tillage by irrigation was significant for Mn and Zn only. Plant available total N, NO_3-N, NH_4-N were decreased in higher irrigation treatments due to leaching. However, those nutrients such as Ca, K, P, Zn, and S that showed significance due to tillage was due to increased availability in the strip-tillage plots as opposed to either no tillage or conventional tillage.

Conservation Tillage and Perennial Grass-Based Biofuel Crop Production Systems

Tawainga Katsvairo
University of Florida
155 Research Road
Quincy, FL 32351
Phone: (850) 875 7155

Abstract

The world is gripped with looming treats of global warming, rising costs of fossil fuel and a need to reduce dependence of petroleum products from unstable regions. Several crops to include perennial grasses, corn, soybean, canola and peanuts have been proposed as bioenergy crops. Both corn and soybeans are grown in abundance in the US and the excess can be used as biofuel. As biofuel crop, perennial grasses especially switchgrass are advantageous because they produce more ethanol at reduced costs than corn. They require less inputs to grow, and can be grown on marginal lands. Switchgrass has 2/3 of its biomass in the root system and this has numerous advantages such as improved water and nutrient uptake and increasing soil organic matter. Because soybean, corn and peanut are mostly produced under conventional tillage in the southeast, there is concern about the potential increase in the acreage of these crops in response to the lure of biofuel demand. However integrating perennial grasses and CT into biofuel crop production, not only provides the much needed biofuel but does so in a sustainable fashion. For the presentation, we propose a bioenergy crop based cropping system which alleviate the above mentioned production challenges.

YIELD AND ECONOMICS FOR PEANUT UNDER TWO TILLAGE SYSTEMS AND PERRENIAL GRASS VS. CONVENTIONAL ROTATION

[1]Kris Balkcom, [1]Dallas Hartzog, [2]Tawainga Katsvairo* and [2]John L. Smith,
[1]Auburn University, Wiregrass Reg. Res. & Ext. Cntr, PO Box 217 Headland, AL 36345
[2]University of Florida, NFREC. 155 Research Rd, Quincy, FL. 32351
*E-mail: katsvair@ufl.edu

ABSTRACT

Conservation tillage (CT) and rotations which include perennial grasses in peanut production are advocated for the southeast (SE). Field studies were conducted in Headland, Alabama, from 2003 to 2006 to compare crop yields, production costs, revenue and net economic returns in the conventional peanut-cotton-peanut (P-C-P) vs. bahiagrass-bahiagrass-peanut-cotton (B-B-P-C) rotations and two tillage systems, strip-till vs. conventional tillage. Strip tillage and the B-B-P-C rotation increased yield and economic returns in 2 of 4 years at this site. Both strip tillage and the B-B-P-C rotation had reduced disease incidences in all 4 years but this did not always result in greater yield. There is a need for continued research to test the consistence of positive yield and economic returns across years and sites for peanut produced under strip tillage and in rotation with perennial grasses.

INTRODUCTION

The attractiveness of conservation tillage (CT) has lead to its widespread adoption as a management tool in many cropping systems. A phrase extracted from the Farm Press reads “The melodic Oklahoma wind that “comes roaring down the plains” may play well in the theater but it plays pure havoc on seedling peanuts” (Farm Press, 2001). In the same article, CT is proposed as a solution to reduce wind erosion. In the SE the need to conserve soil moisture is a powerful driving force behind the adoption of conservation tillage. The rising cost of fuel can be expected to exert new importance in adoption of CT in the future. Benefits of CT on soil and plant health, micro and macro fauna, disease management and environmental stewardship, are documented (Linden et al., 1994; Magdoff, and van Es., 2000; Katsvairo et al., 2006a).

It has been three decades since CT was first introduced in peanut production, yet it is not as widely adopted (in peanut) as in cotton, the common rotation crop to peanut in the SE (National Crop Residue Management Survey. 2002.). The major challenges to CT adoption has been the effect on crop yield. To this end, a sizeable amount of literature document greater yield for peanut under conservation tillage (Hartzog et al., 1998; Baldwin and Hook, 1998; Marois and Wright, 2003). Yet about the same quantity of articles reports the exact opposite- a dreaded reduction in yield under CT (Jordan et al., 2001; Grichar, 1998; Brandenburg et al., 1998; Cox and Scholar, 1995). Clearly the effect of CT on peanut productivity tends to be regional and even seasonal.

It is often said that history goes in cycles. Recent times have seen renewed interest in adoption of diversified cropping systems such as intercrops, alley cropping, and rotations with perennial grasses. In the early to mid 1900s, extension in Africa discouraged forms of intercropping in favor of clean row cropping. Intercrops were considered unclean and the common phrase “cleanliness is next to Godliness” drove home the case against this form of diversified cropping. To date, numerous articles credit improved soil and plant health, reductions in plant disease, environmental stewardship and preservation of wildlife and visual aesthetics to rotations with perennial grasses in cropping systems, a form of diversified cropping (Toth, 1998; Ball et al. 1996; Kabana et al., 1988; Tsigbey et al., 2004; Katsvairo et al., 2006b; Franzluebbers and Triplett, 2006; Katsvairo et al., 2007a). More importantly, greater yields are reported when peanut is rotated with perennial grasses (Dickson and Hewitt, 1989; Brenneman et al., 2003; Katsvairo et al., 2007b).

Ultimately, economics determines adoption of cropping systems. A study by Kabana et al (1988) reported that rotating peanut with perennial grasses was as effective as using aldicard to control nematodes. Using partial budgets a study in Florida reported greater economic returns for peanut in rotation with bahiagrass (Katsvairo et al., 2007b). Headland, Alabama is in the vital peanut growing region of the US. Approximately 90% of the peanuts in the US are produced within 100 miles from Headland. Our objectives were 1) to compare peanut yield and disease infestation under conventional tillage and conservation tillage, and 2) to determine economic returns of peanut under the two cropping systems.

MATERIALS AND METHODS

A 4-yr tillage x rotation study was initiated in the summer of 2002 on a Dothan sandy loam (fine, loamy siliceous, thermic Plinthic Kandiudults) at the Wiregrass Research Station in Headland, Alabama. The experimental site was in peanut and cotton rotation in prior years. The experimental design was randomized complete block design in a split plot treatment arrangement with 4 replications. Main plots consisted of two tillage systems (strip till and moldboard). Subplots consisted of two crop rotations. Crop rotations included a cotton-cotton-peanut rotation, which is the conventional rotation used by growers in the region, and a bahiagrass-bahiagrass-peanut-cotton rotation. Other cultural management practices including pesticides use and harvesting were conducted using the standard extension recommendations from Auburn University. A two-year old bahiagrass sod was used in the rotations to ensure good ground coverage and vigorous growth of the crop.

Costs, revenue, and net returns for the two crop rotations and tillage systems were determined. Costs were developed for a conventional (turned) enterprise production budget separately for each year. Peanut drying and assessment costs were adjusted in accordance with the yields for each individual treatment and energy costs for each year. All other costs such as seed, fertilizer, transport, and other machinery were considered similar across all treatments.

Revenue was calculated for each treatment and rotation. Revenue was calculated as the product of the yield in kg ha^{-1} and the national loan rate for peanut in \$ kg^{-1} for each year. The national loan rates were \$0.391, \$0.372, \$0.392 and \$0.403 for 2006, 2005, 2004 and 2003 respectively. Net returns were calculated as the difference between revenue and total costs.

Yield data were analyzed using SAS general linear models procedures (SAS Institute, 2002). Revenue and production costs were not analyzed statistically since the goal was to determine profitability. The study started in 2002, so the sod rotation in 2003 would have only followed one year of bahiagrass, however in subsequent years the sod rotation follows two years of bahiagrass. Mean separation for main effects and interactions were obtained by Fisher's protected LSD, as described by Little and Hills (1978). Effects were considered significant in all statistical calculations if $P \leq 0.05$.

RESULTS AND DISCUSSION

Average yields varied between the years (Table 1). The years 2003, 2004 had greater average yields 5614 and 6231 kg ha^{-1}, respectively, while yields in 2005 and 2006 averaged 4968 and 5413 respectively. In 2004, peanut in the bahiagrass rotation averaged 700 kg ha^{-1} greater than peanut in the conventional rotation. There were no differences in yield between the rotations systems and furthermore, moldboard tillage resulted in greater yield than strip tillage. By 2006, four years later in the rotation and tillage study, exact opposite results were observed compared to 2004. The conventional rotation yielded over 1000 kg ha^{-1} greater than the bahiagrass rotation, furthermore, moldboard tillage also yielded over 1000 kg ha^{-1} greater than strip tillage. While most studies have shown greater yields in peanut after bahiagrass, inconsistent in peanut yields after bahiagrass have been reported. An earlier study from the same site (Headland, Alabama) showed erratic yields for peanut in rotation with cotton, corn or bahiagrass (Hagan et al. 2003). While a Floridian study reported greater yields in peanut after bahiagrass in two out of three years (Katsvairo et al., 2007) and Brenneman et al. (2003) reported greater yields in peanut after bahiagrass in 5 out of 7 years. The exact reason for the inconsistency in our results is not clear. It is possible that soil compaction could have build up under strip tillage, adversely affecting peanut growth and harvesting. We observed reduced incidences of disease to include tomato wilt spotted virus for peanut in the bahiagrass rotation, however this did not contribute to improved yield for that rotation.

Table 1. Average of yield for two tillage and rotation systems in Alabama

	Strip Till		Moldboard		
Year	B-B-P-C	P-C-P	B-B-P-C	P-C-P	Average
2,003	5,619	5,260	6,084	5,491	5,614
2,004	6,530	5,775	6,665	5,955	6,231
2,005	4,679	4,721	5,472	5,000	4,968
2,006	4,370	5,253	5,273	6,755	5,413
Average	**5,300**	**5,252**	**5,874**	**5,800**	

†Rotations are as follow: B-B-P-C stands for bahiagrass-bahiagrass-peanut-Cotton;

P-C-P stands for peanut-Cotton-Cotton

The effect of tillage on the other hand, was more pronounced than that on crop rotations. The average yield difference over the 4 year period between conventional and strip tillage was 560 kg ha^{-1}. When averaged across years, the conventional tillage yields were greater than their strip till analog, regardless of rotation.

Peanut in the bahiagrass rotation had reduced disease instances compared to peanut in the conventional rotation (data not shown).

Costs increased steadily over the 4 year study period primarily due to the direct and indirect cost of energy. In this regards strip tillage had an advantage over conventional tillage. Strip tilling lowers energy costs by reducing the number of trips across the field. The unit operations and the variable and fixed costs of each operation are shown in Table 2.

Table 2. Machinery and equipment costs for peanut under two tillage systems in 2006

	Conventional Tillage			**Strip Tillage**		
Unit Operation	Times Over	†VC $/Ha	¶FC $/Ha	Times Over	VC $/Ha	FC $/Ha
Strip Till Rig	x	x	x	1	12.67	22.82
Moldboard Plow	1	18.45	23.59	x	x	x
Light Disk	2	13.78	16.06	x	x	x
Fertilize	1	3.88	10.52	1	3.88	10.52
Plant	1	3.19	4.94	1	3.19	4.94
Spray	7	29.91	49.45	8	34.18	56.51
Dig Invert	1	26.87	30.38	1	26.87	30.38
Combine	1	47.35	128.32	1	47.35	128.32
Totals		143.43	263.26		128.14	253.49

†VC stands for variable costs; ¶FC stands for fixed costs

Strip tillage had a $15.29 $ ha^{-1} equipment cost savings over conventional tillage and an overall $25.06 advantage in total costs savings. However the additional cost of $26 ha^{-1} for the use of a burn down herbicide prior to strip till planting negated the strip till equipment advantage.

As expected, revenue followed a similar pattern to yield, being greatest for rotations and tillage systems with the highest yield (Table 3).

Table 3. Comparison of revenue ($/ha) for two tillage systems and rotations in Alabama.

	Strip Till		Turned	
Year	B-B-P-C	P-C-P	B-B-P-C	P-C-P
2,003	2262	2118	2449	2211
2,004	2,557	2,261	2610	2332

2,005	1740	1755	2034	1859
2,006	1706	2051	2059	2638
Average	2066	2046	2288	2260

†Rotations are as follow: B-B-P-C stands for bahiagrass-bahiagrass-peanut-Cotton; P-C-P stands for peanut-Cotton-Cotton

There was a \$24 ha^{-1} difference in revenue generated between peanuts in the bahiagrass and cotton rotations but this was of no practical importance. However, when comparing tillage systems, conventional tillage averaged \$218 ha^{-1} more in revenue than strip tillage.

Projected returns went from strongly positive in 2003 and 2004 (\$300- \$750/ha) in all treatments, to mixed (\$531 – \$-267/ha) in 2005-6. The difference in net returns was due to a combination of decreased yields, increased costs and changes in peanut prices. Peanut prices for 2005-6 were slightly lower than 2003-4, while costs increased steadily from \$1850 to \$2050 ha^{-1}over the 4 year period (Table 4). Also yields between the years 2005-6 yields were 700 – 800 kg ha^{-1} less than 2003-4 (Table 1).

Table 4. Summary of cost, revenue, and net returns for two tillage and rotations systems in Alabama

Year	Rotation	Tillage	Total Costs \$ ha^{-1}	Yield kg ha^{-1}	Market \$/kg^{-1}	Revenue \$ ha^{-1}	Net Returns \$ ha^{-1}
2006	**B-B-P-C**	StripTill	1,973.83	4370	\$0.391	1,706.49	**-267.35**
2006	**P-C-P**	StripTill	2,022.14	5253	\$0.391	2,051.30	**29.16**
2006	**B-B-P-C**	Moldboard	2,025.69	5273	\$0.391	2,059.11	**33.42**
2006	**P-C-P**	Moldboard	2,106.40	6755	\$0.391	2,637.83	**531.42**
2005	**B-B-P-C**	StripTill	1,914.28	4679	\$0.372	1,739.65	**-174.63**
2005	**P-C-P**	StripTill	1,939.19	4720	\$0.372	1,754.90	**-184.29**
2005	**B-B-P-C**	Moldboard	1,957.26	5472	\$0.372	2,034.49	**77.23**
2005	**P-C-P**	Moldboard	1,932.93	5000	\$0.372	1,859.00	**-73.93**
2004	**B-B-P-C**	StripTill	1856.30	6530	\$0.392	2,557.15	**700.85**
2004	**P-C-P**	StripTill	1823.50	5774	\$0.392	2,261.10	**437.60**
2004	**B-B-P-C**	Moldboard	1862.01	6665	\$0.392	2,610.01	**748.01**
2004	**P-C-P**	Moldboard	1891.37	5955	\$0.392	2,331.98	**440.61**
2003	**B-B-P-C**	StripTill	1,807.11	5619	\$0.403	2,262.21	**455.10**
2003	**P-C-P**	StripTill	1823.50	5260	\$0.403	2,117.68	**294.18**
2003	**B-B-P-C**	Moldboard	1,828.61	6084	\$0.403	2,449.42	**620.81**
2003	**P-C-P**	Moldboard	1,803.80	5491	\$0.403	2,210.68	**406.88**

†Rotations are as follow: B-B-P-C stands for bahiagrass-bahiagrass-peanut-Cotton; P-C-P stands for peanut-Cotton-Peanut

When averaged across years, the rotation effect on net return (B-B-P-C net return – P-C-P net return) was only \$39 ha^{-1}(data not shown). The tillage effect, on the other hand is substantially greater at \$187 ha^{-1}. In Tables 5 and 6 net returns are partitioned by rotation and tillage respectively. Table 5 shows the difference in net returns between conventional and strip tillage for each rotation. The average difference in net return was \$191 ha^{-1} for the B-B-P-C rotation and \$182 ha^{-1} for the P-C-P rotation. This data suggests there is minimal if any economic value in using the bahiagrass rotation over the conventional cotton rotation.

Table 5. Differences in net returns two tillage systems and two rotations.

Results are shown in \$ ha^{-1}

	†B-B-P-C	P-C-P
Year	Moldboard-Strip	Moldboard-Strip
2,003	165.71	112.70
2,004	47.16	3.01
2,005	251.86	110.36
2,006	300.76	502.26
Average	**191.37**	**182.08**

†Rotations are as follow: B-B-P-C stands for bahiagrass-bahiagrass-peanut-cotton; P-C-P stands for peanut-cotton-peanut.

Table 6. Differences in net returns between rotations for the two different tillage systems.

Results are shown in \$ ha^{-1}.

	Moldboard	Strip
Year	BBPC-PCC	BBPC-PCC
2,003	213.93	160.92
2,004	307.40	263.25
2,005	151.16	9.66
2,006	-498.01	-296.50
Average - \$ ha^{-1}	**43.62**	**34.33**

†Rotations are as follow: B-B-P-C stands for bahiagrass-bahiagrass-peanut-Cotton; P-C-P stands for peanut-Cotton-Cotton

Table 6 shows the difference in net returns between the two rotations for each tillage type. The average difference in net return between the bahia and cotton rotations for conventional tillage was \$44 ha^{-1} while for strip tillage it was \$34 ha^{-1} indicating little if any economic effect of tillage on peanut production.

The economic returns from this study are not very favorable to cropping peanut in the sod rotation and under strip tillage. The benefits obtained from sod rotation and strip tillage in the good years were negated in other years. Currently less than 2% of the peanuts produced in Georgia are preceded by bahiagrass. There is a need for continued research to achieve consistence in yield and economic benefits of perennial grass rotation in peanut production systems. Also, considerations for livestock should be included in farm systems studies, which add value and reduces risk from having all of the acreages in cash crops.

CONCLUSIONS

Both strip tillage and growing peanut in rotation with bahiagrass increased yield in two years, but both practices reduced yield in the subsequent two years. Peanut in the bahiagrass rotation had reduced incidences of TSW in all years. There is a need to continue research to test the feasibility of growing peanut in rotation with perennial grasses and under reduced tillage under different climatic conditions and also over an extended time period. Strip tillage appeared to reduce equipment operating and fixed cost slightly but the savings were more than offset by an increase in herbicide cost. The type of rotation used overall did not seem to affect yield, revenue or return. Under these circumstances, tillage seemed to be the most important factor in the study, with conventional tillage yielding overall superior than strip tillage both in terms of yield, revenue and net return at this location.

REFERENCES

Ball, D.M., C.S. Hoveland, and G.D. Lacefield. 1996. Southern forages. Potash & Phosphate Inst. and the Foundation for Agron.

Baldwin, J.A., and J. Hook. 1998. Reduced tillage systems for peanut production in Georgia. Proc. Am. Peanut Res. Educ. Soc. 30:48.

Brandenburg, R.L., D.A. Herbert, Jr., G.A. Sullivan, G.C. Naderman, and S.F. Wright. 1998. The impact of tillage practices on thrips injury of peanut in North Carolina and Virginia. Peanut Sci. 25:27–31.

Brenneman, T.B., T. Timper, N.A. Minton, and A.W. Johnson. 2003. Comparison of bahiagrass, corn, and cotton as rotational crops for peanut. p. 59–65. *In* Proc. of Sod-Based Cropping Systems Conf., Quincy, FL. 20–21 Feb. 2003.

Dickson, D. W. and Hewlett, T. E. 1989. Effect of bahiagrass and nematocides on *Meloidogyne arenaria* on peanut. J Nematology 21: No 4S-671-676.

Franzluebbers, A.J. and G.B. Triplet. 2006. Integrated crop-livestock systems to conserve water resources in the southeastern USA. *In* Southern Conservation Systems Conference Proceedings. Amarillo, TX. June 26 - 28.

Grichar, W.J. 1998. Long-term effects of three tillage systems on peanut grade, yield, and stem rot development. Peanut Sci. 25:59–62.

Hagan, A.K., L.H. Campbell, J.R Weeks, M.E. Rivas-Davila, and B. Gamble. 2003. Impact of the cropping frequency of bahiagrass, cotton, and corn on the severity of diseases of peanut and on yield. p. 46-58. *In* Proc. of Sod-Based Cropping Systems Conf., Quincy, FL. 20–21 Feb. 2003

Hartzog, D.L., J.F. Adams, and B. Gamble. 1998. Alternative tillage systems for peanut. Proc. Am. Peanut Res. Educ. Soc. 30:49.

Jordan, D.L., J.S. Barnes, C.R. Bogle, G.C. Naderman, G.T. Roberson, and P.D. Johnson. 2001. Peanut response to tillage and fertilization. Agron. J. 93:1125–1130

Kabana, R.R, C.F. Weaver, D.G. Robertson, H. Ivey. 1988. Bahiagrass for management of Meloidogyne arenaria in peanut. Ann. Appl. Nematol (J. Nematol 20 Supplement) 2:110-114.

Katsvairo, T.W., D.L. Wright, J.J. Marois, D.L. Hartzog, J.R. Rich and P.J. Wiatrak. 2006a. Sod/livestock integration in the peanut/cotton rotation: A systems farming approach. Agron. J. 98: 1156-1171.

Katsvairo, T.W., J.R. Rich and R.A. Dunn. 2006a. Perennial grass rotations: an effective and challenging tactic for nematode management with many other positive effects. Pest Management Sci. 62: 793-796.

Katsvairo, T.W., D.L. Wright, J.J. Marois, D.L. Hartzog, K.B. Balkcom, P. J. Wiatrak and J.R. Rich. 2007a. Cotton roots, earthworms and infiltration characteristics in peanut/cotton cropping systems. Agron. J. 99: 390-398.

Katsvairo, T.W., D.L. Wright, J.J. Marois, D.L. Hartzog, K.B. Balkcom, P. J. Wiatrak and J.R. Rich. 2007b. Peanut, cotton and bahiagrass yields in sod-based cropping systems (Agron. J. Vol. 99: September–October).

Katsvairo, T.W. D.L. Wright, J.J. Marois, D.L. Hartzog, K.B. Balkcom, J.L. Smith, J.R. Rich and P.J. Wiatrak. 2007c. Economics of peanuts in sod-based peanut production systems (In press, Agron. J. Vol. 99).

Marois, J.J., and D.L. Wright. 2003. Effect of tillage system, phorate, and cultivar on tomato spotted wilt of peanut. Agron. J. 95:386–389.

Magdoff, F.R., and H.M. van Es. 2000. Building soils for better crops. Handb. Ser. Book 4. Sustainable Agriculture Network.

National Crop Residue Management Survey. 2002. Conservation of agriculture's future. Available at www.ctic.purdue.edu/Core4/CT/ctsurvey/2002/RegionalSynopses.html

Rodríguez-Kábana, R., Weaver, C. F., Robertson, D. G., and Ivey, H. 1988. Bahiagrass for the management of *Meloidogyne arenaria* in peanut. Annals of Applied Nematology 2:110-114.

Toth, S.J., Jr. 1998. Peanut pesticide use survey in North Carolina. Data report to the USDA NAPIAP. North Carolina Coop. Ext. Serv., Raleigh, NC.

Tsigbey, F.K., J.J. Marois, D.L. Wright, T.W. Katsvairo and P. J. Wiatrak. 2004. Impact of bahiagrass rotation on diseases of peanuts. *In* International annual meetings abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

ROLLER TYPE AND OPERATING SPEED EFFECTS ON RYE KILL RATES, SOIL MOISTURE AND IRRIGATED SWEET CORN YIELD IN AN ALABAMA NO-TILL SYSTEM

Ted S. Kornecki, Andrew J. Price, Randy L. Raper, Francisco J. Arriaga and Quentin M. Stoll
USDA-ARS, National Soil Dynamics Lab., 411 S. Donahue Dr., Auburn, AL 36832
Corresponding author e-mail address: tkornecki@ars.usda.gov

A field experiment was conducted in Cullman, Alabama to evaluate the effects of three different rollers/crimpers on terminating a rye (*Secale cereale* L) cover crop, soil moisture, and sweet corn yield in a no-till system. Three roller types were tested: a straight bar roller, a smooth roller with crimper, and a two-stage roller at speeds of 2 and 4 MPH. Termination rates provided by the three rollers/crimpers were compared to a smooth drum roller (no crimping bar) plus glyphosate (Roundup^{TM} WeatherMax)** applied at 1 lb/acre. Initial data indicates that three weeks after rolling 100% termination was attained by the smooth roller and glyphosate. A termination of 68% was attained following the smooth roller with crimper at 4 MPH; however, no significant differences were found between the straight bar roller at both speeds, the smooth roller with crimper and the two-stage roller at 4 MPH (67%). Roller type did not affect soil moisture after the first and second week from rolling. No significant difference in sweet corn yield was found between straight bar roller at 4 MPH, two-stage roller at 2 MPH, and smooth roller plus glyphosate. The lowest yield was found with smooth drum roller plus glyphosate. The highest yield (15,348 lbs/ac or 6.85 tonnes/ac) was recorded following the smooth roller with crimper at 4 MPH.

INTRODUCTION

Cover crops are an integral element in no-till conservation systems because they provide important benefits to soils and plants. Covers must produce maximum biomass to maximize these benefits (Brady and Weil, 1999). A commonly used cover crop in the southern United States is rye, which can produce 3000 to 10000 lbs/ac (Bowen et al., 2000). Primary benefits include soil protection from impact of rainfall energy leading to reduced soil erosion and surface runoff, decreased soil compaction and increased infiltration (Kern and Johnson, 1993; McGregor and Mutchler, 1992; Reeves, 1994; Raper et al., 2000a; Raper et al., 2000b). Cover crops also provide a physical barrier on the soil surface which inhibits weed emergence and growth. In addition to providing a physical barrier, rye has alleopathic properties that provide weed control similar to applying a pre-emergence herbicide (Barnes and Putman, 1986; Hoffman et al., 1996). Additional benefits are associated with improving soil physical/chemical properties due to increasing soil organic carbon level, resulting in better crop growth.

Rolling/crimping technology has been used to manage mature cover crops by flattening and crimping cover crops such as rye in no-till conservation systems. Crimping cover crop tissue causes plant injury and accelerates its termination rate. In southern U.S. conservation systems, cover crops should be terminated three weeks prior to planting the cash crop which is similar to standard burndown recommendations. Typically, three weeks after rolling, the termination rate for rye is above 95% when rolling is performed at an optimal growth stage from early milk to soft dough (Ashford and Reeves, 2003; Kornecki et al., 2006). Most agricultural extension services recommend terminating the cover crop at least two weeks prior to planting the cash crop to prevent the cover crop from competing for valuable spring soil moisture that could be used by the main cash crop after planting. According to Hargrove and Frye (1987) a minimum time from rolling/crimping should be at least 14 days before planting of cash crop to enable soil water recharge prior to planting. A study conducted by Ashford and Reeves (2003) showed that anthesis growth stage produced 80% termination three weeks after mechanical rolling/crimping of rye.

Optimum residue conditions for planting a cash crop are usually attained 3 weeks after termination, at which time the residue is dry, crisp, brittle, and easy to penetrate with equipment. To speed up the cover crop termination process, herbicide application has been implemented along with rolling in conservation systems in the southeastern U.S. both for field and vegetable crops. However, herbicide use is not allowed in organic vegetable production; thus, cover crop management must be done mechanically by cutting/incorporating or rolling/crimping technology. Different roller designs have been developed to roll and crimp cover crops; however, none have been evaluated in vegetable production systems. The objectives of this study were to determine the effectiveness of different roller designs and two different speeds on mechanical termination of a rye cover crop and the effects on soil volumetric moisture content and sweet corn yield.

METHODS AND MATERIALS

The experiment was conducted at the North Alabama Horticultural Research Center in Cullman, Alabama on a Hartsells fine sandy loam soil (Fine –loamy, siliceous, subactive, thermic Typic Paleudults). Rye as a winter cover crop was planted on October 16, 2005. All treatments were applied in mid-April 2006, when rye was in anthesis growth stage. Termination of rye at the anthesis growth stage was chosen because sweet corn must be planted early in the spring to produce an optimum yield. Treatment arrangement is shown in Fig. 1. A randomized block design (RBD) was utilized with four replications. Each plot was 50 ft long and 18 ft wide. Roller operating speed was set to 2 and 4 MPH.

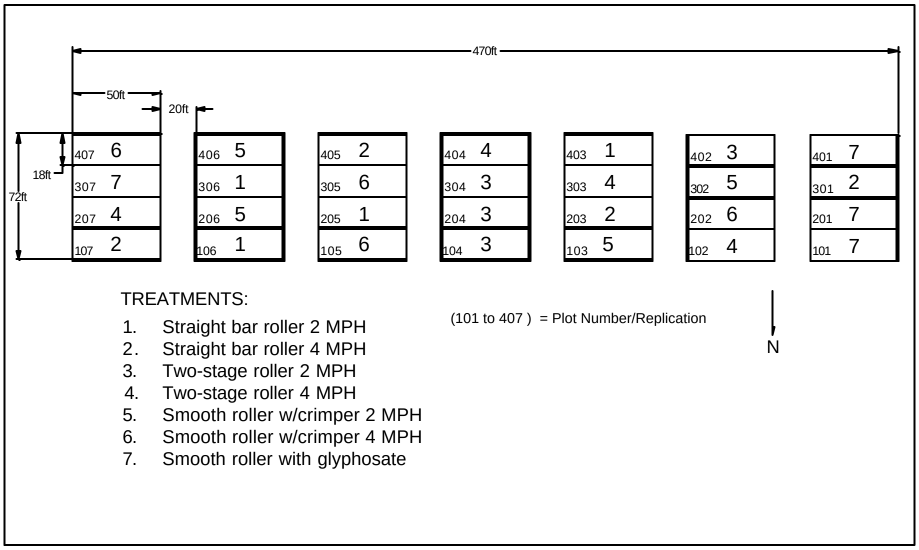


Figure 1. A randomized block design (RBD) experimental layout with four replications.

Three different roller designs having a width of 6 ft were compared: 1. Straight–bar roller, a design based on the original technology from Brazil (Fig. 2); 2. Smooth roller with crimping bar developed at the National Soil Dynamics Lab (NSDL) (Fig. 3); and 3. Two-stage roller also developed at the NSDL, Auburn, AL (Fig. 4). Two operating speeds were chosen: 2 and 4 MPH. Comparison was made with a smooth drum roller with no-crimper attached plus glyphosate applied at 1 lb/acre as a control.

Figure 2. Original straight-bar roller.

Figure 3. Smooth roller with crimping bar.

Figure 4. Two-stage roller comprised of a smooth drum and spring loaded crimping bar drum.

Rye mortality, based on visual observation, was estimated on a scale of 0% (no injury symptoms) to 100% (complete death of all plants) (Frans et al., 1986) and was evaluated at one, two, and three weeks after rolling treatments. Volumetric soil moisture content was measured at the time of rolling treatment and at one and two weeks after treatment using a portable TDR300 meter (Spectrum Technologies, Inc.; Plainfield, Il)** with 4.8 inch stainless steel rods. On April 23, 2006, the day before rolling/crimping of rye, plant biomass and heights were collected. Treatment means were separated by the Fisher's protected least significant difference test at the 0.10 probability level using ANOVA Analyst's linear model in SAS 9.1 (SAS Institute Inc., Cary, NC).

RESULTS

RYE TERMINATION

An average height for rye was 67 in and average dry biomass was 7,656 lbs/acre. Figure 5 shows rye termination at one, two, and three weeks after treatment. At one week after rolling significantly higher termination rate (98%) was obtained for the smooth roller without crimper and glyphosate application compared to other treatments. The second highest termination rate of 33% was found with two-stage roller at both operating speeds; however, there were no significant differences between these treatments and straight bar roller at both speeds and smooth roller/crimper at 4 MPH. Significantly lower termination rates (27%) were recorded for the smooth roller/crimper at 2 MPH.

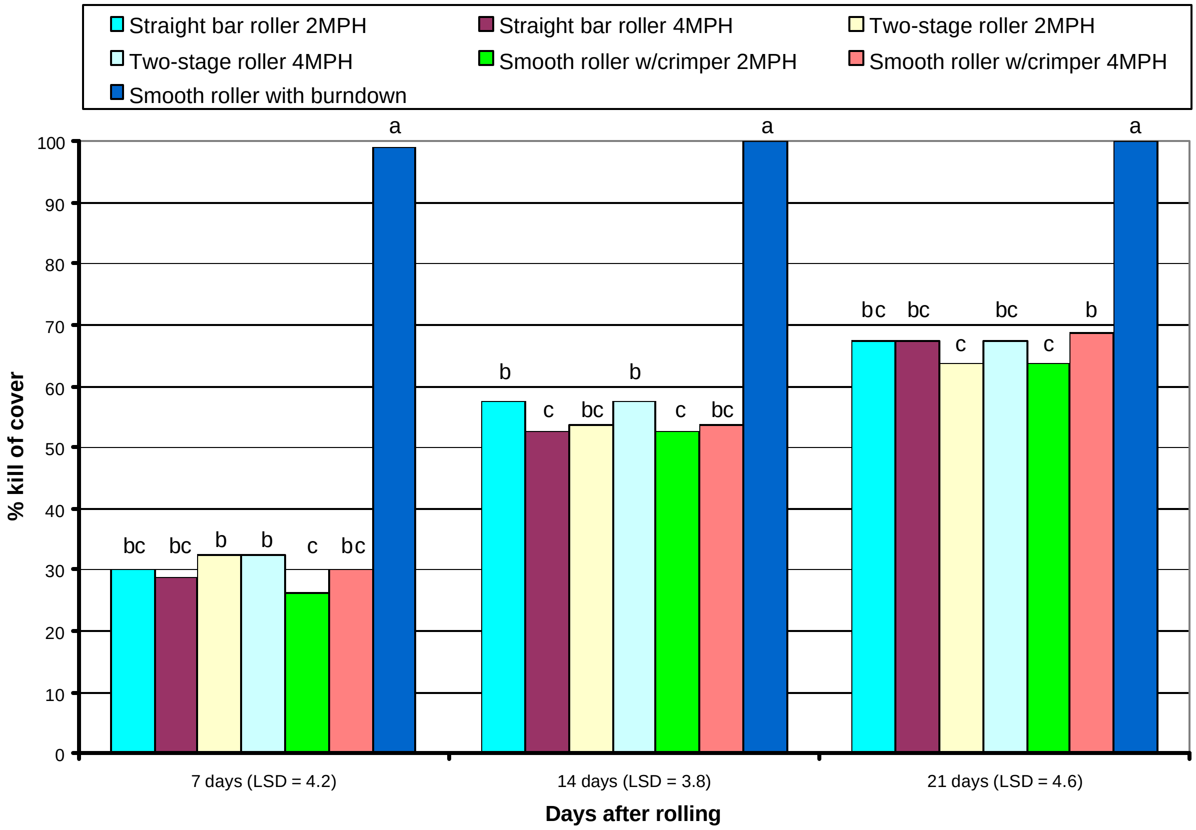


Figure 5. Termination rates of rye for different rolling treatments at one, two, and three weeks after rolling.

Two weeks after rolling treatment, smooth roller drum plus glyphosate produced 100% termination. Significantly lower termination rates (from 53% to 57%, LSD= 3.8) were produced by all other rollers; however, no differences were found between straight bar roller, at 2 MPH, two-stage roller at both speeds and the smooth roller w/crimper at 4 MPH. The lowest termination rate was found with the straight bar roller at 4 MPH, and the smooth roller w/crimper at 2 MPH. Three weeks after treatment, termination rates following rolling/crimping without herbicide application were between 63% and 68% for all rollers and speeds. This level of termination was not sufficient to plant sweet corn at the third week after rolling. Ashford and Reeves (2003) indicated that a termination rate for rye above 90% was acceptable for planting a cash crop into the rolled/crimped rye residue cover. The lower termination rate of rye in this study might be associated with termination too early in the anthesis growth stage which may have allowed rye to recover. Also, uneven soil surface (i.e. depressions from previous raised beds) and possibly lower soil strength resulting from higher volumetric soil moisture content that averaged about 15% at rolling treatment could reduce crimping effectiveness. Nelson et al., (1995) stated that later growth stage such as a soft dough stage for rye might be ideal for mechanical termination. To avoid late planting of sweet corn, an alternative treatment may be needed to fully terminate rye, in addition to mechanical termination using rollers.

SOIL MOISTURE

Soil moisture was measured on the day of roller treatment and, one and two weeks after. Rolling treatment effects on soil moisture are shown in Fig. 6. At time of treatment application, volumetric soil moisture content for all rolled rye treatments varied from 14.0 to 16.0%. These differences might be associated with variations in water holding capacity as influenced by differing soil physical properties within the plot area. Significantly higher soil moisture was recorded for plots treated with the smooth roller/crimper at 2 MPH compared to the straight bar roller at 4 MPH and the smooth roller plus glyphosate. One week after rolling, similar trends in soil moisture content were recorded for all treatments except for the smooth drum roller with glyphosate where volumetric moisture content increased more rapidly (over 5%) compared to other treatments and to the day of treatments application. This can be explained by faster termination of cover crop due to glyphosate treatment, thus conserving more moisture in the soil. Rainfall events totaling 3 in. of depth (May 04-07, 2006), occurring between the first and second week after treatment application, raised volumetric moisture content above 30%, approaching field capacity, and no significant differences in soil moisture were found between all treatments. This rainfall required a waiting period for soil to dry and for the moisture to return to optimum conditions prior to planting sweet corn.

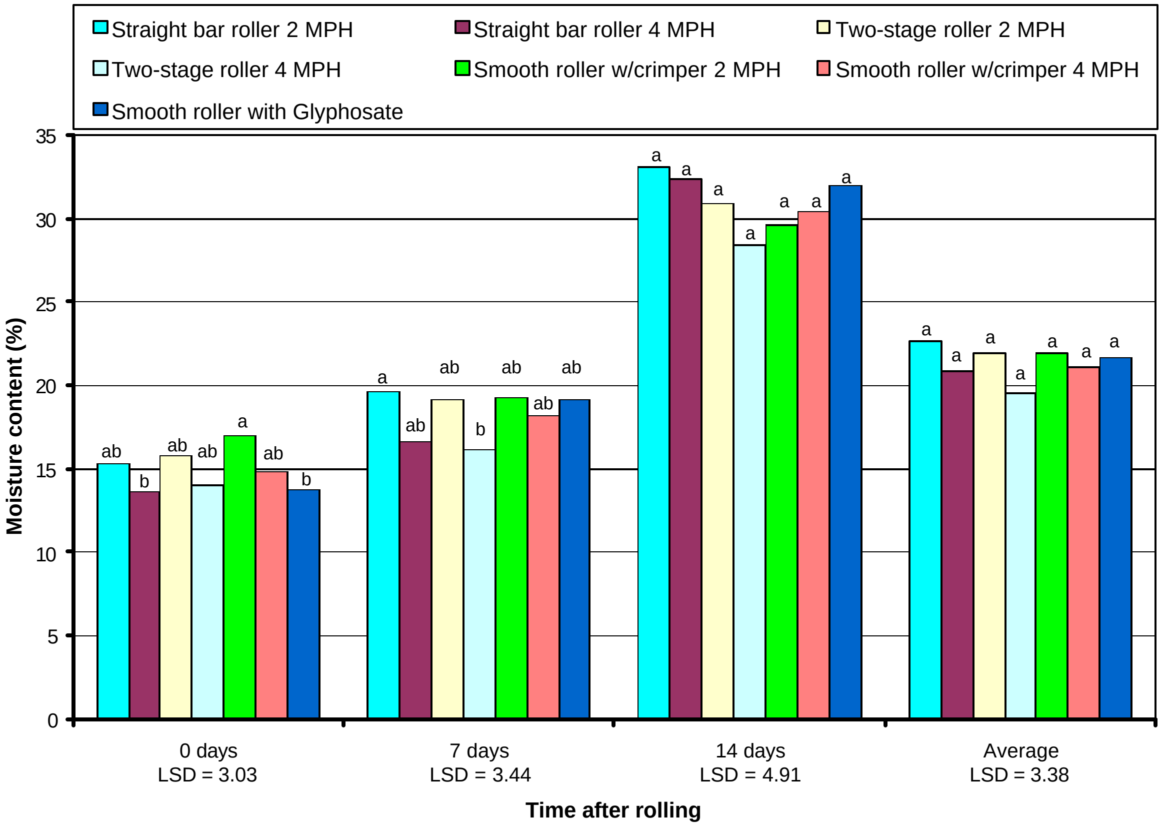


Figure 6. Soil volumetric moisture content at rolling, and one and two weeks after rolling.

SWEET CORN YIELD

No significant differences in sweet corn yield were found between operating speed and roller types. However, operating speed had an effect in increasing yield especially for the two-stage roller where sweet corn yield was 1,800 lbs/ac higher at 4 MPH (Fig. 7). Smaller differences in yield were recorded for the straight bar roller and the smooth roller with crimper. Unexpectedly higher sweet corn yields were found for all rollers and speeds compared to the control treatment of a smooth roller drum with glyphosate application. Significantly lower yield was recorded for the smooth roller drum plus glyphosate application compared to the straight bar roller at 2 MPH, two-stage roller at 4 MPH and smooth roller/crimper at both speeds. Sweet corn yield recorded for the smooth drum roller and glyphosate was 4,000 lbs/ac lower when compared with the highest yield of 15,348 lbs/ac (6.85 tonnes/ac) following the smooth roller/crimper at 4 MPH. It is not clear why flattening and glyphosate treatment resulted in lower yield whereas mechanical rolling did not. One might speculate that perhaps glyphosate inhibited emergence of corn. There is no data suggesting Roundup's negative effects on emergence; however, it has been observed that in vegetable production under plastic, application of a herbicide to treat weeds before plastic installation inhibited vegetable growth, especially in dry years. Lower sweet corn yield from weed competition must be ruled out because all treatments received the same post emergence herbicide application to control weeds. Another explanation for the significantly lower yield reported for the smooth roller drum and glyphosate could be due to possible differences in soil properties within the field leading to different amounts of plant available water during the drought period which occurred in the 2006 growing season.

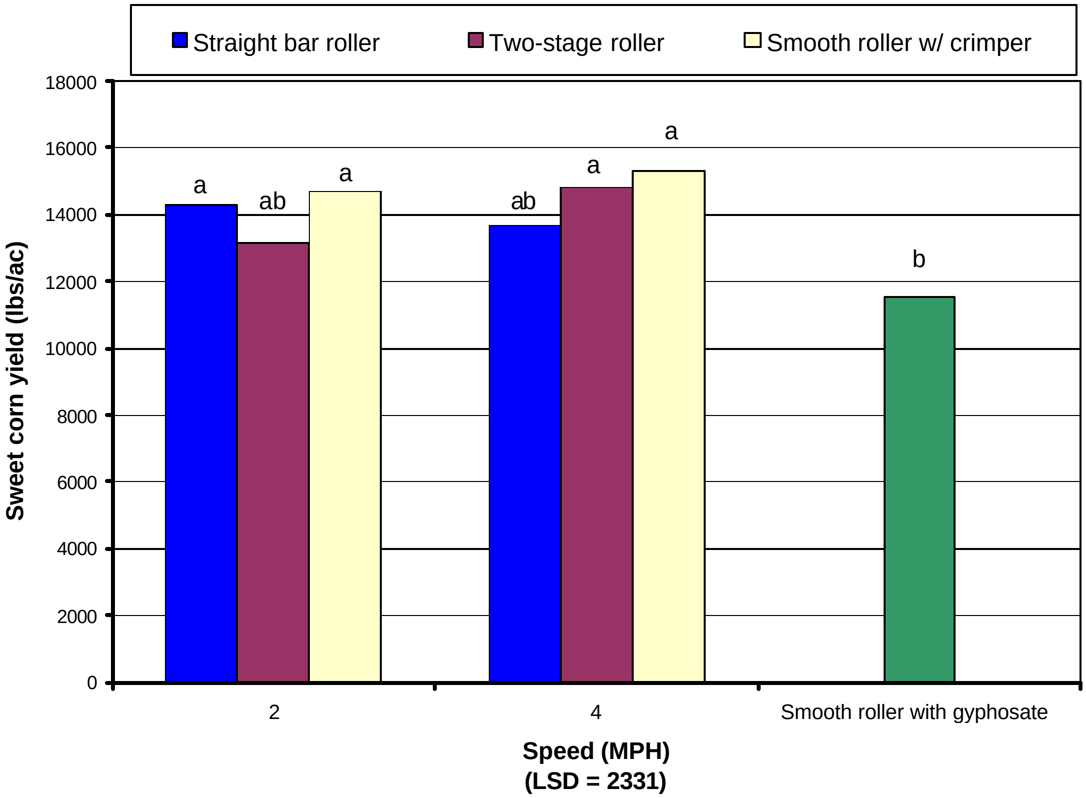


Figure 7. Roller type effect on sweet corn yield.

CONCLUSION

Three different roller designs operated at 2 and 4 MPH were compared to determine roller type and speed effects on rye cover termination, soil volumetric moisture content and sweet corn yield. A smooth drum roller with glyphosate application was used as a control. Based on the results from one growing season (2005-2006) the smooth drum with glyphosate application produced the highest rye termination rates of 98%, 100%, 100% compared to other treatments (30%, 58% and 68%, one, two and three weeks after treatment application, respectively). Lower mechanical termination was most likely caused by anthesis growth stage at time of rolling/crimping. Roller type and operating speed did not affect soil moisture after the first and second week from rolling. Despite lower termination by rollers, sweet corn yield was not affected. These preliminary results suggest that terminating a rye cover crop using rollers/crimpers may not be suitable in no-till organic sweet corn production. However, the use of rollers/crimpers can still be beneficial in no-till vegetable production where chemicals may be used or where the rolling/crimping operation may be performed at the optimum (early milk/soft dough) stage of cover crop growth.

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

REFERENCES

Ashford, D. L., and D. W. Reeves. 2003. Use of a mechanical roller crimper as an alternative termination method for cover crop. American Journal of Alternative Agriculture 18(1): 37-45.

Barnes, J. P., and A. L. Putman. 1986. Evidence for alleopathy by residues and aqueous extracts of rye (Secale cereale). Weed Science 34(3): 384-390.

Bowen, G, C. Shirley, and C. Cramer. 2000. Managing Cover Crops Profitably. Sustainable Agriculture Network Handbook Series, Book 3, National Agricultural Library, Second Edition, Beltsville, MD, pp 212.

Brady, N.C., and R.R. Weil. 1999. The Nature and Properties of Soils. Prentice-Hall, Inc. Twelfth edition. Upper Saddle River, NJ, pp. 881.

Frans, R., R. Talbert, D. Marx, and H. Crowley. 1986. Experimental design and techniques for measuring and analyzing plant response to weed control practices. Pages 37-38 in N. D. Camper (ed.), Research Methods in Weed Science 3rd Ed., Southern Weed Sci. Soc., Champaign, IL.

Hargrove, W.L., and W.W. Frye. 1987. The need for legume cover crops in conservation tillage production. p.1-5. In J.F. Power (ed.) The role of legumes in conservation tillage systems. Soil Conserv. Soc. of Am., Ankeny, IA.

Hoffman, L. M., L. A. Weston, J. C. Snyder, and E. E. Reginer. 1996. Alleopatic influence of germinating seeds and seedlings of cover crops and weed species. Weed Science 44(3): 579-584.

Kern, J.S. and M.G. Johnson. 1993. Conservation tillage impacts on national soils and atmospheric carbon levels. Soil Sci. Soc. Am. J. 57: 200-210.Anderson, G. T., C. V.

Kornecki, T. S., A. J. Price, and R. L. Raper. 2006. Performance of Different Roller Designs In Terminating Rye Cover Crop and Reducing Vibration. Applied Eng. Agric. 22(5): 633-641.

McGregor, K.C. and C.K. Mutchler. 1992. Soil loss from conservation tillage for sorghum. Trans. ASAE 35(6):1841-1845.

Nelson, J. E., K. D. Kephart, A. Bauer, and J. F. Connor. 1995. Growth stage of wheat, barley, and wild oat. University of Missouri Extension Service, 1-20.

Raper, R.L., D.W. Reeves, C.H. Burmester, and E.B. Schwab. 2000a. Tillage depth, tillage timing, and cover crop effects on cotton yield, soil strength, and tillage energy requirements. Applied Eng. Agric. 16(4): 379-385.

Raper, R.L., D.W. Reeves, E.B. Schwab, and C.H. Burmester. 2000b. Reducing soil compaction of Tennessee Valley soils in conservation tillage systems. J. Cotton Sci. 4(2): 84-90.

Reeves, D. W. 1994. Cover crops and rotations. In Advances in Soil Science: Crops Residue Management, eds. J. L. Hatfield and B. A. Stewart. Boca Raton, Fla.: Lewis Publishers.

Sorghum and Soybean Rotation Influence on Cotton Yields as Affected by Tillage and Nitrogen Fertilization

John E. Matocha and James Wilborn, Texas Agricultural Experiment Station, Corpus Christi
Texas A&M University System

Introduction

Interest and use of conservation tillage (reduced till) has increased in the South and Southwest. Factors influencing this change include economics and conservation of soil and moisture. Reduced tillage allows more crop residue to remain on the surface, thereby reducing evaporative losses and, in some cases, increasing crop yield (1).

Crop rotations can be instrumental in improving weed control, nutrient utilization and crop yields (2,3). Cropping systems which utilize biological nitrogen (N) fixation are important in maximizing fertilizer N use efficiency (5). Previous research from our region evaluating crop rotations including legumes under conservation tillage is limiting. The objectives of our research were: 1) develop crop rotation/tillage systems and fertility levels for profitable production of major crops, grain sorghum and cotton, and 2) investigate the contribution of a legume to the N fertility need of cotton grown under minimum till (MT) and conventional tillage (CVT) systems.

Materials and Methods

This experiment was conducted at the Texas A&M University Agricultural Research & Extension Center at Corpus Christi for four years. Grain sorghum (*Sorghum bicolor,* (L.) Moench, variety DK 37) and cotton (*Gossypium hirsutum,* variety CAB-CS) and soybean (*Glycine max,* variety NK 452) were grown on a Victoria clay soil (*Udic Pellusterts*). Seeding rates were 85,000, 55,000 and 96,000 seed/acre for grain sorghum, cotton, and soybean, respectively. Three fertilizer N rates were used in each cropping and tillage system. The three N levels were no fertilization, 0-0-0, 0.5X rate (30-20-0 lb/acre^{-1}) and the 1.0X recommended soil test rate (60-20-0 lb/acre) for the sorg:cotton system. For the soybean:cotton cropping system, N rates were one half of those for the sorghum:cotton. All fertilizer was preplant banded in a 4 x 4 inch placement. The experiment was conducted in a randomized block design and replicated four times. Crop rotation systems were compared as main plots. Reduced tillage (total 5 tillage operations) was compared with CVT tillage (10 tillage operations) in a split-plot design. Fertilizer rates were evaluated in a split-split plot design.

Results and Discussion

Yields for the first year were drastically reduced due to drought and are not presented. In the second year, with rainfall well distributed during the growing season above average lint yields for the region were measured. Significant differences in lint yield among rotation systems were measured only in the CT systems and at the medium N rate (Fig. 1). Cotton following sorghum responded to the 30 and 60 lb N/acre when grown with CVT tillage with yields of 961 and 999 lb lint/acre respectively. In the soybean:cotton rotation, yield response peaked at the medium N rate (15 lb N/acre) and decreased with additional N when cotton was grown in the CVT system.

In this system, lint yields peaked at 1040 lb/acre which was 80 lb/acre additional yield over the sorghum:cotton system. A substantial yield increase (205 lb lint/acre) from 15 lb N/acre was measured in the legume rotation with CVT tillage but much lesser response was observed in the MT system. In general, cotton grown with MT following soybean showed only a slight response to N. In contrast, a near curvilinear relationship between lint yields and N fertilizer rate was apparent in the sorghum:cotton rotation in both tillage systems. Yield data averaged over N rates and crop rotations, show that cotton grown under MT was as productive (933 lb/acre) as that produced in the CVT system (940 lb/acre) during this second year of the study.

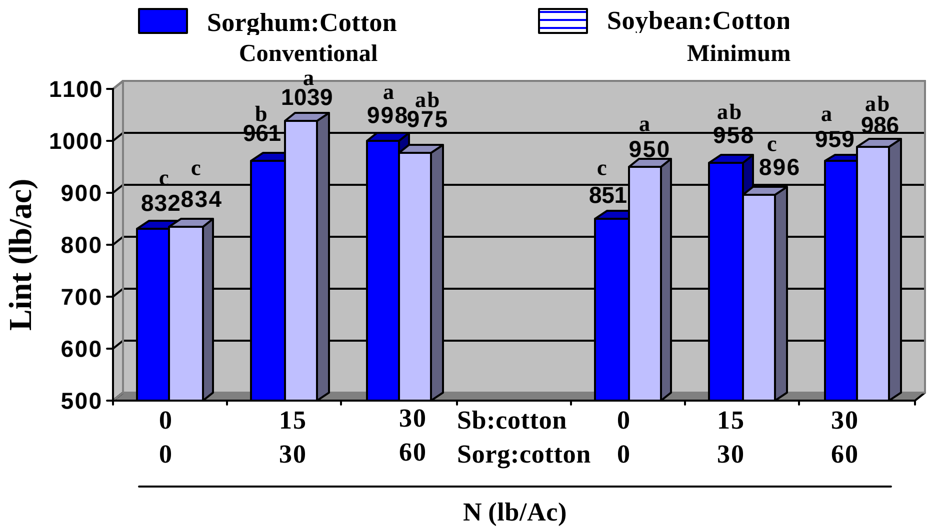


Fig. 1. Effect of soybean grown in alternate years with cotton and tillage on lint yields at three N fertilizer rates.

The scheduled sequence of crop rotations for the third year did not provide an evaluation of rotation effects on cotton. However, data for the fourth year of the experiment are summarized in Figures 2. The contribution of soybean grown in alternate years with cotton in a zero N fertilizer system was strongly reflected in 116% and 92% yield increases for CVT and MT systems, respectively, over the sorghum:cotton rotation (Fig. 2). These percentages represent substantial lint yield increases of 325 and 280 lbs/acre solely due to the legume used in the rotation. When N rate was applied at 30 lb N/acre to sorghum:cotton and 15 lb N/acre to soybean:cotton, 14% and 33% increases in lint yields were measured which equaled 80 and 185 lb/acre additional lint, respectively, for the CVT and MT systems. Increasing N rates 15 and 30 lb N/acre in the CVT system increased yields in the Sb:cotton rotation. However, yields were not increased at the higher rate of N in the MT system.

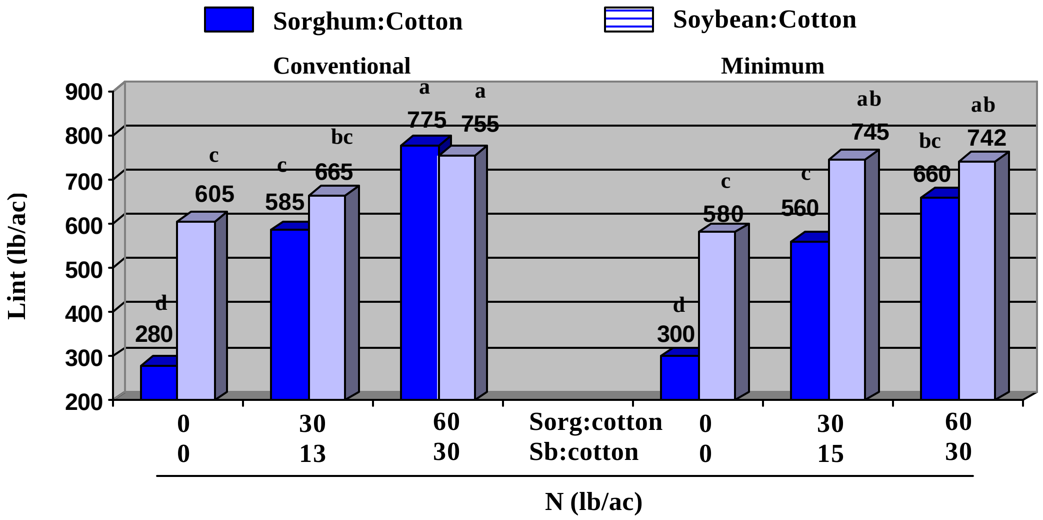


Fig. 2. Effect of soybean in crop rotation and tillage on lint yields at three N fertilizer rates. Bars topped by the same letter across all treatments are not significantly different at the P=0.05 level (Duncan's MR test).

The soybean crop grown in alternate years is harvested as a cash crop. Although the approximate 20 bu/acre yields from the beans does not appear to add much to the cash flow, the contribution from biologically fixed N and other benefits from the legume reflected in the 280 lb/acre additional lint are quite substantial. Results of this study show that 1.5-2.0 bale per acre cotton can be produced with a meager 15 lb N/acre when soybeans are grown in alternate years.

Summary

- A 1-year soybean:1-year cotton rotation system became highly productive in the fourth season requiring minimal fertilizer N input.
- Lint yields increased up to 92% from soybean as compared to sorghum rotations.
- Net contribution from the legume in the rotation increased substantially with time.
- Benefits from legume rotation were greatest in the MT tillage system.
- With the current substantial increases in fertilizer N costs the research results from this study can provide some useful guidelines in producer maximization of fertilizer N utilization. The legume:cotton cropping system is proving to perform best in a MT system. At 15 lb/acre of N fertilizer (less than ¼ of soil test recommended rate and about 1/5 of current rates used by many producers) the soybean:cotton system produced 185 lb/acre additional lint over the traditional sorghum:cotton rotation in the MT system as compared to 80 lb/acre with CVT system. In addition to increased yields, savings in fuel and labor costs with reduced tillage can add to increased profits in cotton production.

Literature Cited

Matocha, J.E. 2007. Invited Paper. Adoption of Reduced Tillage Practices in the Coastal Bend Area of South Texas. Proceedings of National Conservation Tillage Cotton and Rice Conference. Houston, TX.

Matocha, J.E. 2006. Trace. Impact of Crop Rotations and Tillage Frequencies at Varying Nitrogen Fertility on Corn Yields. Proceedings of Southern Conservation Systems Conference. Amarillo, TX.

Wright, A.L., Frank M. Hons and John E. Matocha. 2005. Tillage Impacts on Microbial Biomass and Carbon and Nitrogen Dynamics of Corn and Cotton Rotations. Applied Soil Ecology 29 (2005) 85-92.

The impact of Cropping Systems and Cultural Practices on Asian Soybean Rust

D. Narvaez[1], J. Marois[1], D. Wright[1], E. De Wolf[2], Nick Dufault[3], S. Isard[3], P. Esker[4]

[1]North Florida Research and Education Center, Quincy, FL 32351 USA
[2]Department of Plant Pathology, Kansas State University, Manhattan, KS 66506 USA
[3]Department of Plant Pathology, Penn State University, State College, PA 16802 USA
[4]Department of Plant Pathology, Iowa State University, Ames, IA 50011 USA

INTRODUCTION

Soybean farmers are switching to reduced tillage and other cultural practices to reduce soil erosion and input costs. This allows them to manage more acres with less labor and comply with the government conservation programs.

Cultural practices have been shown to affect the incidence and severity of many pests, including plant pathogens. The use of lowered seed rates, increased row widths, and proper row orientation to the sun (to help minimize leaf wetness duration) have been prescribed as environmental modifications that create a microclimate less conducive to foliar disease development (Cook and Yarham, 1998).

Row spacing, for example, has the potential to alter canopy architecture, canopy closure, canopy microclimate, leaf area index and solar radiation at the soil and canopy level and have proven to maximize yield, reduce herbicide usage, and create a more favorable environment that affect disease incidence and severity (Blad, Steadman et al., 1978; Grau and Radke, 1984; Marois et al., 2004).

Growers leave crop residues on the soil surface rather than incorporating them in. However, with the arrival of *Phakopsora pachyrhizi*, causal agent of Asian Soybean Rust (ASR), many crop advisers and farmers have expressed concern regarding the appropriate use of these cultural practices to avoid or reduce the development of ASR on soybean fields.

With its arrival on the continental United States in 2004, ASR has the potential to be an economic threat to U.S. soybean producers, (Schneider, Hollier et al., 2005). Soybean rust has been a prevalent tropical and subtropical foliar disease throughout the world.

Our objectives are to review and address the impact of cropping systems and cultural practices use to produce the highest yielding, most profitable crop on the development of Asian Soybean Rust

CONSERVATION TILLAGE

Conservation tillage, defined as a system that leaves 30% or more of the soil surface covered by crop residue after planting, helps to reduce soil erosion, conserve energy and soil moisture, and increase crop yields. However, many soilborne plant pathogens survive in the previous year's crop residue making disease more problematic under reduced-tillage conditions. Reduced tillage can favor pathogens of soybean by such mechanisms as protecting the pathogen's refuge in the residue from microbial degradation, lowering soil temperature, increasing soil moisture, and leaving soil undisturbed. Tillage can spread Soybean cyst nematode within and in between fields. White mold disease can be favored by tillage because this fungus produces sclerotia (overwinters up to 7 yrs in deep soil) that can be brought up to the surface and germinate. Tillage can reduce infection of other diseases such *Phytophthora,* Sudden Death Syndrome by increasing soil temperature in the planting season. Even so, the national average difference in soybean yield between no-tillage and conventional tillage was found to be negligible with a 0.7 percent advantage to no till while little difference has been found in the southeast http://agroecology.clemson.edu/soybean.htm except to in row subsoiling to break the compaction layer. Soybean yields tended to benefit more from crop rotation in no-till compared to continuous cropping

It is thought that *Phakopsora pachyrhizi* cannot survive in crop residue. However, ASR spores may survive on their own about 40 days, and the probability that spores would survive the winter likely depends on the location. Soybean rust will most likely come to the field on air currents from south; there is no reason to think tillage (or absence of tillage) would influence rust likelihood or severity. However, most of the soybeans planted in the SE are planted behind a crop of small grain for grain and conservation tillage is widely used in the double cropped fields. Therefore, in those situations tillage may affect the number of volunteer soybeans that can serve as overwintering host in south; which was the case of the first finding of ASR on a soybean volunteer plant in GA in 2005.

ROW SPACING

Row spacing has been used effectively to reduce the disease incidence and severity of several diseases. In cotton, the use of ultra-narrow rows (7 inches or 17.8cm) in comparison to regular row width (36 inches or 91.4 cm) caused reduced canopy temperature and vapor pressure deficit along with increased relative humidity within the plant canopy prior to reaching 1 meter in height (Marois et al., 2004).

Although row spacing has been shown to affect disease incidence and severity, there are many reasons to vary row spacing. Environmental factors often dictate what row spacing is adopted by farmers. In the South-Eastern U.S., the sandy loam soil compacts easily requiring the use of subsoiling equipment to ensure a compaction-reduced root zone (David Wright, personal communication). Since most row crops (cotton, peanuts) are grown on wide rows (36"), the adaptation of equipment for planting soybeans at narrow rows is not economical due to lower-than-average soybean yields compared to northern and western states.

In the Southern and Mid-Southern states, soybean research has focused on the effects of cultural practices, mainly row spacing, cultivar selection, and plant population, on regions that experience droughts in August. Wide row spacing has been shown to reduce leaf size and reduce canopy closure when compared to narrow row soybeans in the arid region of North Texas, but these results seem inconsistent with insignificant effects on yield (Heitholt, Farr et al., 2005).

The LAI of a crop canopy is altered by row spacing and has been shown to impact herbicide and fungicide applications in many row crops. In peanut studies an inverse correlation has been found that as the LAI increases the penetration of fungicides within the canopy decreases substantially(Zhu, Rowland et al., 2002). In glyphosate resistant varieties of soybeans, the use of narrow row practices encourages early canopy closure, reducing weed pressure and allowing for a single application of glyphosate to control most weeds without the use of a residual herbicide (Norsworthy, 2004).

There are no significant differences in ASR incidence and severity among different row spacing. In a wide-row situation, it is thought that there is more turbulence within the rows during a rain-storm, which could result in greater dispersal of spores throughout the canopy and field. Narrow rows create more favored microenvironments for rust development because longer periods of high relative humidity compared to wide-row spacing. The reduction in temperature, increase in free moisture, and increased relatively humidity are often implicated in increased disease pressure.

In a series of experiments begun in 2006 at Quincy, Fl, row spacing was manipulated to determine its effect on soybean canopy microclimate and disease spread from a point source of inoculation.

Materials and Methods

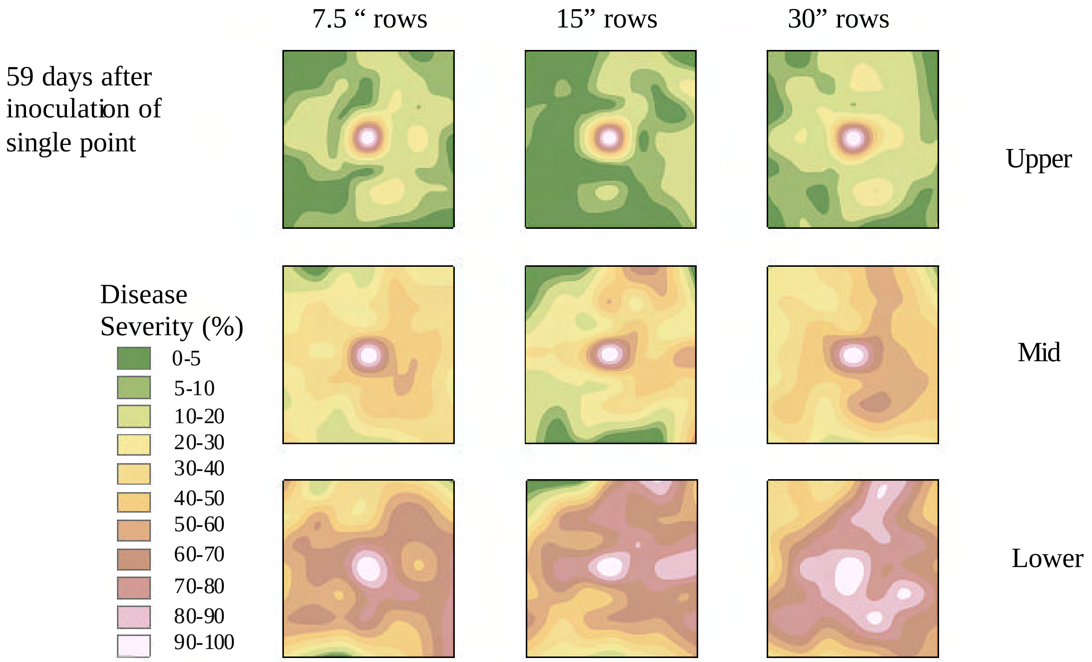
A field (216' x 680') was at the North Florida Research and Education Center (NFREC) (University of Florida, Quincy, FL). This experiment was planted in a randomized block design, with two replications and row spacing as treatments (7.5", 15", and 30") and planted at 172,500 seeds per acre to achieve 150,000 plants per acre population, regardless of row spacing. Treatment plots were triplicate 80' x 80', with adjacent fungicide plots 30' x 80', and 10' boarders surrounding the field to reduce potential edge effect. The fungicide controls were used as "disease-free" control plots for the microclimate analysis and also to quantify the yield impact of soybean rust on the inoculated treatments.

The soybean rust epidemic was induced once the field reached a early reproductive stage (R1-R2) by placing one severely infected soybean plants in the center of each designated foci. Each of the 9 treatment plots has been divided into 49 10'x10' grids. Plants will be sampled from the corner of each grid. Incidence and severity were evaluated at 5 leaves from each the low, mid, and high canopy at each of the grids except for the inoculated foci (coordinates 44 (XY). The foci were not sampled to prevent interfering with the natural disease spread. Assessments was made 23, 30, 40, 44, 51 & 59 days after inoculation and distance was calculated as Euclidian distance from point of inoculation, and observations in all directions (no directional component)

The canopy microclimate analysis was monitored assessing air temperature at low, mid, and upper canopy locations; leaf wetness duration at low, mid, and upper canopy locations; solar irradiance above and below the canopy, relative humidity at mid canopy, wind speed at mid canopy and above the canopy, and soil temperature.

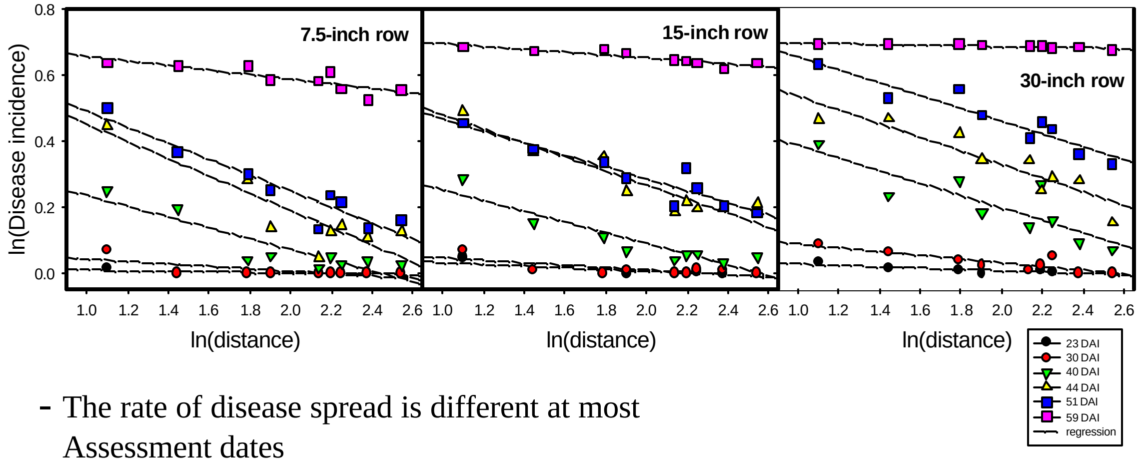
Fig 1. Soybean planted at 30 inch row spacing

Fig 2. Spatial Distribution of Soybean Rust



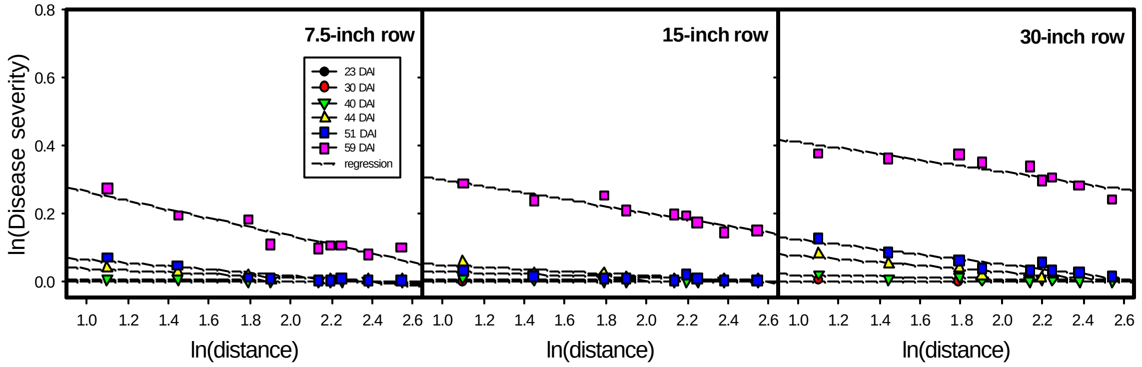
Annalisa Ariatti, Penn State

Fig 3. Rate of Disease Spread as Influenced by Row Spacing (Disease Incidence)



- The rate of disease spread is different at most Assessment dates
- The rate of disease spread does not differ with row spacing for most assessment dates

Fig 4. Rate of Disease Spread as Influenced by Row Spacing (Disease Severity)



- Similar patterns in rate of disease spread observed with disease severity.

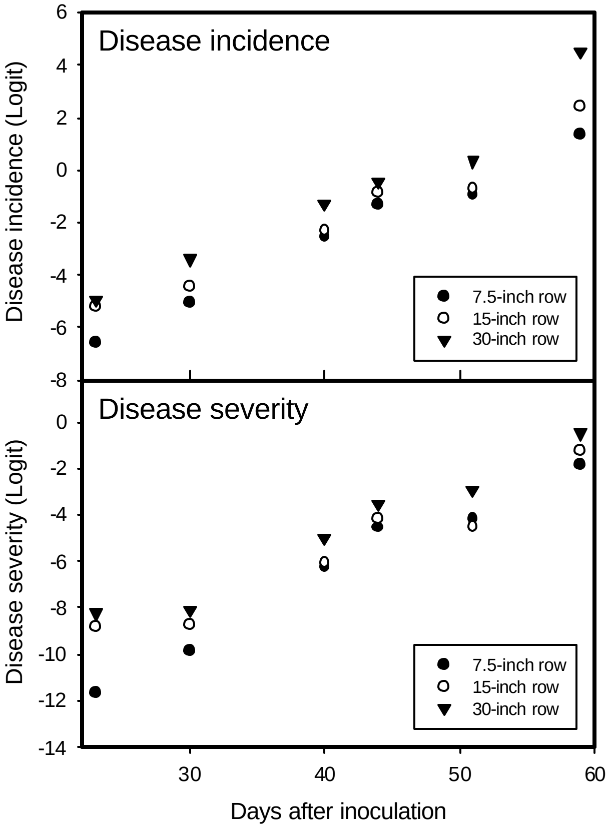


Fig 5. Disease progress over time with different row spacing

The rate of disease spread is different at most assessment dates

The rate of disease spread does not differ with row spacing for most assessment dates

? Growing soybeans in 7.5, 15 or 30 inch rows did not significantly alter the rate of disease spread or disease increase over time

? Significant differences of disease at discrete time periods will likely not translate into meaningful management since it will be quickly eliminated by rapid increase of disease (less than 5 days)

? Explosive rate of progress will make scouting for disease difficult but our best chance is with disease incidence

? Rate of disease increase does not vary among 7.5, 15 and 30 inch row spacings

Preliminary results of conducting wet and dry deposition field studies of *Phakopsora pachyrhizi* urediniospores indicate that spores deposited by short durations of simulated rainfall and dry depositions are distributed evenly throughout a soybean canopy.

Fig 6. Wet Deposition: Rainfall Washout Simulation

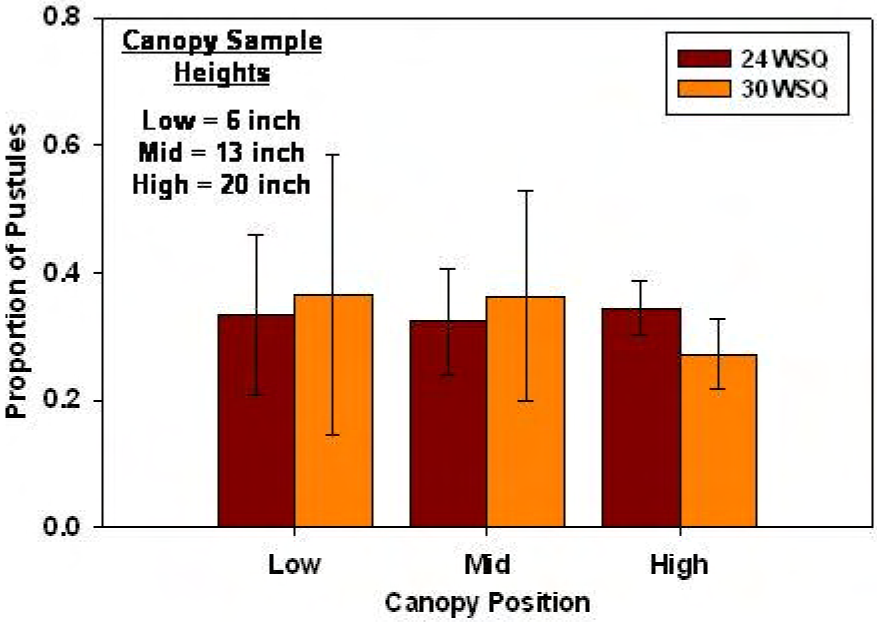
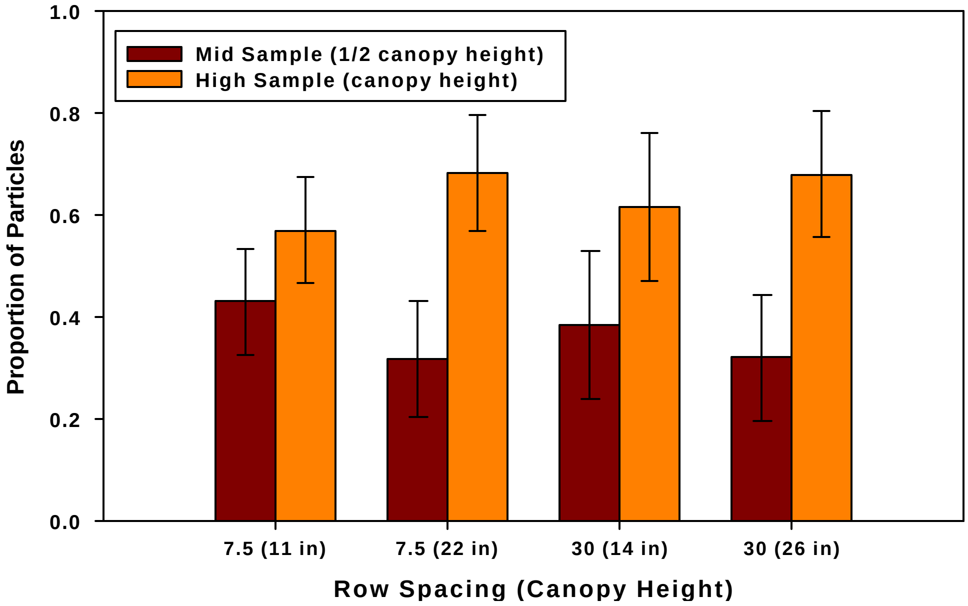


Fig 7 Dry deposition (Impaction)



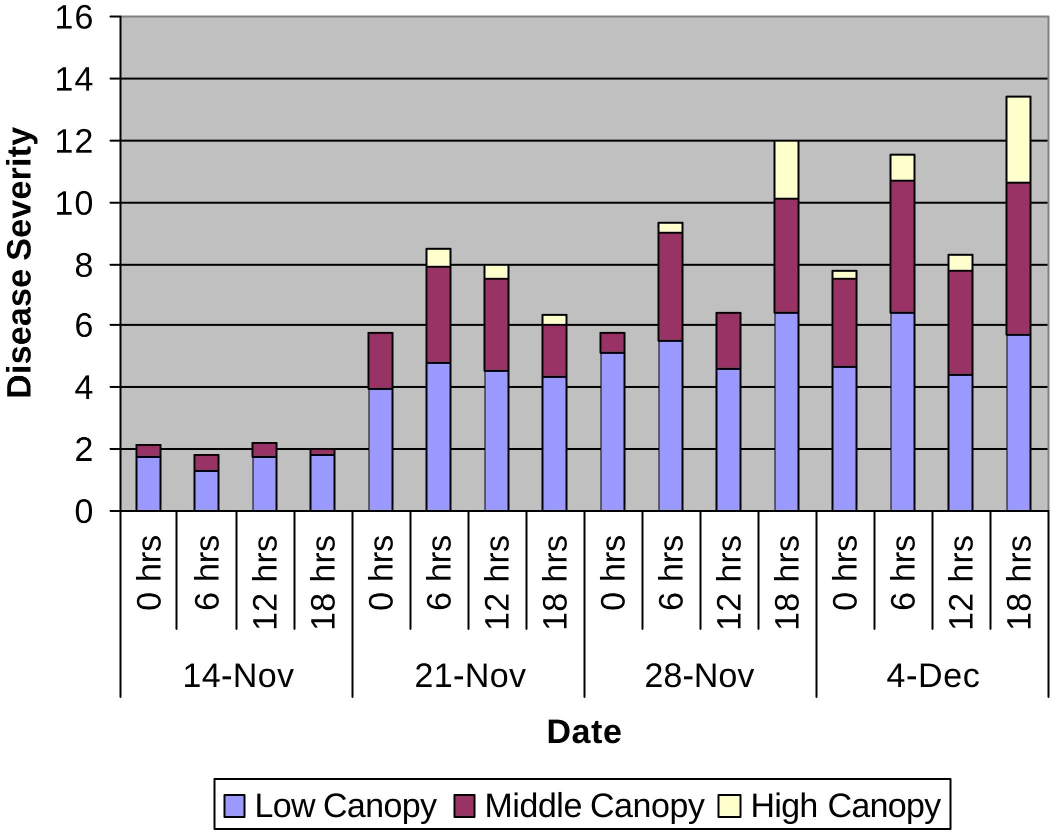
IRRIGATION AND LEAF WETNESS

Crops suffer from periods of drought each year in Florida. Soybeans require little early irrigation except to get good plant height and provide canopy closure. Soybeans require the highest amount of water during late flowering through pod fill. Irrigation helps stabilize yields and makes more dependable marketing strategies. ASR begins germination after 1.5 hrs of leaf wetness/dew, and a period of 6 hrs of leaf wetness/dew is sufficient for ASR infection.

A misting irrigation system on MG5 implemented at one of the sentinel plots in Quincy, Fl to evaluate the effect of leaf wetness duration on the development of ASR, showed that not only did longer periods of leaf wetness increase disease severity but also the speed of the incidence/spread of the disease to upper leaves. (Fig 8)

Misting irrigation was applied for 1 minute on 30 minutes intervals for a 0, 6, 12 and 18 hr periods. Micro-environmental changes within the soybean canopy, caused by the different misting periods were recorded with Log Tag card microloggers from MicroDAQ.com, Ltd. PO Box 439 Contoocook, NH 03229 U.S.A.

Fig 8. Effect of Leaf Wetness on Soybean Rust Development



PLANTING DATE

Planting date does not directly affect rust incidence or severity. However, by planting early, the crop matures earlier. This potentially reduces the time the crop is exposed to ASR, since spore numbers usually increase throughout the season. Therefore, more disease would be expected on later planted soybeans. Additionally, planting seed into cold soils will delay germination and increase the risk of seedling disease, which could reduce stand and yield. I don't know of this problem in the SE. We have Lesser corn stalk borere problems in dry soils and we normally treat for velvet bean caterpillar late in the season along with stinkbug. Planting date usually does not influence these.

DOUBLE-CROP SOYBEAN SYSTEMS

Double-crop soybean are not inherently more susceptible to ASR than full season soybeans; however double-crop soybean face more disease pressure due to later maturity dates, compared to the full-season soybeans. Since double-cropped soybeans are planted at the end of May or the first of June. They are likely to be at an earlier development stage when colonized by ASR and would, therefore, be exposed to the pathogen for longer period of time.

ASR could affect both systems equally if ASR were to arrive early in the season when full-season soybeans are in the R1 to R2 stage. However, since double-crop soybeans lag 10-15 days in development, they present a higher risk of exposure to higher inoculum levels of ASR. However, dry and hot weather could greatly decreased establishment/development/movement of ASR. Also, the canopy in double-crop soybean is smaller and less dense and will not support disease development as well as the larger, denser canopy of full-season soybeans

PLANTING OF MATURITY GROUPS

The susceptibility or predisposition of a maturity group to ASR pathogen depends on the overwintering of ASR in the region. In regions where ASR cannot over winter ASR must move in from somewhere else in the south. Later maturity groups are more likely to be exposed to ASR and have higher inoculum levels than early maturity groups. Early maturity groups will initiate reproductive process sooner; therefore, these cultivars are likely to be in the later growth stages when ASR arrives. Yield loses will vary depending on the soybean growth stage at which the ASR attack occurs.

CONCLUSIONS

Most cropping systems and cultural practices such as narrow-row or wide-row planting, planting date, double-crop soybean, maturity group, tillage system does not directly affect

ASR incidence or severity; however some cropping systems and cultural practices may vary in the disease pressure due to extended time that the crop is exposed in the field. Furthermore, what challenges most cropping systems and cultural practices is that, alternative host plants grow year round resulting in continuous spore production. The selection of the most suitable crop system or cultural practice should not only be considered in terms of efficacy to control/reduce the impact of ASR but also to manage other soybean diseases and also in terms of the efficacy related to the forecast weather conditions.

One should choose the planting date that will give the best yield and then implement ASR control measurements if needed

Scouting during pot stages (R4-R5) for ASR incidence is still necessary regardless of when the soybean is planted

The amount of canopy and weather may have more impact on disease development than planting date or maturity group.

Continue to use recommended practices to produce the highest yielding, most profitable crop. A healthy crop will tolerate ASR better than a stressed crop

REFERENCES AND ASR SOURCES

Asian Soybean Rust website at Virginia Tech-
http://www.ppws.vt..edu/ipm/soybeanrust/index.html

Asian Soybean Rust- Frenquently Asked Questions IV: Cropping Systems and Cultural practices. Virginia Cooperative extension 450-304

USDA Soybean Rust Tracking site-
http://www.sbrusa.net

The Southern Plant Disease Network-
http://spdn.ifas.ufl.edu/soybean_rust.html

Influence of Tillage on Soybean Yield in the United States and Canada. M. DeFelice, P. Carter, S. Mitchel. CROP INSIGHTS. Vol. 16- 11.

Bean leaf beetles and soybean planting date. INTEGRATED CROP MANAGEMENT (ICM) IC-490 (6). April 28, 2003.

Blad, B. L., J. R. Steadman, et al. (1978). Canopy structure and irrigation influence white mold disease and microclimate of dry edible beans. Phytopathology **68**: 1431-1437.

Cook, R. J. and D. J. Yarham (1998). Epidemiology in sustainable systems. The Epidemiology of Plant Diseases. D. G. Jones. Norwell, MA, Kluwar Academic Publishers.

Grau, C. R. and V. L. Radke (1984). Effects of cultivars and cultural practices on *Sclerotinia* stem rot of soybean. Plant Disease **68**(1): 56-58.

Heitholt, J. J., J. B. Farr, et al. (2005). Planting configuration x cultivar effects on soybean production in low-yielding environments. Crop Science **45**: 1800-1808.

Marois, J. J., D. L. Wright, et al. (2004). Effect of row width and nitrogen on cotton morphology and canopy microclimate. Crop Science **44**(3): 870-877.

Norsworthy, J. K. (2004). Soil-applied herbicide use in wide- and narrow-row glyphosate-resistant soybean (*Glycine max*). Crop Protection **23**: 1237-1244.

Schneider, R. W., C. A. Hollier, et al. (2005). First report of soybean rust caused by *Phakopsora pachyrhizi* in the continental United States. Plant Disease **89**: 774.

Zhu, H., D. L. Rowland, et al. (2002). Influence of plant structure, orifice size, and nozzle inclination on spray penetration into peanut canopy. Transactions of the ASAE **45**(5): 1295-1301.

Vertical Simulated Weed Seed Movement Following Various Tillage Practices and Overhead Irrigation Intensities.

Price, A.J., R.L. Raper, and J.S. Bergtold.

Abstract

Vertical weed seed movement has been shown to be influenced by tillage system. The objective of this study was to evaluate vertical movement of simulated weed seed in conservation-tillage practices in a Coastal Plain field at the E.V. Smith Research and Extension Center near Shorter, AL. 10,500 1 mm ceramic beads (5,250 = specific gravity of water; 5,250 = specific gravity of water) were scattered evenly in nine equally divided square cells within a one square meter area in each plot, centered on the crop row, prior to tillage and irrigation treatments. Tillage treatments included: 1) none, 2) a KMC™ straight leg subsoiler, and 3) a bent leg Paratill™. Cotton was then planted using a row-cleaner equipped John Deere® MaxEmerge™ planter. Plots were then overhead irrigated with 0, 2.5, or 5 cm of water. The ceramic beads were then vacuumed from the nine cells separately. Additionally, visible beads outside the square meter were vacuumed into one sample. Following vacuuming, a 25 cm diameter soil core was taken to a maximum depth of 40 cm and divided vertically into 5 cm increments. Soil samples were then sieved. Beads from each sub-sample were removed and counted.

Weed Seedbank Composition in a Long-term Tillage and Landscape Variability Study

Andrew Price
USDA-ARS-NSDL
411 S. Donahue Drive
Auburn, Alabama 36832
Phone: (334) 332-2948

Abstract

Weed composition has been shown to be influenced by numerous environmental and cropping system attributes. The objective of this study was to evaluate cropping and landscape effects on weed seedbank composition. Soil samples at two depths were collected from an established experiment located on a 24-acre Coastal Plain field at the E.V. Smith Research and Extension Center near Shorter, AL. The experimental design was a factorial arrangement of two tillage systems (conventional and non-inversion subsoiling), with and without manure, a corn-cotton rotation with both phases of the rotation present each year, with six replications imposed on 20-ft by 787-ft long strips across the field. Each strip in the field was divided into 20-ft by 60-ft cells. Soil samples were placed in plastic trays and kept moist for three months. Weed seedling were identified and removed over time. The six major weeds (totaling 19,087 individual seedlings) included annual bluegrass (739), carpetweed (539), common chickweed (851), henbit (15,376), purple cudweed (398), and smallflowered bittercress (587). Sample depth, tillage, manure, and the manure by tillage interaction significantly influenced weed composition and density.

DRAWBAR POWER REQUIREMENTS AND SOIL DISRUPTION OF IN-ROW SUBSOILER POINTS FOR CONSERVATION TILLAGE

J.G. Zhang[1], R.L. Raper[2], K.S. Balkcom[2], F.J. Arriaga[2], T.S. Kornecki[2], and E.B. Schwab[2]

[1]Agriculture University of Hebei, 071001 Baoding, China
[2]USDA-ARS National Soil Dynamics Laboratory, 411 South Donahue Drive, Auburn, AL 36832. Corresponding author email address: rlraper@ars.usda.gov

ABSTRACT

Soil compaction can reduce crop yields by restricting root development. In-row subsoiling is a common tillage practice for disrupting the compacted soil profile, allowing roots to proliferate downward to obtain adequate soil moisture. The subsoiler system is composed of many important components, but the point assembly is the first element to contact the soil and can largely determine the draft requirement and soil disruption of the subsoiler. Two points were evaluated in a soil bin experiment at the USDA-ARS National Soil Dynamics Laboratory in Auburn, AL. A standard ripper point was compared with a 'splitter point' which is designed to fracture the soil and reduce above-ground soil disruption, especially in dry conditions. The subsoiler system was mounted on a three-dimensional dynamometer where measurements of draft force, vertical force, side force, speed, and depth of operation were determined and tillage power requirements were calculated. Measurements of soil disruption including spoil cross-sectional area, trench cross-sectional area and trench specific resistance were determined. Results showed that the splitter point required significantly greater drawbar power (28%) compared to standard ripper point the while disturbing similar amounts of below-ground soil. However, the splitter point did reduce the above-ground soil disruption by more than 10%. The splitter point was helpful in reducing above-ground disruption but the added energy cost could be prohibitive for many producers.

Keywords. Tillage, Subsoiling, Soil compaction, Draft force, Ripper Point

INTRODUCTION

Soil compaction can reduce crop yields by restricting root development as well as water and air movement in the soil (Petersen et al., 2004; Wells et al., 2005). Deep soil compaction is difficult to alleviate by tillage and may have long-lasting implications for crop production (Hamlett et al., 1990; Raper et al., 1994; Petersen et al., 2004; Wells et al., 2005). One of the most common methods used to remove compacted soil conditions is subsoiling (Saveson and Lund, 1958; Box and Langdale, 1984; Busscher et al., 1986; Mullins et al., 1992; Vepraskas et al., 1995). 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, 2005b; Wells et al., 2005).

Because of the significant draft force required to subsoil compacted profiles, many different types of subsoilers have been designed and tested. The shape of the subsoiler shank can have a large effect on the required draft and soil disruption. Raper (2005a) reported that bentleg shanks had the lowest aboveground soil disruption when compared to several straight shanks for non-inversion in-row subsoiling. This type of shank was found to be suitable for a conservation tillage system. Smith and Williford (1988) reported that a parabolic subsoiler required reduced draft compared to a conventional subsoiler and a triplex subsoiler.

The subsoiler's point configuration has a large effect on the required draft and soil disruption. Some producers have reported that their draft force and their soil disturbance have been reduced by using a 'splitter point' on their subsoiler. This point, manufactured by Kelley Manufacturing Company[1] (Tifton, GA) has a dramatically raised ridge near the center of the point that 'splits' the soil as the shank travels forward.

Therefore, the objectives of this study were to:
- determine required draft forces for a standard ripper point and a splitter point at different depths of operation, and
- determine the amount of soil disruption caused by the different points at each depth of operation.

MATERIALS AND METHODS

The experiment was conducted in Nov. 2006 in the soil bins at the USDA-ARS National Soil Dynamics Laboratory in Auburn, Alabama. The soil bin is 20 ft wide, 190 ft long and 5 ft deep. The soil chosen for the study was a Norfolk sandy loam soil (sand 72%, silt 17%, and clay 11%) from the southeastern United States. A hardpan was formed in the soil bin to simulate a condition that is commonly found in this region. The hardpan condition was created in the soil bin by using a moldboard plow to laterally move the soil followed by a rigid wheel to pack the soil left exposed in the plow furrow. A small amount of soil was packed at a time and the entire procedure was repeated until the entire bin had been traversed.

The shanks used for this experiment were manufactured by Kelley Manufacturing Company and are commonly referred to as Generation I shanks. They are 1.25 in thick and have a forward angle of 52 degrees. Each point is 2.25 in wide and has an angle of 30 degrees with the horizontal. The splitter point has a 0.375 in thick fin attached to the top that extends back at an angle of 56 degrees with the horizontal and is 3.75 in high at the rear of the point (fig. 1).

Figure 1. Points used in the soil bin experiment. On the left is the splitter point (SP) and on the right is the standard ripper point (P).

---

[1] The use of company names or tradenames does not indicate endorsement by Agriculture University of Hebei or USDA-ARS.

The subsoiler system which included shank, point, and coulter were mounted on a three-dimensional dynamometer on a soil bin car at the NSDL (fig. 2). Draft force, vertical force, side force, speed, and depth of operation were recorded continuously for the shank for each test. The speed of tillage for all tests was held constant at 1 mph.

Figure 2. Subsoiler system mounted on the three-dimensional dynamometer in the NSDL soil bins.

Three depths of operation were evaluated for each point: 9, 12, and 15 in with the depth of the coulter remaining constant at 3 in (see table 1). The soil bin was partitioned into four blocks along the length of the bin. Six plots of dimensions 5 ft wide by 16.4 ft long were created within each block. A total of 24 plots were arranged in a randomized complete block design with two subsoiler points, three tillage depths, and four replications.

Table 1. Experimental treatments used for the soil bin experiment.

Treatments	Point	Depths of operation (in)
SP9	Splitter Point	9
SP12	Splitter Point	12
SP15	Splitter Point	15
P9	Standard Ripper Point	9
P12	Standard Ripper Point	12
P15	Standard Ripper Point	15

Before the tests were conducted in each plot, a set of five cone index measurements were acquired with a multiple-probe soil cone penetrometer measurement system (Raper et al., 1999). This set of measurements was taken with all five cone index measurements being equally spaced at an 8 in distance across the soil with the middle measurement being directly in the path of the shank. As soon as the subsoiler system had been tested in each plot, another set of five cone index measurement was also taken in the disturbed soil in close proximity to the original cone index measurements.

Measurements of bulk density and moisture content were taken in undisturbed regions of each replication for analysis. Values were collected from each plot using the soil measurement system (Raper et al., 1999) in increments of 2 in down to a depth of 20 in.

After each set of tillage operations was conducted, a laser profile meter (Raper et al., 2004) was used to determine the width and volume of soil disturbed by each tillage event. Disturbed soil was manually excavated from each subsoiled zone for approximately 3 ft along the travel path to allow five independent measurement of the subsoiled zone. Care was taken to ensure that only soil loosened by tillage was removed. The trench specific resistance was then calculated by dividing the drawbar power by the trench cross-sectional area to determine the relative efficiency of the tillage operation (Raper, 2005a)

A 2 (points) x 3 (depths) factorial design was used to evaluate the treatment effects and Fisher's protected least significant difference (LSD) was used for mean comparison using PROC MIXED (SAS; Cary, North Carolina). A probability level of 0.1 was chosen to test the null hypothesis that no differences existed between points or tillage depths.

RESULTS AND DISCUSSION

INITIAL SOIL CONDITIONS

Initial soil moisture content and bulk density for 0-20 in depth are shown in figs. 3 and 4. The gravimetric moisture content (dry basis) was approximately 7.9% near the surface and 8.4% at the 10-to 12-in depth. Bulk density values showed that the approximate location of the hardpan that was created in the soil bin started at a depth of 7.5 in. The soil within the hardpan, at a depth of 6 to 8 in and a depth of 16 to 18 in, had higher bulk density values [116.7 lb ft^{-3} and 118.0 lb ft^{-3} (1.87 Mg m^{-3} and 1.89 Mg m^{-3})] compared to the shallower layer of bulk density [100.5 lb ft^{-3} (1.61 Mg m^{-3})] at a depth of 4 to 6 in. Initial values of cone index increased gradually from the depth of 6 in to beneath the hardpan layer and increased again from 14 in (Fig. 5). These values indicated a similar pattern in soil compaction to the bulk density values. The different depths of tillage are also seen in figure 5 with extremely low cone index values being found down to the tillage depth.

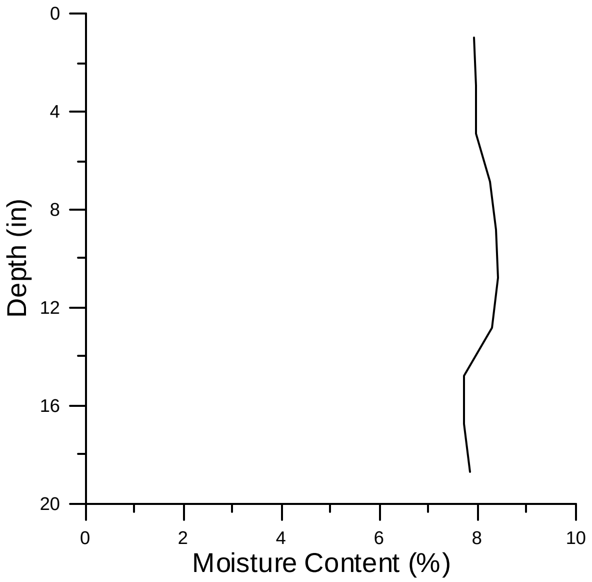


Figure 3. Initial soil moisture content of the soil bin.

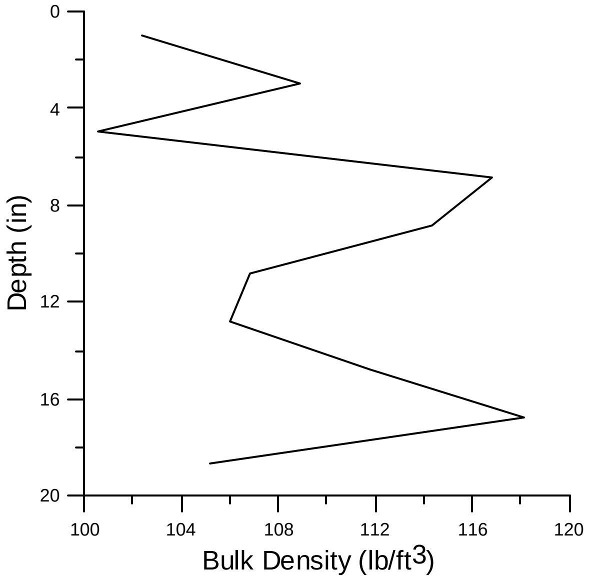


Figure 4. Initial bulk density of the soil bin.

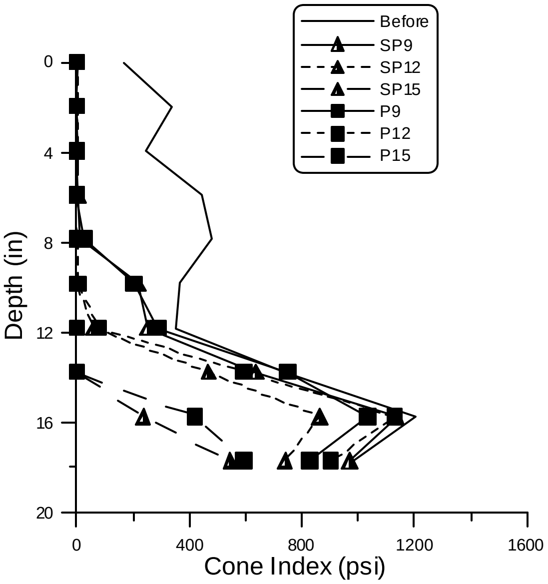


Figure 5. Cone index values obtained prior to tillage operations and after each tillage treatment in the center of the subsoiled zone.

DRAWBAR POWER

Values of drawbar power measured in soil bin experiments are typically reduced from typical field measurements due to the soil contained in the soil bin facility and the slow speed of operation at which experiments are conducted. The main effect of tillage depth was found to be highly significant (p = 0.01) on drawbar power (fig. 6). Minimum values of drawbar power (2.91 hp) were found at the shallowest tillage depth (9 in) and maximum values of drawbar power (10.6 hp) were found at the deepest tillage depth (15 in). Drawbar power increased almost 100% between each of the equally spaced depths of 9, 12, and 15 in.

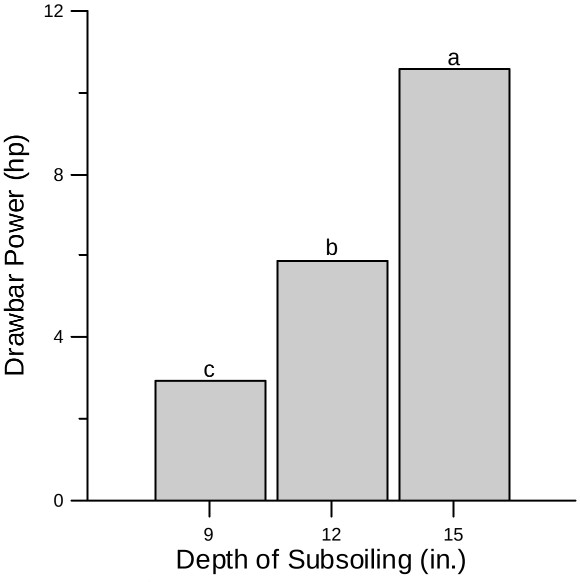


Figure 6. Drawbar power of subsoiler points averaged across points. Letters indicate differences at LSD$_{0.1}$.

The main effect of the subsoiler point was also found to be highly significant (p = 0.01) on drawbar power (fig. 7). The splitter point required 28% greater drawbar power (7.38 hp) compared to the standard ripper point (5.76 hp). No significant interactions were found between the two main effects of tillage depth and ripper points.

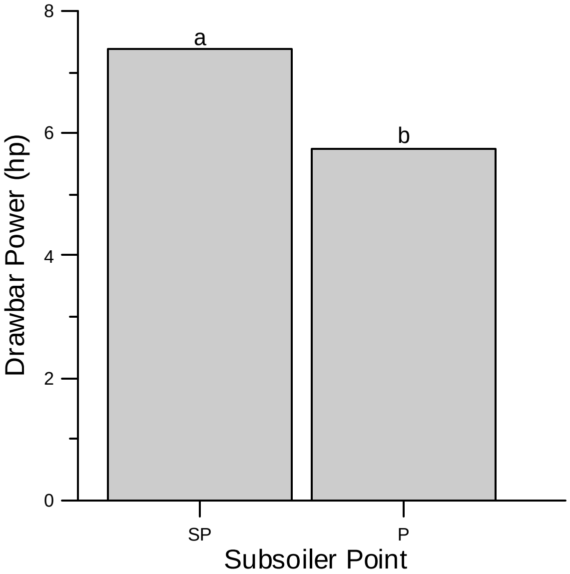


Figure 7. Drawbar power of subsoiler points averaged across depths. Letters indicate differences at $LSD_{0.1}$.

SOIL DISRUPTION

Spoil cross-sectional area was significantly affected by the main effect of tillage depth (p = 0.01; table 4) and ripper point (p = 0.01; table 5). Spoil gradually increased with tillage depth with minimum values occurring nearest the soil surface and maximum values occurring at the deepest depth. Also, the splitter point significantly reduced the spoil compared to the standard ripper point.

The trench cross-sectional area was significantly affected only by the tillage depth (p = 0.01; table 4) with maximum values of disruption occurring at the two deepest depths of 12 and 15 in and minimum values of trench disruption occurring at the shallowest depth of 9 in. The ripper point had no significant affect on below-ground disruption (table 5).

The trench specific resistance was also significantly affected by both tillage depth (p = 0.01; table 4) and ripper point (p = 0.01; table 5). Smaller amounts of trench specific resistance are advantageous because they indicate reduced amounts of power required to disrupt a specific volume of soil. Based on this parameter, the shallowest depth of operation required the minimum trench specific resistance while the deepest depth of operation required the maximum trench specific resistance (table 4). The standard ripper point also had minimum values of trench specific resistance as compared to the splitter point (table 5).

Table 4. Soil disruption parameters averaged across ripper points resulting from the soil bin experiments. Letters indicate differences $LSD_{0.1}$.

Treatments	Spoil Cross-Sectional Area (in^2)	Trench Cross-Sectional Area (in^2)	Trench Specific Resistance (hp/in^2)
9	46.08 c	64.47 b	0.047 b
12	54.31 b	104.18 a	0.058 b
15	67.65 a	112.20 a	0.096 a

Table 5. Soil disruption parameters averaged across tillage depths resulting from the soil bin experiments. Letters indicate differences $LSD_{0.1}$.

Treatments	Spoil Cross-Sectional Area (in^2)	Trench Cross-Sectional Area (in^2)	Trench Specific Resistance (hp/in^2)
P	59.02 a	98.16	0.056 b
SP	52.86 b	90.00	0.076 a

CONCLUSIONS

- Subsoiling conducted with the splitter point required significantly increased drawbar power than with the standard ripper point. The results showed that 28% more drawbar power was required to subsoil with splitter points than with standard ripper points.
- To reduce energy use and minimize above-ground soil disruption, reduced tillage depths should be considered. Tilling deeper than necessary wastes energy and excessively disturbs the soil surface.
- The splitter point reduced the amount of above-ground soil disturbance compared to the standard ripper point by more than 10%. However, the standard ripper point was more efficient using the trench specific resistance compared to the splitter point.

REFERENCES

Box, J., and G. W. Langdale. 1984. The effects of in-row subsoil tillage and soil water on corn yields in the southeastern Coastal Plain of the United States. Soil Till. Res. 4(1): 67-78.

Busscher, W. J., R. E. Sojka, and C. W. Doty. 1986. Residual effects of tillage on Coastal Plain soil strength. Soil Sci. 141(2): 144-148.

Hamlett, J. M., S. W. Melvin, and R. Horton. 1990. Traffic and soil amendment effects on infiltration and compaction. Trans. ASAE 33(3): 821-826.

Mullins, G. L., D. W. Reeves, C. H. Burmester, and H. H. Bryant. 1992. Effect of subsoiling and the deep placement of K on root growth and soil water depletion by cotton. In Proc. Beltwide Cotton Production Research Conf., 1134-1138. Nashville, TN. National Cotton Council.

Petersen, M., P. Ayers and D. Westfall, 2004. Managing Soil Compaction. CSU Cooperative Extension Agriculture No: 0.519.

Raper, R.L. 2005a. Force requirements and soil disruption of straight and bentleg subsoilers for conservation tillage system. Appl. Eng. Agr. 21(5): 787-794.

Raper, R.L. 2005b. Subsoiler shapes for site-specific tillage. Appl. Eng. Agr. 21(1): 25-30.

Raper, R.L., T. E. Grift, and M. Z. Tekeste. 2004. A portable tillage profiler for measuring subsoiling disruption. Trans. ASAE 47(1): 23-27.

Raper, R.L., D. W. Reeves, E. Burt, and H. A. Torbert. 1994. Conservation tillage and traffic effects on soil condition. Trans. ASAE 37(3): 763-768.

Raper, R.L., B.H. Washington, and J.D. Jerrell. 1999. A tractor mounted multiple-probe soil cone penetrometer. Appl. Eng. Agric. 15:287–290.

Saveson, I. L., and Z. F. Lund. 1958. Deep tillage for crop production. Trans. ASAE 2(1):40-42.

Smith, L.A., and J.R. Williford. 1988. Power requirements of conventional, triplex, and parabolic subsoilers. Trans. ASAE 41(6): 1611-1615.

Wells, L. G., T. S. Stombaugh, and S. A. Shearer. 2005. Crop yield response to precision deep tillage. Trans. ASAE 48(3): 895-901.

Vepraskas, M. J., W. J. Busscher, and J. H. Edwards. 1995. Residual effects of deep tillage vs. no-till on corn root growth and grain yield. J. Prod. Agric. 8(3): 401-405.

Host Status of 22 Weed Species to five Meloidogyne spp.

Jimmy Rich
University of Florida
155 Research Road
Quincy, FL 32351
Phone: (850) 875-7130
Fax: (850) 875-7188

Abstract

Root-knot nematodes (Meloidogyne spp.) cause significant crop losses worldwide. The host range of root-knot nematodes in agriculturally important plants is broad and well-defined, but of the hundreds of problematic weeds known worldwide, only about 97 have been identified as hosts of various Meloidogyne spp. Host suitability studies of 22 weed species commonly found in Florida, USA to five root-knot nematode species (Meloidogyne arenaria race 1, M. floridensis, M. incognita race 4, M. javanica race 1and M. mayaguensis) were conducted under greenhouse conditions. Number of eggs/g root were recorded at plant harvest, and a reproduction factor (Rf = final population/initial population) was calculated to determine the host status for each plant species. Nine weed species (Abutilon theophrasti, Amaranthus retroflexus, A. spinosus, Cnidoscolus stimulosus, Cucumis anguria, Dichondra repens, Ipomoea triloba, Leonotis nepetaefolia, and Phytolacca americana) were good hosts (Rf ¡Ý 1) to the five root-knot nematode species evaluated. Non-hosts of the five Meloidogyne spp. were Cassia occidentalis, Crotolaria spectabilis, Dactyloctenium aegyptium, Desmodium purpureum, Digitaria sanguinalis, Panicum dichotomiflorum, Oenothera biennis, Setaria pumila, and Sorghum halepense. Current studies indicate that 12 out of 22 weed species tested are good hosts of at least one of the five root-knot nematode species evaluated.

J. R. Rich, R. Kaur, J. A. Brito and M. V. Barber. University of Florida, IFAS/NFREC, 155 Research Road, Quincy, FL 32351

Reduction of Soil Compaction in a Cotton and Peanut Rotation Using Conservation Systems

R.P.Simoes[1], R.L. Raper[2], F.J. Arriaga[2], K.S. Balkcom[2] and J.N. Shaw[1]

Corresponding author's email address: simoerp@auburn.edu

ABSTRACT

Southern Coastal Plain soils benefit from the adoption of conservation tillage systems as water retention and organic matter increase which improves soil structure. However, some Coastal Plain soils are prone to compaction and tend to form hardpans which restrict root growth and reduce yields. The adoption of non-inversion deep tillage has been recommended to disrupt compacted soil layers and create an adequate medium for crop development. In spite of its efficacy, increased fuel prices have many producers questioning in-row subsoiling as too expensive. This has led to research on development of subsoiler shanks that minimally disrupt soil surface and require reduced horsepower. Three subsoiling implements were evaluated against a no-subsoiled treatment with and without a rye cover crop at the Wiregrass Research Station in Headland, AL on a Dothan loamy sand soil. Plant, soil and machinery parameters were evaluated: crop yield, cover crop biomass, cotton leaf temperature, soil moisture, bulk density, and cone index. Results showed consistently lower yields for no-subsoiled treatments. In one year of the study which was dramatically affected by drought, significantly increased yields were found with the use of a cover crop. No differences between implements were found.

INTRODUCTION

Conservation tillage has been used to reduce soil erosion and decrease production costs worldwide. In the southeastern USA, conservation systems are used on approximately 50% of the 7.2 million acres of cotton (*Gossypium hirsutum L.)* planted in 2004 (CTIC, 2005). Another important southeastern US crop, peanut (*Arachis hypogaea L.*), has shown an increased acreage of 80,000 acres under conservation systems from 2002 to 2004. In 2005, peanut was planted on 1.3 million acres in the Southeast with 55% of the total area being in rotation with cotton (CTIC, 2005).

Southern Coastal Plain soils show benefits when producers adopt conservation systems due to increased water retention, increased organic matter, and improved soil structure (Reeves, 1994; Ess et al.,1998; Raper et al., 2000a; Raper et al., 2000b). However, these soils have a natural susceptibility to compaction and tend to form hardpans extending from the surface Ap to the transitional E horizon, restricting root growth and reducing yields (Busscher et al., 1996; Raper et al., 2005). These hardpans are a product of soil reconsolidation which may occur through multiple cycles of wetting and drying causing the soil bulk density to increase (Mapa et al., 1986; Assouline, 2006). The formation of these hardpans may cause the transition from conventional to no-tillage systems more difficult as deep tillage may always be required.

---

[1] Department of Agronomy and Soils, Auburn University, 36849

[2] USDA-ARS National Soil Dynamics Laboratory, Auburn, AL 36832

The adoption of non-inversion deep tillage has been recommended to disrupt compacted soil layers and create an adequate medium for crop development (Reeder et al., 1993; Khalilian et al., 1988; Raper, 2005). Even though in-row subsoiling has been shown to ameliorate effects of compaction, it is still considered to be an expensive operation, especially with increased fuel prices. Additional research is needed to investigate alternative methods of in-row subsoiling which may reduce energy use and produce optimum crop yields. Additionally, due to the extensive soil disruption that takes place with peanut harvesting, this study will also determine if additional in-row subsoiling is beneficial after this harvesting process.

The objectives of this study were to compare three different subsoiling implements against a strict no-till system where a winter rye crop *(Secale cereale L.)* was used as a cover crop in a four-year cotton-peanut rotation in a highly compactable southern Coastal Plain soil.

MATERIALS AND METHODS

This study started in fall of 2002 at the Wiregrass Research and Extension Center in Headland AL with the planting of a cover crop. The soil type is Dothan fine-loamy, kaolinitic, thermic Plinthic Kandiudults; this soil series is extensive and is distributed throughout the Coastal Plain of Alabama, Florida, Georgia, North Carolina, South Carolina, and Virginia. The site has a 0 to 1% slope and has been cropped for many years under conventional tillage.

The experimental design was a split-plot with four replications and treatments were arranged in a two by four factorial. The two factors were a rye *(Secale cereale L.)* winter cover crop (cover or no cover) and in-row subsoilng (no-till and three subsoiler treatments). In-row subsoiling was implemented at 15 in depth using the following implements: KMC[3] strip-till (Kelley manufacturing Co., Tifton GA); Paratill (Bigham Brothers, Inc., Lubbock, TX); and Terramax Worksaver (Worksaver Inc., Litchfield, IL).

Rye cover crop was sprayed with 1qt/ac of glyphosate and mechanically terminated using a roller prior to spring planting. The variety of peanut planted was Georgia Green in 2003 and 2005, while the variety of cotton planted was the transgenic Delta Pine 555 BG/RR triple stacked for 2004 and 2006. Peanuts and cotton were planted with a John Deere 1700 (Deere & Company, Moline, IL) 4-row vacuum planter. Cotton received 90 lb/ac of nitrogen, 90 lb/ac of potassium and 20 lb/ac of sulfur while the peanut crop received no fertilization.

Volumetric water content was determined using the dielectric method using the ECHO probes (Decagon Devices Inc, Pullman WA) installed in the planted rows at 12 in depth. These probes were connected to an EM5 data logger (Decagon Devices Inc, Pullman WA) recording moisture values for the 2006 growing season. Volumetric water content was collected for the 2006 cotton crop from June to August. These probes were 8 in long and were placed below the planting row at 14 in depth at a 45 degree angle so the depth of reading was from 11 to 16.5 in.

A tractor-mounted, hydraulically-driven, soil cone penetrometer was used for determination of soil strength after subsoiling and planting in 2003, 2004, 2005, and 2006 (Raper et al., 1999).

---

[3] The use of company names or tradenames does not indicate endorsement by Auburn University or USDA-ARS.

The tractor-mounted penetrometer determined soil strength in five positions simultaneously: (i) in-row, (ii) 9 in from the row in the trafficked middle, (iii) 18 in (midway) from the row in the trafficked middle, (iv) 9 in from the row in the nontrafficked middle, and (v) 18 in (midway) from the row in the nontrafficked middle. A cone with a base area of 0.2 sq. in was used on each of the penetrometers (American Society of Agricultural Engineers, 1998).Three readings per plot were taken continuously (25 points per second) throughout the soil profile to a depth of 16 in. The cone index data were then averaged every 2 in for statistical analysis and for graphs.

The same soil sampling unit was used to obtain measurements of bulk density at 2-in depth increments following harvest of the 2006 crop. A total of 45 cores per plot were taken at three positions: (i) in-row, (ii) trafficked middle and (iii) nontrafficked. Within each position, soil bulk density values were taken at the following depths: (i) 0-2 in; (ii) 2-4 in; (iii) 4-6 in; (iv) 8-10 in and (v) 12-14 in.

Cotton leaf temperature was recorded weekly using Raynger MX (Raytek Corporation, Santa Cruz, CA) hand-held infrared thermometer during the 2006 at cotton blooming. Leaf temperature can be correlated to plant moisture stress and consequently grow performance and productivity (Pettigrew, 2004).

Harvesting of cotton consisted of picking the two middle rows with a John Deere 9910 (Deere & Company; Moline, IL) two row cotton harvester. Peanut was harvested with a Hustler 5000 (Gregory Manufacturing, Lewiston Woodville NC) in the two middle rows. The amount of cover crop above-ground biomass was determined prior to termination from 2004 to 2006 by two 2.68 ft^2 area samples from each plot.

Data was subjected to ANOVA using Statistical Analysis System (SAS Institute, 1988), where it was analyzed by year due to the crop rotation. Multiple means comparisons were done by using Fisher's protected LSD and Least Square Means at significance level of $P< 0.1$.

RESULTS AND DISCUSSION

Cover Crop Biomass

The use of winter cover can have a positive impact on soil quality that is accomplished by increasing soil organic matter, aggregate stability, water retention, and consequently reducing soil bulk density and soil strength (table 1). Our results showed that cover crop production was substantially lower in the no-till treatment from 2004 through 2006 compared to any other treatment. However, in 2005, this difference was not statistically significant which could be explained by a shorter growing period for the 2005 year of 175 days. In 2004, the growing season was 189 days and in 2006 it was 185 days. There were no significant differences among the subsoiling implements for any year of the study. These results confirmed the expected outcome that subsoiling increased cover crop production.

Table1. Rye dry matter production as affected by deep tillage.

Subsoiling Treatment	2004	2005	2006
		lb.ac^{-1}	
No-Till	3107 b	2098a	2062 b
Worksaver	4758 a	2544a	3892 a
Strip-Till	4294 ab	2678a	4107 a
Paratill	4035 ab	2437a	3642 a
LSD(0.10)	1303	1142	892

Soil Moisture

Soil moisture results showed that no statistical difference was found among tillage treatments. The presence of a cover crop, however, had a pronounced effect on soil water content (table 2) with much greater soil moisture being present throughout the growing season as compared to the no cover treatment.

Table 2. Soil volumetric water content as affect by rye cover crop for the 2006 cropping season.

	Volumetric water content %		
Week	Cover	No cover	LSD (0.10)
29-Jun	21.2	17.6	NS
6-Jul	22.5	17.7	3.7
13-Jul	21.4	15.3	3.9
20-Jul	19.0	13.9	4.3
27-Jul	21.3	16.1	3.5
3-Aug	20.0	15.1	3.7
10-Aug	20.3	15.3	4.0
17-Aug	18.0	13.7	3.5
24-Aug	17.0	13.7	NS

Soil Compaction

Only the data from the most recent cone index sampling for each crop will be shown. The data presented was taken immediately after in-row subsoiling was completed in the spring. There were no significant main effects despite the clear differences in the graphs that showed that no-till treatment had the greatest compaction based on increased cone index values (figs. 1 and 2). However, an important interaction occurred involving depth x position x subsoiling for both crops ($P < 0.0001$ for cotton and $P < 0.0001$ for peanuts). These graphs show that subsoiling effectively reduced soil compaction. Paying particular attention to the in-row position for cotton (fig. 1), it is clear that the cone index for the no-till tillage treatment is much greater than any of the other tillage treatments that received subsoiling. As an example, at the 4 in depth the no-till treatment had cone index of 532 psi which was significantly greater than any of the other in-row subsoiling treatments; KMC strip-till (130 psi), Paratill (209 psi), and Worksaver (178 psi). These values confirm that in-row subsoiling was effective in reducing soil strength to below 290 psi which is considered to be detrimental to cotton root development (Taylor and Gardner, 1963).

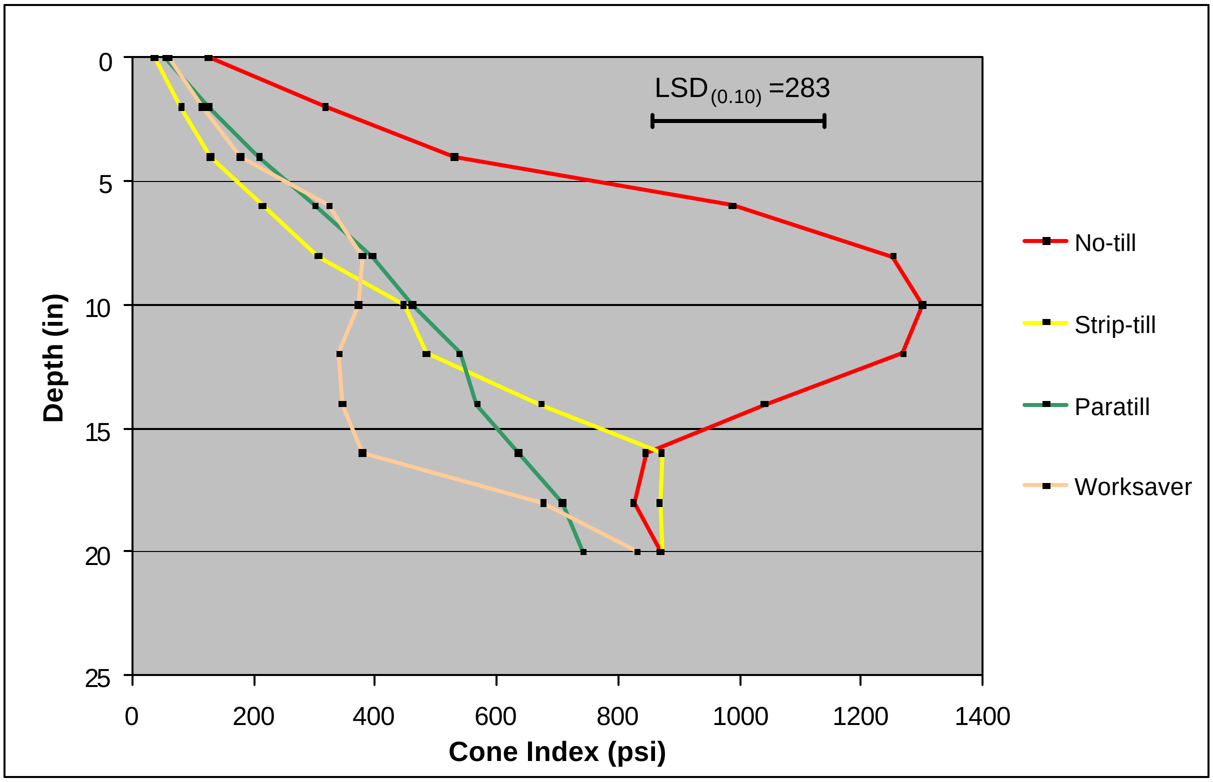


Figure1. Soil cone index values at in-row position for cotton in 2006.

Similar information for cone index for peanut is shown in figure 2. The no-till treatment had the highest values of cone index which reached the limiting value of 290 psi at an approximate depth of 5 in for the in-row position. As an example, at the 6 in depth we observed that the no-till treatment had cone index value of 702 psi which was significantly greater than either the KMC strip-till (20 psi), the Paratill (249 psi) or the Worksaver (24 psi). Coincidentally, the LSD values were nearly the same for peanut and cotton analysis.

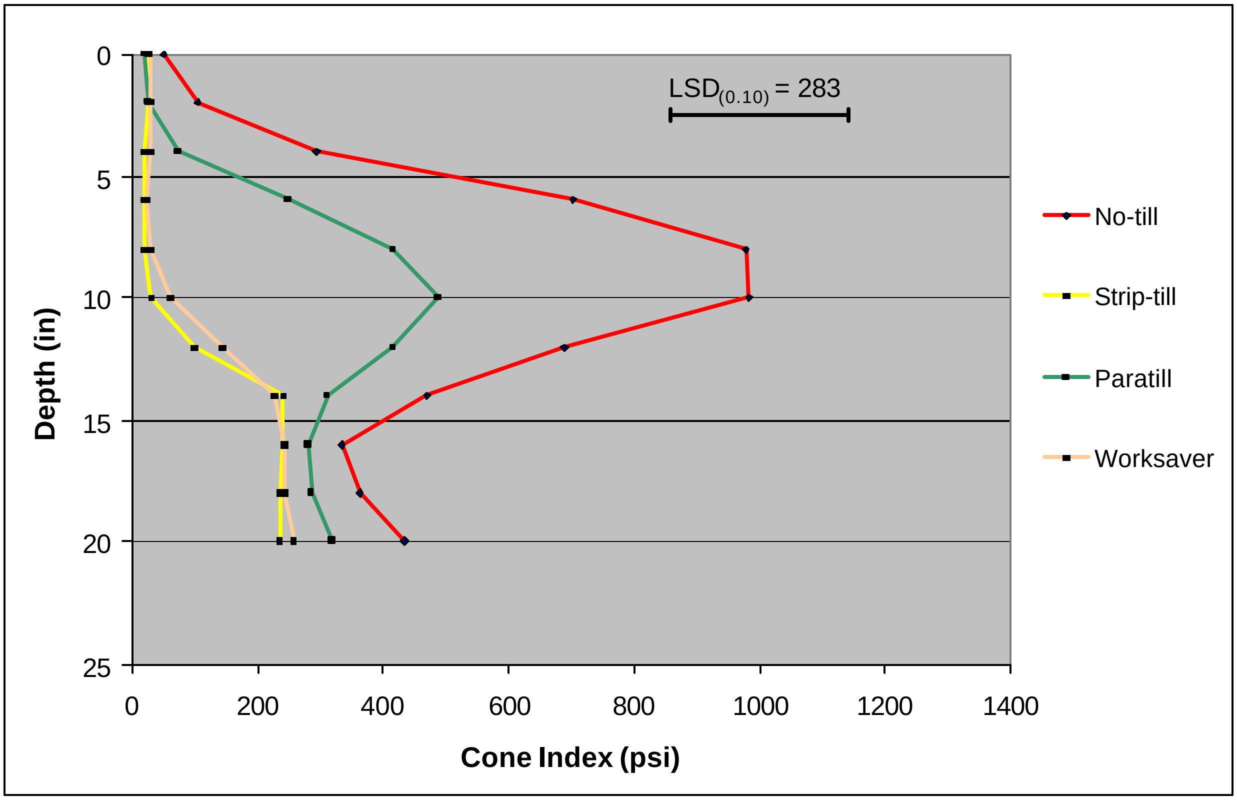


Figure 2. Soil cone index values at in-row position for peanuts in 2005.

Bulk density was affected by subsoiling treatment ($P<0.0002$), position ($P<0.0001$) and depth ($P<0.0001$). The overall means for no-till were significantly higher than any of the subsoiled treatments (table 3).

Table 3. Bulk density by subsoiling treatment

Subsoiling treatment	Bulk density, g cm^{-3}
No-Till	1.918a
Strip-Till	1.878b
Paratill	1.869b
Worksaver	1.863b
LSD(0.10)	0.015

Also, significant interactions between cover and treatment ($P < 0.0951$) and treatment and depth ($P < 0.010$) were found. Due to its important effect on root growth, the in-row bulk density values that had a cover crop were investigated further (fig. 3). The no-till tillage treatment had the highest values of bulk density especially below depths of 5 in. The KMC strip-till had the minimum values of bulk density above 6 inches that could be attributed to its design of being a straight-leg subsoiler. The bent-leg subsoilers like the Paratill and the Worksaver were designed to cause minimal surface disturbance and may not disrupt the soil in the in-row position quite as effectively as the KMC strip-till.

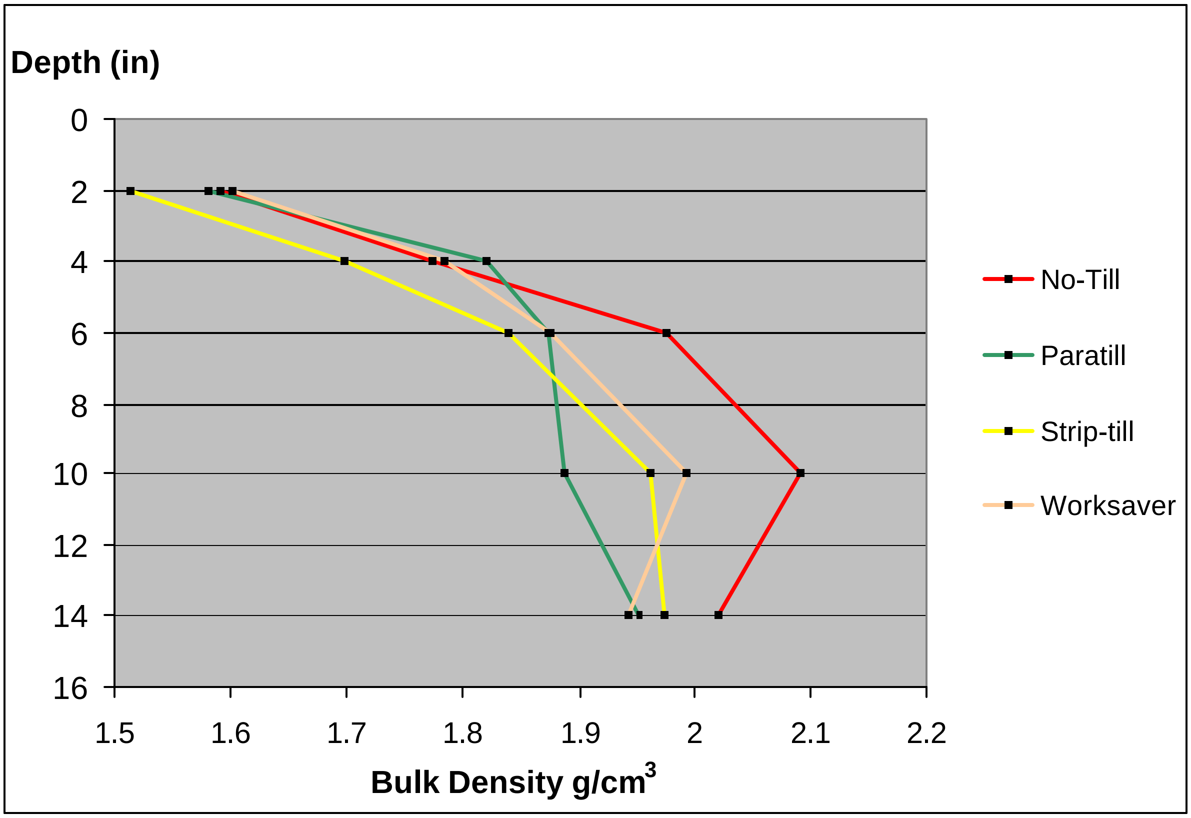


Figure 3. In-row bulk density with a cover crop as affected by subsoiling treatment.

Cotton Leaf Temperature

There was no statistical significance for cotton leaf temperature for subsoiling treatments. However, the cover crop had a positive effect in lowering leaf temperature as shown in table 4. This could be related to increased soil moisture provided by the cover crop that prevented plant stress and reduced leaf temperature (table 2).

Table 4. Cotton leaf temperature affected by cover crop.

Date	Cover °F	No-cover °F	LSD (0.10)
18-Jul	94.89	97.01	1.67
28-Jul	91.95	94.31	0.97
7-Aug	89.18	89.78	1.00 ns
17-Aug	85.74	87.63	0.55

Seed Cotton and Peanut Yield

Results showed that subsoiling treatments significantly increased yields for peanuts and cotton in 2004 ($P<0.001$), 2005 ($P<0.0003$) and 2006 ($P<0.0003$). Crop yields for no-till treatment were the lowest in every year but 2003 when no-till had the highest peanut production (although not significant). The 2003 peanut crop had abundant rain (fig. 4) from April to October where precipitation was approximately 37 in. (Optimal peanut production water requirements are normally approximately 20 to 30 in, Baker et al., 2000). Paratilling also produced the highest yields from 2004 to 2006 although they were not statistically different from the other in-row subsoiling treatments.

Table 5. Peanut and cotton seed yield by treatment.

Subsoiling Treatment	2003 Peanut	2004 Cotton	2005 Peanut	2006 Cotton
	lb ac^{-1}			
No-Till	4367a	1956b	1728b	1337c
Worksaver	4212a	2809a	2838a	1838b
Strip-till	3654a	2886a	2795a	2165ab
Paratill	3531a	2940a	3179a	2332a
LSD(0.10)	NS	295	478	329

The effect of the cover crop on crop yield was only significant for the 2006 cotton crop when a severe drought hit the Southeastern states and Alabama farmers suffered great losses. During 2006, in the period of April to October, the total precipitation was 19 in which is 28% below the minimum requirement for cotton (27.5 in; Brouwer, 1986). The cover crop significantly ($P<0.013$) increased cotton seed yield in 2006 with 2139 lb ac^{-1} versus 1900 lb ac^{-1} for rye cover and no-cover, respectively. The results suggest that cover crop benefits were especially important when water was the limiting factor. This conclusion concurred with results for soil moisture obtained in 2006 which indicated significantly increased volumetric water under a cover crop (table 2).

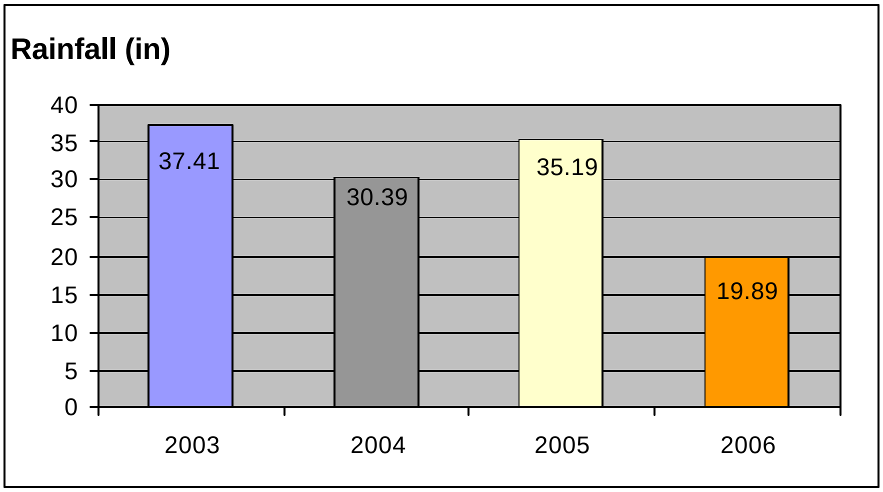


Figure 4. Cumulative precipitation at Wiregrass Research Station from April to October

CONCLUSIONS

1. In-row subsoiling was particularly effective in reducing soil compaction as measured by cone index values and bulk density. Consequently, cash and cover productivity were also increased by in-row subsoiling regardless of the implement model.

2. The cover crop increased volumetric water content and lowered cotton leaf temperature. During an especially dry year of 2006, the cover crop also was responsible increased soil moisture and for significantly increasing cotton yield.

3. We conclude that subsoiling is an indispensable practice for obtaining satisfactory productivity in southern Coastal Plain soils and should be coupled with a winter cover crop which can increase yield, especially during a summer drought.

REFERENCES

American Society of Agricultural Engineers. 1998. ASAE Standards, engineering, and data. ASAE Standard S313.2. ASAE, St. Joseph, MI.

Assouline, S. 2006. Modeling the relationship between soil bulk density and the water retention curve. Vadose Zone J. 5:554–563 (2006).

Baker, R.D., R.G. Taylor, and F. McAlister. 2000. Peanut Production Guide H-648. http://cahe.nmsu.edu/pubs/_h/h-648.html New Mexico State University, accessed 5/11/2007.

Brouwer, C**.** 1986. FAO Irrigation Water Management Training Manual No. 3 http://www.fao.org/docrep/S2022E/s2022e02.htm , accessed 5/1/2007.

Busscher, W.J., P.J. Bauer, D.W. Reeves, G.W. Langdale, and E.C. Burt**.** 1996. Minimum tillage cultivation in a hardpan soil**.** Proceedings of the 19th Annual Southern Conservation Tillage Conference for Sustainable Agriculture, Jackson, Tennessee.

CTIC. 2005. National crop residue management survey. Conservation Technology Information Center, West Lafayette, IN.

Ess, D. R., D. H. Vaughan, and J. V. Perumpral. 1998. Crop residue and root effects on soil compaction. Trans. ASAE 41(5): 1271-1275.

Khalilian, A., T.H. Garner, H.L. Musen, R.B. Dodd, and S.A. Hale. 1988. Energy for conservation tillage in Coastal Plain soils. Trans. ASAE 31(5):1333-1337.

Mapa, R.B., R.E. Green, and L. Santo. 1986. Temporal variability of soil hydraulic properties with wetting and drying subsequent to tillage. Soil Sci. Soc. Am. J. 50:1133–1138.

Pettigrew, W.T. 2004. Physiological Consequences of Moisture Deficit Stress in Cotton. Crop Sci. 44:1265–1272.

Raper, R.L. 2005. Agricultural traffic effects on soil. J. Terramechanics 42(3-4):259-280.

Raper, R. L., D. W. Reeves, C. H. Burmester, and E. B. Schwab. 2000a. Tillage depth, tillage timing, and cover crop effects on cotton yield, soil strength, and tillage energy requirements. Appl. Eng. Agric.16(4): 379-385.

Raper, R. L., D. W. Reeves, E. B. Schwab, and C. H. Burmester. 2000b. Reducing soil compaction of Tennessee Valley soils in conservation tillage systems. J. Cotton Sci. 4(2): 84-90.

Raper, R. L., D. W. Reeves, J.N. Shaw, E. van Santen, P.L. Mask. 2005. Using site-specific subsoiling to minimize draft and optimize corn yields. Trans ASAE. Vol. 48(6): 2047-2052.

Raper, R.L., B.H. Washington, and J.D. Jerrell. 1999. A tractor mounted multiple-probe soil cone penetrometer. Appl. Eng. Agric. 15(4):287–290.

Reeder, R.C., R.K.Wood, and C.L. Finck. 1993. Five subsoiler designs and their effects on soil properties and crop yields. Trans. ASAE 36(6):1525–1531.

Reeves, D. W. 1994. Cover crops and rotations. In Advances in Soil Science: Crops Residue Management, ed. J. L. Hatfield and B.A. Stewart, 125-172. Boca Raton, Fla.: Lewis Publishers.

SAS Institute. 1988. SAS/STAT User's Guide. Version 9.1. SAS Inst., Cary, NC.

Taylor, H. M. and H.R. Gardner. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content and strength of soil. Soil Sci. J. 96(3):153-156.

EFFECTS OF ELEVATED ATMOSPHERIC CO_2 ON SOIL CO_2 EFFLUX IN CONVENTIONAL AND CONSERVATION CROPPING SYSTEMS

G.B. Runion, S.A. Prior, H.H. Rogers, H.A. Torbert
USDA-ARS National Soil Dynamics Laboratory
411 S. Donahue Drive, Auburn, Alabama 36832

Author for correspondence
G. Brett Runion
USDA-ARS, National Soil Dynamics Laboratory
411 S. Donahue Drive
Auburn, Alabama 36832
tel: 334 844 4517
fax: 334 887 8597
email: gbrunion@ars.usda.gov

ABSTRACT

Elevated atmospheric carbon dioxide (CO_2) can affect both the quantity and quality of plant tissues produced, which will impact the cycling and storage of carbon (C) within plant/soil systems and thus the rate of CO_2 release back to the atmosphere. Research is needed to more accurately quantify the effects of elevated CO_2 and associated feedbacks on soil CO_2 efflux in order to predict the potential of terrestrial ecosystems to sequester C. Effects of elevated atmospheric CO_2 on soil CO_2 efflux were examined in a long-term study comparing row crops managed as either a conventional or a conservation tillage system. In the conventional system, grain sorghum and soybean were rotated each year using conventional tillage practices and winter fallow. The conservation system also uses a grain sorghum-soybean rotation, with three winter cover crops: wheat, crimson clover, and sunn hemp which were also rotated. All crops in the conservation system were grown using "no-till" practices. Plants were exposed to either 365 ppm (ambient) or 725 ppm (elevated) levels of atmospheric CO_2 using open top field chambers. Soil CO_2 efflux, over a full two-year cropping cycle, was increased by both elevated atmospheric CO_2 and by conservation management; these increases were due, primarily, to increased biomass inputs from these treatments. Implications of these data on soil carbon storage in these systems will be discussed.

INTRODUCTION

Carbon dioxide is the first molecular link from atmosphere to biosphere. It is essential for photosynthesis which sustains the entire food chain. No substance is more pivotal for ecosystems, either natural or managed. The increasing CO_2 content of the atmosphere may be the most significant change taking place on the earth today. Atmospheric CO_2 concentration has risen well over 30% in past two centuries since the onset of the Industrial Revolution in the late 18th century. The steady increase in CO_2 (along with increases in other greenhouse gases such as methane and nitrous oxide) has led to many predicted results and unknown outcomes with regard to changes in global climate, particularly warming. The general enhancement of crop growth brought about by increased levels of CO_2 suggests that CO_2 removed from the atmosphere by plants and stored in the soil could help to mitigate global climate change. The amount of CO_2 taken up from the air and its subsequent sequestration in the soil is important, but so is the amount lost through soil respiration. The management of the crop, its residue, and the soil will play a key role in rate of efflux of CO_2 from soil respiration.

As the ability of terrestrial ecosystems to store C in biomass and in soil is not based solely on net primary productivity (Cardon ,1996), elevated atmospheric CO_2 may also influence terrestrial ecosystem C storage through its effects on plant tissue quality, which will impact soil microbes, decomposition processes, and subsequent soil C storage. Plant tissue produced under high levels of CO_2 often has higher C:N ratios (Mellilo, 1983; Prior et al., 1997b) and may be structurally different, with alterations in leaf anatomy (Thomas and Harvey, 1983) and epicuticular waxes (Graham and Nobel, 1996; Prior et al., 1997a). Plants grown under elevated CO_2 also may exhibit altered tissue chemistry, including lower N concentrations (Norby et al., 1986; Runion et al., 1999), higher concentrations of carbohydrates (Yelle et al., 1989; Runion et al., 1999), and increased levels of defense compounds such as phenolics (Lindroth et al., 1993; Pritchard et al., 1997).

The fate of C within crop systems is affected by the full biological chain of events starting with transfer of C from air to leaf, transformation within the plant, translocation within the plant/soil system, return of plant residue to the soil, decomposition, and is impacted by the effects of other environmental factors (e.g., temperature, nutrients, and water) on these processes. Therefore, the ability of terrestrial ecosystems to sequester C will depend on the cycling of C among the various biomass and soil pools and on the residence time of the C in these pools (Hungate et al., 1997).

At many stages in the cycling of C within terrestrial ecosystems, CO_2 is transferred back to the atmosphere by both autotrophic and heterotrophic respiration. Soil respiration is a significant source of CO_2 efflux from terrestrial ecosystems to the atmosphere (Schlesinger and Andrews, 2000), with global estimates ranging from 68 Pg C yr^{-1} (Raich and Schlesinger, 1992) to 100 Pg C yr^{-1} (Musselman and Fox, 1991). Therefore, even small shifts in soil CO_2 efflux could have major implications for increasing or decreasing atmospheric CO_2 concentration and its potential impacts on global climate change (Rustad et al., 2000). Through its impact on the quantity and quality of C within the plant and soil system, elevated CO_2 can affect this feedback of C to the atmosphere. For example, an increase in root growth under elevated CO_2 could increase root respiration (Ball and Drake, 1998), while changes in root exudation and/or quality of high CO_2-grown plant material might enhance (Luo et al., 1996; Hungate et al., 1997) or suppress (Prior et al., 1997b; Ineson et al., 1998) microbial respiration. The combined effects on total soil CO_2 respired back to the atmosphere, and the potential for C sequestration, are difficult to predict.

A recent review of soil and microbial respiration demonstrates that elevated atmospheric CO_2 generally increases belowground respiration, with overall estimates ranging from 40-50 % for soil respiration and

20-35 % for microbial respiration (Zak et al., 2000); these estimates are in agreement with another review which reported an overall increase of 37 % for forest species (Janssens and Ceulemans, 2000). Other studies report stimulation of root or total soil respiration for plants growing under elevated CO_2 in the range of 15-50% (Gifford et al., 1985; Nakayama et al., 1994; Verburg, 1998), with even greater stimulation reported in some cases (Griffin et al., 1997; Vose et al., 1997). Enhanced root or soil respiration under high CO_2 is often related to increases in root biomass, i.e., autotrophic respiration (Nakayama et al., 1994; Vose et al., 1997; Griffin et al., 1997; Zak et al., 2000) and/or increases in the size or activity of the microbial community, i.e., heterotrophic respiration (Nakayama et al., 1994; Rice et al., 1994; Vose et al., 1997; Zak et al., 2000). However, elevated CO_2 has been shown to suppress soil respiration in some cases (Gifford et al., 1985; Ineson et al., 1998) or to have no effect in others (Oberbauer et al., 1986; Johnson et al., 2001). Soil CO_2 efflux can be highly variable on temporal and spatial scales within a single field experiment (Nakayama et al., 1994; Xu and Qi, 2001) and among experiments; therefore, even relatively large increases in soil efflux under elevated CO_2 may not be statistically significant (Zak et al., 2000). Some of the variation among individual studies may be due to differences in plant species, experimental conditions, or methods used for the determination of CO_2 efflux.

A major drawback of most methods for determining soil CO_2 efflux concerns the timescale of measurements (i.e., cumulative totals across hours to days with NaOH traps or discreet points in time with soil collars and gas exchange devises); efflux between measurement periods is then generally assumed to be linearly integrative across the intervening time periods (Nakayama et al., 1994; Vose et al., 1997). Given the variation in response of soil CO_2 efflux to elevated atmospheric CO_2 and the drawbacks of current measurement technology, more research is needed before we can confidently predict the impacts of elevated atmospheric CO_2 on the ability of terrestrial ecosystems to sequester C. The objective of this experiment was to assess the response of soil CO_2 efflux (root plus microbial respiration) to atmospheric CO_2 enrichment of two cropping systemsB conventional and conservationBusing a novel, continuous, CO_2 efflux monitoring system.

MATERIALS AND METHODS

The research on efflux of soil CO_2 is being conducted within open top chambers on soil bin facilities at the USDA-ARS National Soil Dynamics Laboratory (NSDL). A ten-year study comparing conventional and conservation tillage systems exposed to controlled levels of atmospheric CO_2 is underway. We are nearing completion of the fifth two-year cropping cycle. In the conventional system, grain sorghum (*Sorghum bicolor* L. Moench) and soybean (*Glycine max* L. Merr.) are being rotated each year using conventional tillage practices and winter fallow. The conservation system also uses a grain sorghum-soybean rotation, with three winter cover crops (wheat (*Triticum aestivum* L.), crimson clover (*Trifolium incarnatum* L.), and sun hemp (*Crotalaria juncea* L.)) which are also rotated. All crops in the conservation system are grown using "no-till" practices. The wheat serves as cover as well as a grain crop. These five species offer contrasting characteristics with respect to photosynthetic pathways (C_3 and C_4), responses to CO_2, rooting patterns, N_2-fixation, decomposition rates, and their impact on soil C and N cycling; most are prominent the world over.

Two levels of atmospheric CO_2 (ambient = 365 ppm or elevated = 725 ppm) will be used for exposure of both cropping systems; exposures will run 24 hours per day throughout the entire growing season. Open top chambers (10 ft diameter), with state-of-the-art data acquisition and processing, are used for exposure. In addition, ambient plots (without chambers) have been included as a check on chamber effects. For the study, plots have been established along the length of an outdoor soil bin (20 ft X 250 ft X 6 ft deep) filled with a Decatur silt loam soil (clayey, kaolinitic, thermic Rhodic Paleudults).

The design is a split-plot with three blocks; one-half of each block is being managed as a conventional system and the other half as a conservation system. Split-plot treatments (CO_2 level) were randomly assigned within blocks. All statistical analyses will be performed using mixed model procedures (Proc Mixed) of the Statistical Analysis System (Littell et al., 1996).

Soil CO_2 efflux was measured using the Automated Carbon Efflux System (ACES) (U.S. patent # 6,692,970), developed at USDA Forest Service, Southern Research Station Laboratory in Research Triangle Park, NC; a description of the ACES has been previously reported (Butnor et al., 2003). Briefly, ACES is a chamber-based, multi-port respiration measurement system, which uses open system, dynamic soil respiration chambers measuring 9.8 in diameter (76 in^2) equipped with air and soil thermocouples (soil thermocouples were inserted to depth of 2 in). The soil chambers are designed with pressure equilibration ports to ensure that differences in chamber pressure do not compromise the quality of the respiration measurement (Fang and Moncrieff, 1996). Each ACES has 15 sample chambers and one null calibration chamber which are measured sequentially for 10 minutes each, allowing a complete run every 2 hours and 40 minutes or nine complete runs per day. When not being actively sampled, all chambers are refreshed with reference air to prevent buildup of CO_2. The ACES units constructed for our study were modified to allow use of reference air from two sources, owing to the differential atmospheric CO_2 concentrations employed; soil chambers in ambient CO_2 open top chambers were refreshed with ambient CO_2 air, while those in elevated open top chambers were refreshed with elevated CO_2 air. Ambient CO_2 reference air was obtained by placing an air compressor in an additional, empty, ambient open top chamber located on an adjacent soil bay and using the same CO_2 delivery system as the main study; elevated CO_2 reference air was similarly obtained by placing a second air compressor in an additional, empty, elevated open top chamber. The air compressors replace the ballast tanks commonly used with the ACES, which provide reference air for the ACES that is buffered against fluctuations in atmospheric CO_2 concentration (Butnor et al., 2003).

Constraints on distance between soil respiration chambers and the main ACES unit (housing the infra-red gas analyzer and data logger) necessitated use of two ACES units in this study; one was used for blocks 1-3, and a second for blocks 4-6. Two soil chambers were placed into each of the 12 open top chambers; the three additional soil chambers for each system were placed outside of open top chambers. Calibration chambers were placed into the ambient open top chamber nearest each main ACES unit. A soil moisture probe was placed adjacent to each calibration chamber and inserted to a depth of 8 in.

To minimize the effect of precipitation exclusion on the soil substrate within the soil chambers, soil chambers were moved every 3-4 days between two sample points (A and B) within each open top chamber. Litter on the soil surface was not removed from each sample point, but all points were kept free of live vegetation. The ACES units were installed on November 9, 2001, at the beginning of the second two-year cycle following planting of clover. The ACES units have run continuously (with the exception of brief periods for maintenance or due to system/power failures) since this date; however, data presented here include only the complete second cycle which ran through October 20, 2003 at which time soybean plants were harvested.

RESULTS AND DISCUSSION

Soil CO_2 efflux, over the full two-year cropping cycle, was increased by both elevated atmospheric CO_2 and by conservation management; in both cases soil CO_2 efflux was increased by approximately 50 % due to these treatments. This increase is consistent with other reports in the literature (Gifford et al., 1985; Nakayama et al., 1994; Verburg, 1998). While the combination of elevated CO_2 and conservation management did result in the greatest soil CO_2 efflux, the effects of these two treatments were not additive.

It is obvious that the conservation system would have higher CO_2 efflux during periods when cover crops were being grown, as the conventional plots were fallow (with the exception of weed invasion) during these periods. In fact, soil CO_2 efflux in the conservation system was sometimes 100+ % greater in the conservation than the conventional system during these periods. Autotrophic (cover crop vs. weed) respiration was likely primarily responsible for the differences in soil CO_2 efflux noted during these periods. However, heterotrophic (soil microbe) respiration might have added to the differences due to increased residue inputs in the conservation system. Soil CO_2 efflux was also greater in the conservation system during primary row crop (i.e., sorghum and soybean) production periods; these increases were most likely a result of differences in heterotrophic respiration due to the increased residue inputs occurring in the conservation system.

Elevated atmospheric CO_2 also increased soil CO_2 efflux in both the conservation and the conventional systems. Exposure to elevated CO_2 increased growth for all crops. These larger plants had larger root systems, which implies an increase in autotrophic respiration. However, increased plant growth led to greater plant residues returned to the soil (as well as a potential for increased root exudation) which implies larger amounts of substrate for microbial decomposition and, thus, an increase in heterotrophic respiration.

Increased efflux of CO_2 from soils to the atmosphere adds to the continually rising concentration of atmospheric CO_2. However, despite higher levels of soil CO_2 efflux, these systems may still increase soil C sequestration and contribute to mitigation of the rising atmospheric CO_2 concentration. Although this may appear contradictory, the total amount of C fixed by plants, either due to elevated atmospheric CO_2 and/or use of no-till management with cover crops (as in our conservation system) can far exceed that released back to the atmosphere as soil CO_2 efflux; we observed this same effect in a previous study with longleaf pine (Runion et al, 2007).

REFERENCES

Ball, A.S. and B.G. Drake. 1998. Stimulation of soil respiration by carbon dioxide enrichment of marsh vegetation. Soil Biol. Biochem. 30:1203-1205.

Butnor, J.R., K.H. Johnsen, R. Oren and G.G. Katul. 2003. Reduction of forest floor respiration by fertilization on both carbon dioxide-enriched and reference 17-year-old loblolly pine stands. Global Change Biol. 9:849-861.

Cardon, Z.G. 1996. Influence of rhizodeposition under elevated CO_2 on plant nutrition and soil organic matter. Plant Soil 187:277-288.

Fang, C. and J.B. Moncrieff. 1996. An improved dynamic chamber technique for measuring CO_2 efflux from the surface of soil. Func. Ecol. 10:297-305.

Gifford, R.M., H. Lambers and J.I.L. Morison. 1985. Respiration of crop species under CO_2 enrichment. Physiol. Plant. 63:351-356.

Graham, E.A. and P.S. Nobel. 1996. Long-term effects of a doubled atmospheric CO_2 concentration on the CAM species *Agave deserti.* J. Exp. Bot. 47:61-69.

Griffin, K.L., M.A. Bashkin, R.B. Thomas and B.R. Strain. 1997. Interactive effects of soil nitrogen and atmospheric carbon dioxide on root/rhizosphere carbon dioxide efflux from loblolly and ponderosa pine seedlings. Plant Soil 190:11-18.

Hungate, B.A., E.A. Holland, R.B. Jackson, F.S. Chapin III, H.A. Mooney and C.B. Field. 1997. The fate of carbon in grasslands under carbon dioxide enrichment. Nature 388:576-579.

Ineson, P., P.A. Coward and U.A. Hartwig. 1998. Soil gas fluxes of N_2O, CH_4 and CO_2 beneath *Lolium perenne* under elevated CO_2: the Swiss free air carbon dioxide enrichment experiment. Plant Soil 198:89-95.

Janssens, I.A. and R. Ceulemans. 2000. The response of soil CO_2 efflux under trees grown in elevated atmospheric CO_2: a literature review. Phyton (Horn). 40:97-101.

Johnson, D.W., B.A. Hungate, P. Dijkstra, G. Hymus and B. Drake. 2001. Effects of elevated carbon dioxide on soils in a Florida scrub oak ecosystem. J. Environ. Qual 30:501-507.

Lindroth, R.L., K.K. Kinney and C.L. Platz. 1993. Responses of deciduous trees to elevated atmospheric CO_2: productivity, phytochemistry, and insect performance. Ecol. 74:763-777.

Littell, R.C., G.A. Milliken, W.W. Stroup and R.D. Wolfinger. 1996. SAS System for Mixed Models, SAS Institute, Inc., Cary, NC. 633 p.

Luo, Y., R.B. Jackson, C.B. Field and H.A. Mooney. 1996. Elevated CO_2 increases belowground respiration in California grasslands. Oecologia 108:130-137.

Mellilo, J.M. 1983. Will increases in atmospheric CO_2 concentrations affect decay processes? pp. 10-11. *In:* Ecosystems Center Annual Report, Marine Biology Laboratory, Woods Hole, MA.

Musselman, R.C. and D.G. Fox. 1991. A review of the role of temperate forests in the global CO_2 balance. J. Air Waste Manage. Assoc. 41:798-807.

Nakayama, F.S., G. Huluka, B.A. Kimball, K.F. Lewin, J. Nagy and G.R. Hendrey. 1994. Soil carbon dioxide fluxes in natural and CO_2-enriched systems. Agric. For. Meteor. 70:131-140.

Norby, R.J., E.G. O'Neill and R.J. Luxmoore. 1986. Effects of atmospheric CO_2 enrichment on the growth and mineral nutrition of *Quercus alba* seedlings in nutrient-poor soil. Plant Physiol. 82:83-89.

Oberbauer, S.F., W.C. Oechel and G.H. Riechers. 1986. Soil respiration of Alaskan tundra at elevated atmospheric carbon dioxide concentrations. Plant Soil 96:145-148.

Prior, S.A., S.G. Pritchard, G.B. Runion, H.H. Rogers and R.J. Mitchell. 1997a. Influence of atmospheric CO_2 enrichment, soil N, and water stress on needle surface wax formation in *Pinus palustris* (Pinaceae). Amer. J. Bot. 84:1070-1077.

Prior, S.A., H.H. Rogers, G.B. Runion, H.A. Torbert and D.C. Reicosky. 1997b. Carbon dioxide-enriched agroecosystems: influence of tillage on short-term soil carbon dioxide efflux. J. Environ. Qual. 26:244-252.

Pritchard, S., C. Peterson, G.B. Runion, S. Prior and H. Rogers. 1997. Atmospheric CO_2 concentration, N availability, and water status affect patterns of ergastic substance deposition in longleaf pine (*Pinus palustris* Mill.) foliage. Trees 11:494-503.

Raich, J.W. and W.H. Schlesinger. 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus 44:81-89.

Rice, C.W., F.O. Garci, C.O. Hampton and C.E. Owensby. 1994. Soil microbial response in tallgrass prairie to elevated CO_2. Plant Soil 165:67-74.

Runion, G.B., J.R. Butnor, S.A. Prior, R.J. Mitchell, H.A. Torbert, M.A. Davis, S.G. Pritchard, H.H. Rogers, and K.H. Johnsen. 2007. Elevated atmospheric CO_2 increases soil respiration in a model regenerating longleaf pine ecosystem. J. Environ. Qual. (Submitted).

Runion, G.B., J.A. Entry, S.A. Prior, R.J. Mitchell and H.H. Rogers. 1999. Tissue chemistry and carbon allocation in seedlings of *Pinus palustris* subjected to elevated atmospheric CO_2 and water stress. Tree Physiol. 19:329-335.

Rustad, L.E., T.G. Huntington and R.D. Boone. 2000. Controls on soil respiration: implications for climate change. Biogeochem. 48:1-6.

Schlesinger, W.H. and J.A. Andrews. 2000. Soil respiration and the global carbon cycle. Biogeochem. 48:7-20.

Thomas, J.F., and C.N. Harvey. 1983. Leaf anatomy of four species grown under continuous CO_2 enrichment. Bot. Gaz. 144:303-309.

Verburg, P.S.J., A. Gorissen and W.J. Arp. 1998. Carbon allocation and decomposition of root-derived organic matter in a plant-soil system of *Calluna vulgaris* as affected by elevated CO_2. Soil Biol. Biochem. 30:1251-1258.

Vose, J.M., K.J. Elliot, D.W. Johnson, D.T. Tingey and M.G. Johnson. 1997. Soil respiration response to three years of elevated CO_2 and N fertilization in ponderosa pine (*Pinus ponderosa* Doug. ex Laws.). Plant Soil 190:19-28.

Xu, M. and Y. Qi. 2001. Soil-surface CO_2 efflux and its spatial and temporal variations in a young ponderosa pine plantation in northern California. Global Change Biol. 7:667-677.

Yelle, S., R.C. Beeson Jr., M.J. Trudel and A. Gosselin. 1989. Acclimation of two tomato species to high atmospheric CO_2. I. Starch and sugar concentrations. Plant Physiol. 90:1465-1472.

Zak, D.R., K.S. Pregitzer, J.S. King and W.E. Holmes. 2000. Elevated atmospheric CO_2, fine roots and the respnse of soil microorganisms: a review and hypothesis. New Phytol. 147:201-222.

INTEGRATING CATTLE IN A SOUTHERN PIEDMONT CONSERVATION TILLAGE COTTON-COVER CROP SYSTEM

Harry H. Schomberg, D. Wayne Reeves, Dwight S. Fisher, Randy L. Raper, Dinku M. Endale, and Michael B. Jenkins.
USDA-ARS J. Phil Campbell, Sr., Natural Resource Conservation Center in Watkinsville, GA
harry.schomberg@ars.usda.gov

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 directly influence water infiltration 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). The degree of 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 profile soil water content 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 (Endale et al., 2006). Other factors influencing soil response to cattle may also be spatially variable but need to be quantified before management strategies can be developed to both reduce compaction initially and apply ameliorative remedies on a spatial basis. By identifying important spatially variable factors, the potential exists to combine new technologies for evaluating spatial variability with GPS technology and in cab GIS maps to identify management zones requiring deep tillage. Performing deep tillage only on areas with a high probability of compaction would therefore reduce producer costs.

Our objectives were to evaluate on a spatial scale the impact of cattle grazing winter annual small grains on (1) cotton and (2) animal production and (3) soil compaction. We measured a number of spatially distributed soil and plant properties to identify those that might easily be combined to define management zones for applying remedies for soil compaction.

MATERIALS AND METHODS

This study started in the fall of 2005 and will continue over three cotton growing seasons (2006-2008). 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 (*Gossipium hirsutum* L.) and supplemental N is added as needed for cotton and rye. On two fields, rye is grazed with heifer cattle for 10 to 14 days starting in late-March. The other two fields are not grazed and the rye is killed with glyphosate the second week of April. Cattle in the grazing treatment are weighed at the beginning and end of the grazing period. Stocking rate is established based on forage availability and estimated intake so that pastures are defoliated in approximately 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. 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.

Prior to planting in the fall of 2006, we sampled the fields using standard soil survey characterization techniques on a 12-m by 12-m grid (˜ 10 points acre^{-1}) using a trailer mounted hydraulic sampler equipped with Differential Global Positioning System (DGPS) to determine soil characteristics. Soil cores were 5 cm diameter by 60 cm depth and are being characterized for soil texture, soil C, soil N, depth to the Bt layer, and plant nutrients by depth. Soil electrical conductivity (EC) was determined with a Veris Technologies 3100 Soil Electrical Conductivity Mapping system equipped with DGPS. Soil penetration resistance was measured using a tractor mounted penetrometer with DGPS. Soil type, EC data, depth to Bt, and soil penetrometer data are being combined in a Geographic Information System (GIS) for developing plant sampling zones for the second cotton growing season.

To determine the cumulative grazing effects on soil compaction, soil penetration resistance measurements are repeated each year at the same locations in the spring following cotton planting. Geostatistical methods will be used to analyze soil, water, and plant data to determine landscape and grazing effects on cotton productivity. At the end of the study, soil samples will be collected from the 0 to 5 and 5 to 10 cm depths to evaluate changes in soil C and soil quality parameters (particulate soil carbon and nitrogen, soil microbial biomass, aggregate stability).

The data will also be used to develop guidelines for decisions on subsoiling after cattle grazing. Economic costs of grazing winter rye in a cotton system will be determined. Grazing effects on runoff characteristics (water loss, sediment, nutrients and microorganisms) of the watersheds will be determined and evaluated against historic runoff and soil loss characteristics of the fields.

RESULTS AND DISCUSSION

Identification of management areas

Management zones were developed for future guidance in the development of sampling schemes and to test for relationships between management zone designations associated with grazed versus ungrazed fields. Thus far management zones were developed in 2 ways. First we utilized the spatially referenced variables of;

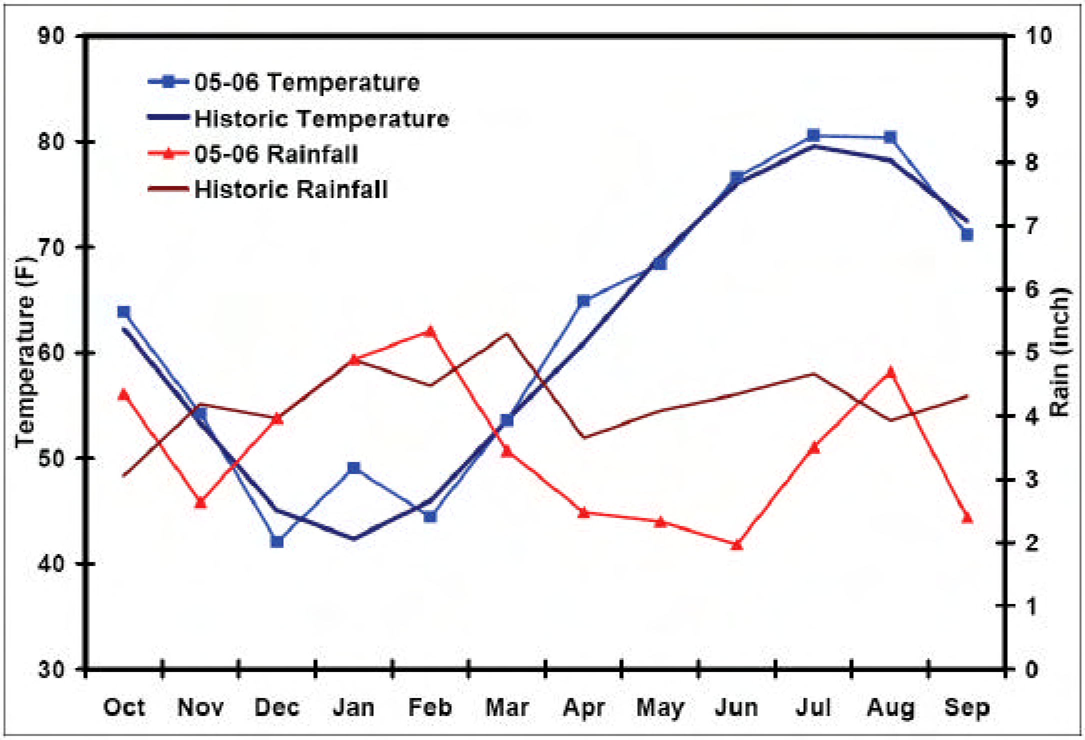
1) Elevation,
2) Slope,
3) Plan curvature,
4) Profile curvature,
5) Compound topographic index,
6) Soil electrical conductivity at two depths (0 to 30 cm and 0 to 90 cm),
7) Depth to the Bt soil horizon,
8) Normalized Difference Vegetation Index collected during early growth of fall planted small grains in 2006, and
9) Cotton yield from 2006.

Secondly, we estimated the principle components of a dataset consisting of these variables and used the orthogonal variables from the principle component analysis to developed management zones. In both cases, the data currently support 2 to 5 management zones and zones do not show a relationship with the grazing treatment. Management zones were defined across all four fields and the analysis indicated only one zone was well represented in all fields while other zones were missing in some fields. Currently we have 5 variables describing the topography, 2 variables related to soil properties, and two plant growth variables. In the future, we will add additional soil and plant variables to the dataset and repeat the statistical analysis testing for changes in the management zones with time as related to treatment variables and to soil variables influenced by management.

Weather data

Cover crop growing period temperature and rainfall were similar to long term averages. Rainfall deficits occurred in November, March, and April of the rye growing period. The rainfall deficit in the spring did not appear to negatively impact rye growth or availability of forage in the first year of the study.

During the cotton growing season, temperatures were near the historic trends. However, there was a period of cool temperatures during the two weeks following cotton planting in mid-May that appeared to prolong germination and stand establishment. Limited rainfall during June reduced cotton growth, whereas rain in July and August coincided with blooming and boll formation. Total rainfall during the cotton growing period from May to September was 14.9 inches; 6.4 inches below the long term average.



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

Grazing Data

In the first year, cereal rye (*Secale cereale* L.) herbage grew from approximately 1000 lbs/acre in February to 8000 lbs/acre in mid April. The area was grazed with 59 Angus heifers for 11 days (in March and April) beginning with an initial herbage mass of approximately 3000 lbs/acre, which ultimately provided approximately 4000 lbs/acre of grazed forage during the grazing period.

In the second year with fewer animals (40 Angus heifers) we began grazing during a period of rapid growth with a herbage mass of only 2000 lbs/acre defoliated over 7 days harvesting an estimated 2300 lbs/acre. However, because of the earlier start the fields were defoliated twice although the second defoliation, only yielding approximately half of the original grazed forage.

We estimated that a stocking rate of 1.4 animals/acre would have kept the area defoliated between February 1st and April 15th if animal management and agronomic management are efficient and climate is adequate.

Yield data

Cotton was planted May 12th and 15th just prior to 10 days of cool weather which delayed germination and growth. Cotton was harvested in the fall of 2006 using a picker with a yield monitor. Seed cotton yields ranged from 2140 lbs/ac to 2950 lb/ac. No significant yield differences were detected between grazed and ungrazed fields (both treatments averaged approximately 2500 lb/ac). After ginning, our yield per acre averaged 1008 lb lint/ac. Conservation tillage, heavy residue from the rye cover crop, late season rain in August and a dry fall were critical for producing yields in this range. Georgia's cotton production for 2006 totaled 2.12 million bales (480 lb lint/bale) on 1.33 million acres and averaged 765 lb/ac or 1.6 bales/ac.

CONCLUSIONS

Preliminary results indicate grazing cover crops can be a viable option for cotton producers in the Southern Piedmont because of the potential to increase revenues from grazing without reducing cotton yields.

ACKNOWLEDGMENTS

This research was supported in part by a grant from Cotton Incorporated and the Georgia Commodity Commission for Cotton. Additional support came from USDA ARS base funding. Many individuals contributed to the growing of crops and collection of data and their contributions are greatly appreciated. Robin Woodroof, Stephen Norris, Tony Dillard, Jeff Scarbrough, Eric Elsner, Dwight Seaman, Ryne Branner, Ronald Phillips, Robert Sheats, Clara Parker, Mike Thornton and Eric Schwab provided expert assistance. Ralecia Hamm and Michael Underwood were valuable student helpers on the project.

References

Bruce, RR, GW Langdale, LT West, and WP Miller. 1995. Surface soil degradation and soil productivity restoration and maintenance. Soil Sci. Soc. Am. J. 59: 654-660.

Causarano HJ, AJ Franzluebbers, DW Reeves, JN Shaw and ML Norfleet. 2005. Potential for soil carbon sequestration in cotton production systems of the southeastern USA. Cotton Incorporated Report. http://msa.ars.usda.gov/al/auburn/nsdl/csr/docs/reeves/causarano/causarano05b.pdf

Dabney, SM, JA Delgado, and DW Reeves. 2001. Using winter cover crops to improve soil and water quality. Comm. Soil Sci. Plant Anal. 32: 1221–1250.

Endale, DM, DS Fisher, and HH Schomberg. 2006. Soil Water Regime in Space and Time in a Small Georgia Piedmont Catchment under Pasture. Soil Sci. Soc. Am. J. 70: 1-13.

Miller, MS, DW Reeves, BE Gamble, and R Rodriguez-Kabana. 1997. Soil compaction in cotton double-cropped with grazed and ungrazed winter covers. Proc. Beltwide Cotton Conf. Jan 6-10, 1997. New Orleans, LA. Vol. 1, pp. 647-648. National Cotton Council.

Mullins, GL, and CH Burmester. 1997. Starter fertilizer and the method and rate of potassium fertilizer effects on cotton grown on soils with and without winter grazing by cattle. Comm. Soil Sci. Plant Anal. 28 : 739-746.

Siri-Prieto, G, DW Reeves, RL Raper, D Bransby, BE Gamble. 2003. Integrating winter annual grazing in a cotton-peanut rotation:forage and tillage system selection. Proc. Sod Based Cropping Systems Conf., Feb. 20-21,2003. North Florida Research and Education Center-Quincy, University of Florida, Quincy FL.

Snapp SS, SM Swinton, R Labarta, D Mutch, JR Black, R Leep, J Nyiraneza, and K O'Neil. 2005. Evaluating Cover Crops for Benefits, Costs and Performance within Cropping System Niches. Agron. J. 97:322–332.

Taboada, MA, and RS Lavado. 1993. Influence of cattle trampling on soil porosity under alternate dry and ponded conditions. Soil Use and Management 9: 139-142.

Touchton, JT, and JW Johnson. 1982. Soybean tillage and planting method effects on yield of double-cropped wheat and soybeans. Agron. J. 74:57-59.

EFFECT OF PERENNIAL-PASTURE AND TILLAGE SYSTEMS ON SOIL ORGANIC CARBON AND AGGREGATE STABILITY IN WESTERN URUGUAY

Guillermo Siri-Prieto, Oswaldo Ernst,
Departamento de Producción Vegetal, Facultad de Agronomía, Universidad de la República O. del Uruguay
siriprieto@fagro.edu.uy

ABSTRACT

Soil degradation due to unnecessary tillage is the main restrain to sustainable agriculture in Uruguayan soils. The impact of crop-pasture rotation by tillage systems interaction has not been evaluated or is scare in the long-term. The experiment located in western Uruguay was established in 1993 on a clay loam (Typic Argiudol) to determine the influence of tillage systems and inclusion of perennial pasture on soil properties. Pasture (with or without perennial pasture) and tillage systems (conventional and no-till) were evaluated through 1993 to 2005. Soil samples at three depths (0-2.4, 2.4-4.8, and 4.8-7.2 in) were taken twice (1994 and 2005) and analyzed for soil organic carbon content (SOC), Total SOC (TSOC) and water stable aggregate (WAS). Interaction among inclusion of perennial pasture and tillage systems occurred on SOC and TSOC after 12-y. Conventional tillage without pasture resulted in the lowest SOC and TSOC (9% and 10% less than the overall mean, respectively). Within no-till systems, perennial pasture did not have effect on SOC content. No-till systems had more SOC and TSOC stratification than conventional ones. Within conventional tillage, continuous agriculture had 58% lower WAS than crop pasture rotation. On the other hand, within no-till systems did not have effect on WAS. No-till systems significantly improved soil fertility indicators with or without pasture, but for conventional tillage, the inclusion of pasture was necessary.

INTRODUCTION

Maintenance and improvement in soil organic carbon (SOC) content is generally accepted as being an important objective for any sustainable system of agriculture. Soil organic carbon and soil aggregation declines quickly in the first years after cultivation of unperturbed soil (Six et al., 1999). The magnitude and speed of the loss vary with the soil type, weather conditions, crop sequence, soil tillage, quantity of stubble returned to the soil (Paustian, el al., 1997). These authors found that SOC was improved with systems that include pastures or grazed crops. Haynes et al. (1991) reported that aggregate stability increases quickly, both due to a lack of tillage disturbance and the characteristic dense and fibrous root systems of the perennial grasses. These changes are stabilized if the perennial pasture stays in time, but they are lost quickly if soil is tilled again. In Uruguay, Díaz, (1994) quantified after 28 years a SOC loss of 25% for continuous annual crops systems with tillage systems in relation to the initial value. This negative tendency was reverted with a crops-pasture rotation. A synthesis of the produced information about crop-pasture rotation in Uruguay was presented by García-Préchac et al. (2004). About 35% of the dry crop production system in Uruguay was planted in no-till system in 2001. This area under no-till systems without pasture in the rotations has extended quickly in the last 10 years, due to farmers and technicians were looking for means to increase crop profitability and reduced soil erosion and soil degradation.

The objective of this study is to quantify the effect of tillage system in crop-pasture rotation in relationship to the continuous annual crops in changes in soil organic carbon and aggregates stabilities.

MATERIALS AND METHODS

Site description

The long-term crop-pasture tillage system experiment is located 10 km from Paysandu (32° 21' S and 58° 02' W; 61m elevation) in the northwest of Uruguay, South America. The region is mesothermal sub-humid climate with a mean daily temperature of 77^o and 55^o F for summer and winter seasons, respectively. The area receives an average of 43-in of annual precipitations, with a moderately uniform throughout months, but very unpredictable among years. Potential evapotranspiration is greater during summer than winter season, consequently, through summer exists water deficits (maximum in January, 4 in) and during winter exists water excess (maximum in July, 2.5 in). Soil at the site is a fertile Typic Argiudol (Table 1).

Table 1. Surface (0-8-in) characteristics of the experimental site where tillage systems with inclusion or not of pastures were evaluated in the long-term experiment in Paysandú, Uruguay (1993-2005).

Classification	Typic Argiudol
Texture	clay loam
% Clay	29
% Silt	44
% Sand	27
Soil organic carbon (%)	2.4
pH	7.0
P content (mg kg^{-1})	15
K content (cmol kg^{-1})	1.9
Ca content (cmol kg^{-1})	27.7
Mg content (cmol kg^{-1})	2.4
Cation exchange capacity (cmol kg^{-1})	32.7

Site Management

The experimental area was under continuous crops (a wheat-fallow rotation) under conventional tillage among 1940 to 1970. Since 1970 until 1993, the experimental area was under crop-pasture rotation (3 year pasture-3 year crops) with conventional tillage. The long-term experiment was established in 1993 following a sod-legume pasture composed originally by Birdsfoot Trefoil (*Lotus corniculatus*), White Clover (*Trifolium repens* L.) and Tall Fescue (*Festuca Arundinacea* L.) dominated by bermudagrass (*Cynodon Dactylon* L.)

The crop rotation used included: wheat (*Triticum aestivum* L.), barley ((*Hordeum vulgare* L.), and oat (*Avena sativa* L.) for winter crops and corn (*Zea mais* L.), sunflower (*Helianthus annus* L.), sorghum (*Sorghum bicolor* L. *Moech.*), and soybean (*Glycine max* (L.) Merr.) for summer crops. The table 2 shows the crops order used for all treatments among 1993 to 2005. The experimental design was a randomized complete block (RCB) design with two replications in 1994 and three replications for 2005. Four treatments were evaluated from 1993 to 2005.

Table 2. Crops evaluated in a combination of two tillage systems and two rotations (inclusion or not of pastures) in the long-term experiment in Paysandú, Uruguay (1993-2005).

Year	Crop-Pasture Rotation (ROT)		Continuous Cropping (CC)	
	Winter	Summer	Winter	Summer
1993	Barley	Sorghum	Barley	Sorghum
1994	Wheat	Sunflower	Wheat	Sunflower
1995	Wheat/pasture	Pasture	Wheat	Sorghum
1996	Pasture	Pasture	-- †	Corn
1997	Pasture	Pasture	Oat	Soybean
1998	Pasture	Corn	--	Corn
1999	Wheat	--	Wheat	--
2000	Wheat	Soybean	Wheat	Soybean
2001	--	Sunflower	--	Sunflower
2002	Wheat/pasture	Pasture	Wheat	Soybean
2003	Pasture	Pasture	--	Sunflower
2004	Pasture	Pasture	Barley	Soybean
2005	Pasture	Pasture	Wheat	

† means fallow due to impossibility to plant for weather conditions

These treatments included the combinations of two tillage systems with the inclusion or not of perennial pastures:

1. Continuous cropping with conventional tillage (CC $_{\text{Conv}}$). Continuous cropping for twelve years using conventional tillage systems. The tillage includes a combination of moldboard or chisel (depending on year) to a depth of 8-10 in followed by disking to a depth of 4-6 in previous to winter crops. A disk harrow to a depth of 6-8 in together with field cultivator to a depth of 4-6 in was used previous summer crops.
2. Continuous cropping with no-till (CC $_{\text{NT}}$). Same crops than CC $_{\text{Conv.}}$ In no-till plots glyphosate were applied at the rate of 1.25 to 1.75 lb a.i. acre^{-1} depending of weed infestation and weather conditions.
3. Crop-pasture rotation with conventional tillage (ROT $_{\text{Conv}}$). The rotation was 3-yr crop-3-yr pasture cycle. This system is in operation since 1970. The same tillage used in CC$_{\text{CONV}}$. The pasture was planted together with the winter crop (in the same planting operation) in 1995 and 2002. The pasture consists of birdsfoot, trefoil white clover, and tall fescue.
4. Crop-pasture rotation with no-till (ROT $_{\text{NT}}$). The same tillage used in CC$_{\text{NT}}$. The rotation was the same used in conventional tillage (ROT $_{\text{Conv}}$)

Pre and post emergent herbicides were applied in all treatments to control weeds as needed. The experiment occupied approximately 5 acre with individuals' plots of 150 × 30 ft in size, thereby allowing use of field-scale equipment for all operations.

Soil Organic Carbon

Soil samples for SOC were collected two times: on January 1994 (six months after initiated the experiment) and June 2005. Ten samples were composited at each plot. These plots were sampled at three depths (0 - 2.4, 2.4 - 4.8, and 4.8 - 7.2 in). Samples were lightly crushed and sieved through a 2-mm mesh. Soil organic carbon was determined using the Walkey and Black technique (Nelson and Sommers, 1982). Soil bulk density (?$_{b}$) was determined by the core method (Blake and Hartge, 1986), with core dimensions of 1.81-in diameter by 2.36 in height. Core samples were taken at the same depths as SOC determinations at the same time, 5 replicates per plot, dried to 105^{o}C and weighed.

Wet Aggregate Stability

Soil samples were collected to evaluate wet aggregate stability on June 2005 using a wet sieving procedure of Yoder (1936) as modified by Kemper and Rosenau (1986). Three samples for the 0-6 in layer were collected from each plot. Immediately after collection, aggregates of between 4.5 and 9.5 mm were separated form the composite sample. To facilitate this, large clods were gently broken by hand to free aggregates of the preferred size. Moist aggregates (30 g) of between 4.5 to 9.5 mm were spread evenly on the uppermost sieve of a nest of 4.5, 2.8, 2.0, 1.0, 0.6 and 0.3 mm diameter and were gently moistened to avoid sudden rupture of the aggregates. The water level in the shaking apparatus was adjusted so that aggregates on the uppermost sieve were just submerged on the highest point of the cycle. Samples were oscillated from 15 min at 40 strokes per minute with the amplitude of the action set at 8 cm. The soil remaining on every sieve at the end of the 15 min was transferred into a beaker and oven-dried at 105^{o}C for 48 h and then weighed. The strength of aggregates in water was calculated as mean weight diameter (MWD) = S (X_i W_i), where X is the average diameter of the openings of two consecutive sieves, and W the weight ratio of aggregates remained on the $_{i}$th sieve. The multipliers used in our study after wet sieving were 7, 3.65, 2.4, 1.5, 0.8, and 0.45 mm for the sieves, respectively, and 0.15 mm for the residue.

Statistical Analysis

Treatment effects on soil indicators were evaluated using the appropriate randomized complete block (RCB) design with the PROC MIXED procedure of the Statistical Analysis System (SAS)(Littell et al., 1996). Replication and its interactions were considered random effects and treatments were considered fixed effects. Sampling depths were analyzed as a split in the design. Least square means comparisons were made using Fisher’s protected least significant differences (LSD). A significance level of $P = 0.10$ was established *a priori*.

RESULTS AND DISCUSSION

Soil Organic Carbon

Soil samples were collected at intervals to 2.4 in until 7.2 in depth to identify any soil chemical changes among treatments. Changes on SOC and TSOC resulting from combinations of tillage systems and inclusion or not of perennial pastures averaged over the 0-7.2 in depth range in 1994 and 2005 are presented in Figure 1. For our study, only tillage treatments effects within crop-pasture rotation are presented in 1994 because continuous cropping did not impact at this moment. Six months after started the experiment (January 1994) there were no significant differences among tillage systems for soil organic carbon (SOC) (2.0 vs. 2.22 % for conventional tillage and no-till, respectively). However, for TSOC there were differences between these two tillage systems (19.65 vs. 22.59 tons acre^{-1}; $P \leq 0.03$, for conventional tillage and no-till, respectively). Our results are explained by higher bulk density of no-till at the beginning of the experiment (data not shown) between these two tillage systems. Ellert and Bettany (1995) found that estimates of TSOC at fixed sampling depth (calculates as the product of concentration, bulk density and thickness) usually resulted in comparisons among unequal soil masses. These authors concluded that bulk densities and masses of no-till systems often are greater than those of conventional ones. Based on this demand, estimate TSOC (include bulk density) for our study would be smaller for calculations bases on an equivalent mass than for calculations bases on fixed sampling depths.

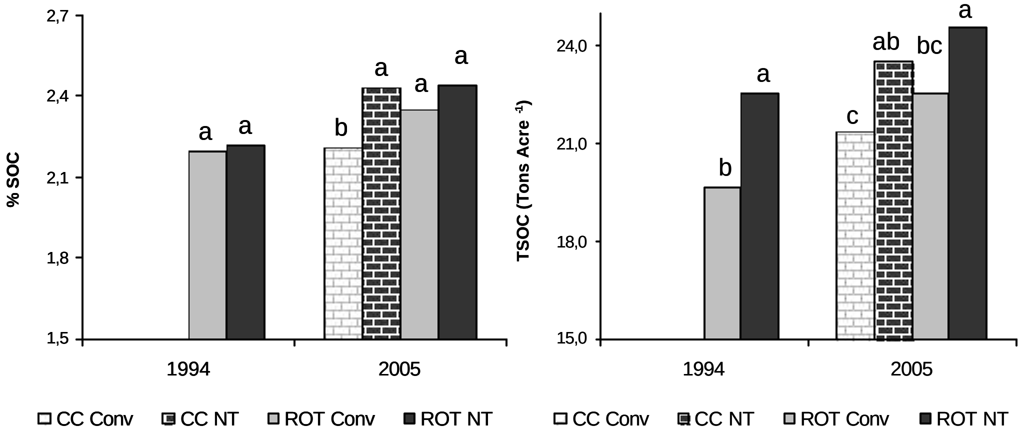


Figure 1. Soil organic carbon and total soil organic carbon at two sampling dates (1994 and 2005) at 0-7.2 in depth in response to tillage type and inclusion or not of pastures in the long-term experiment in Paysandú, Uruguay (1993-2005). The means market with the same letter in the same year are not significantly different at p=0.10.

The lowest carbon concentrations after twelve years initiated the experiment were obtained using conventional tillage without pasture (9% and 10% for SOC and TSOC less than the overall mean, respectively; Figure 1). It is well established that SOC is lower with conventional tillage than no-till systems attributable to several reasons: quick residue decomposition, more oxidation process, erosion, etc. (Dalal et al., 1989). Nevertheless, studies in Argentine have reported that no-till systems after 15 years had higher loss of CO2-C compared to plow tillage (Alvarez et al, 1998). These authors hypothesized that to change from conventional to no-tillage exist an initial phase of carbon accumulation but is followed by a phase of increase in carbon losses. This increase would be due to soil cover that affects the decomposition and mineralization process. Our study has 12 years, and could be considered in a transition phase between conventional to no-till systems.

There was a tillage type and pasture use interaction for SOC. The differences on carbon concentration were detected between the uses or not of pasture in the conventional tillage, and did not have effect in the no-till systems for SOC contents (Figure 1). These results agree with the general finding of Amstrong et al. (2004) and Heenan et al. (2004) where the use of pasture increased the soil organic carbon and total nitrogen. As mentioned previously from Amstrong et al. (2004), these authors found a quick increase in SOC over 3 years partly due to retaining plant residues on the plots. Grace et al, 1995 found that the inclusion of longer term pasture reduced the decline in SOC level. After 68 years of different crop rotation, SOC declined linearly with increasing frequency of fallows and decreasing frequency of pasture in the rotation. In contrast, increasing the frequency of pasture in the rotation caused SOC to increase significantly (Grace et al, 1995). The relative effect of particular rotation phases on SOC showed an increase during pasture phase and a decrease during crop phase. Our soil cores in June 2005 were taken after three years of pasture phase, then we expected an increase in the SOC level in the treatment than include pasture in the rotations.

Janzen et al, (1998) estimate a gain in SOC about 2.64 tons acre^{-1} or less within a decade by adoption of improved practices, like conservation tillage, intensification cropping systems, improved crop nutrition and perennial pastures in Canadian prairies. This change in SOC content is of finite duration and magnitude. For our study, TSOC averaged with or without pasture, we found an increase of 2.93 and 0.86 ton acre^{-1} for use of no-till systems and conventional ones, respectively after twelve years.

Treatment effect on soil organic carbon and total SOC were principally limited to the surface 2-in (Table 3). A significant treatment × depth interaction was obtained for SOC and TSOC in both years (Table 3). Significant stratification of SOC and TSOC occurred just only 6 months after establishment of the experiment with the inclusion of no-till system (ratio of 0-2.4/4.8-7.2 in depth was 1.36 and 1.43 for SOC and TSOC, respectively). In 2005, after 12 years initiated the experiment, the stratification was similar found in 1994, but for the conventional tillage, that stratification was only 1.18 averaged with or without pasture rotation. These results confirms early finding of Franzluebbers et al. (2002) that most the impact of no-till systems is observed in surface soil.

Twelve years after initiated the experiment, within no till systems, continuous crops had higher SOC content in the first 0-2.4-in compared to pasture rotation (3.0% vs. 2.77%, p=0.07). However, in the following depth (2.4-4.8 in) ROT $_{NT}$ had higher SOC content than CC $_{NT}$ (2.42% vs. 2.19%). This could indicate the more capacity that the pasture can have to increase SOC in deepest area for the root systems. Within conventional tillage, the inclusion of pasture increased the SOC content in the first 0-2.4 in depth (2.67% vs. 2.32% for ROT $_{Conv}$ and CC $_{Conv}$, respectively) without difference in deepest zones.

Comparing tillage systems in continuous crops (CC $_{NT}$ vs. CC $_{Conv}$), the no-till systems presented only in the shallowest area more SOC than conventional ones (3.00% vs. 2.32%). In deepest areas no difference were detected. However, some authors have reported higher SOC contents at deeper layers under conventional tillage compared to no-till due to residue incorporations by burying. On the other hand, comparing these tillage systems with use of pasture rotations (ROT $_{NT}$ vs. ROT $_{Conv}$) did not show difference for SOC content for any profile under study. Primarily continuous cropping with conventional tillage resulted in the worst-case scenario, presenting the lowest SOC and total SOC content.

Table 3. Soil organic carbon (SOC) and TSOC at two sampling dates in response of tillage type and inclusion or not of pastures at three different depths in the long-term experiment in Paysandú, Uruguay (1993-2005).

		Treatments †							
Sampling Date		Soil Organic Carbon (SOC)				Total Soil Organic Carbon (TSOC)			
		CC_{CONV}	CC_{NT}	ROT_{CONV}	ROT_{NT}	CC_{CONV}	CC_{NT}	ROT_{CONV}	ROT_{NT}
	Depth	%				Ton Acre^{-1}			
January, 1994	0 - 2.4	--‡	--	2,36	2,61	--	--	6,95	9,16
	2.4 - 4.8	–	--	2,16	2,12	--	--	5,84	7,04
	4.8 - 7.2	–	--	2,08	1,94	--	--	6,85	6,39
	LSD $_{(0.10)}$ (treatment*depth)	*0,34*				*1,33*			
June, 2005	0 - 2.4	2,32	3,00	2,67	2,77	7,53	9,77	8,38	9,26
	2.4 - 4.8	2,22	2,19	2,24	2,42	7,09	7,09	7,12	7,99
	4.8 - 7.2	2,10	2,11	2,13	2,14	6,74	6,67	7,08	7,32
	LSD $_{(0.10)}$ (treatment*depth)	*0,19*				*1,05*			

† CC_{CONV} = Continuous cropping with conventional tillage; CC_{NT} = Continuous cropping with no-till; ROT_{CONV} = Crop-pasture rotation with conventional tillage; ROT_{NT} = Crop-pasture rotation with no-till.

‡ Since the treatments started in July, 1993, continuous cropping with or without tillage are not consider.

Wet Aggregate Stability

Mean weight diameter (MWD) calculated after wet sieving was significant different among treatments. In our study, within conventional ones, the use of pasture rotations increased by 140% the MWD compared to without pasture after twelve years initiated the experiment (Fig. 2). However, for no-till systems, this beneficial effect of use pasture to improve the aggregate stability did not happen. Changes in aggregate stability with no-till systems have been reported under different whether conditions (Dalal, 1989; Beare et al, 1994). Investigation by Haynes et al. (1991) indicated the strong influence of mixed cropping rotation on SOC and water stable aggregation. This relation was improved when microbial biomass carbon and soil carbohydrate content were considered (Haynes and Francis, 1993). Soil aggregate stability increase rapidly after perennial grasses are established both due to a lack of tillage disturbance and to characteristics of root systems of grasses (Paustian, 1997). In our study, the use of perennial pasture in no-till systems determined the highest soil aggregate stability. On the other hand, the worst case scenario in term of soil aggregate stability was continuous cropping in conventional tillage.

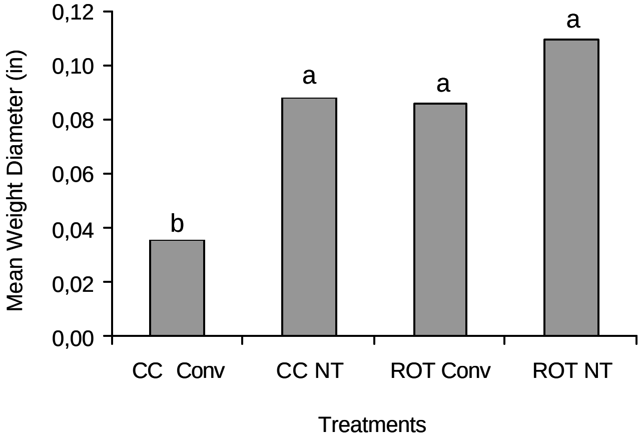


Figure 2. Mean weight diameter (in) among tillage and pasture combination at June 2005 in the long-term experiment in Paysandú, Uruguay (1993-2002). Same letter are not significantly different at p=0.10.

CONCLUSIONS

Our study indicates that conventional tillage without pasture resulted in the lowest SOC and TSOC (9% and 10% less than the overall mean, respectively) after 12 years initiated the study. Within no-till systems, perennial pasture did not have effect on SOC averaged over 0-7.2 in depth. However, CC_{NT} presented more SOC in the first 0-2.4 in than ROT_{NT}, but ROT_{NT} presented more SOC in the 2.4-4.8 in than CC_{NT}. No-till systems had more SOC and TSOC stratification than conventional ones. Within conventional tillage, continuous crops had 58% lower WAS than crop pasture rotation, and did not have effect within no-till systems on WAS. No-till systems significantly improved soil fertility indicators with or without pasture compared to conventional ones. The use of pasture was necessary to improve these soil indicators in the conventional tillage for the sub-humid climate conditions in Uruguay.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. Juan Acevedo and Agronomist Edith Elliot (Technicians, Experimental Station Mario.A.Cassinnonni) Faculty of Agronomy-UDELAR for their assistance in conducting this study.

REFERENCES

Beare, M.H., Cabrera, M.L., Hendrix, P.F. and Coleman, D.C. (1994). Aggregated-protected and anprotected pools of organic matter in conventional tillage and no-tillage soils. Soil Sci. Soc. Am. J. 58: 787-795.

Bremner, J.M., Mulvaney, C.S. (1982). Nitrogen-total. In; Page, A.L., Miller, D.R. (Eds), Methods of Soil Analysis II. Chemical and Micro-biological Properties. American Society of Agronomy, Madison, WI, pp. 595-624.

Dalal, R.C. (1989). Long-Tern effects on no-tillage, crop residue, and nitrogen application on properties of a vertisol. Soil Science Society of American Journal 53: 1511-1515.

Díaz-Roselló, R. (1992). Evolución de la materia orgánica en rotaciones de cultivos con pasturas (Organic matter evolution in crops and pastures rotations). Revista. INIA-Uruguay Inv. Agr. 1, Tomo I. pp. 103-110.

Díaz-Rosselló, R. (1994). Long-term Changes of Soil Carbon and Nitrogen under Rotation of Legume Pastures and Arable Crops. In: Transactions of the 15th World Congress of Soil Science, Volume 9, pp. 304-305 pp.

Ellert, B.H. and Battany, J.R. (1995). Calculation of organic matter and nutrient stored under contrasting management regimes. Can. J. Soil Sci. 75: 529-538.

Eynarda A., Schumachera, T.E., Lindstromb, M.J. and Maloa, D.D. (2005). Effects of agricultural management systems on soil organic carbon in aggregates of Ustolls and Usterts. Soil Till. Res. 81: 253-263.

Franzluebbers, A.J. (2002). Soil organic matter stratification ratio as an indicator of soil quality. Soil Till. Res. 66: 95-106.

García-Préchac, F., Ernst, O., Siri-Prieto, G. and Terra, J.A. (2004). Integrating no-till into crop–pasture rotations in Uruguay. Soil Till. Res. 77: 1-13.

Haynes, R.J. Swift, R.S., Stephen, R.C. (1991). Influence of mixed cropping rotatiosn (pasture arable) on organic matter content, water stable aggregations an clod porosity in a group of soils. Soil Till. Res.19:77-87.

Haynes, R.J., Francis, G.S. (1993). Changes in microbial biomasa C soil carbohydrate composition and aggregate stability induced by growth of selected crop and forage species under field conditions. Journal of Soil Science 44:665-675.

Heenan, D.P., Chan, K.Y., Knight, P.G. (2004). Long-term impact of rotations, tillage and stubble management of the loss of soil organic cargon and nitrogen from a Chromic Luvisol. Soil Till. Res. 76: 59-68.

Janzen, H.H., Campbell, C.A., Izaurralde, R.C., Ellert, B.H., Juma, N., Mc Gill, W.B., Zenter, R.P. (1998). Management effects on soil carbon storage on the Canadian pairies. Soil Till. Res. 47: 181-195.

Littel, R.C., Milliden, G.A., Stroup, W.W., Wolfinger, R.D. (1996). SAS system for mixed models. SAS Inst., Cary, NC.

Miglierna, A.M., Iglesias, J.O., Landricini, M.R., Galantini, J.A. and Rosell, R.A. (2000). The effects of crop rotation and fertilization on wheat productivity in the Pampean semiarid region of Argentina. 1. Soil physical and chemical properties. Soil Till. Res. 53: 129-135.

Nelson, D.W., Sommers L.E. (1982). Total carbon, organic carbon, and organic matter. In; Page, A.L., Miller, D.R. (Eds), Methods of Soil Analysis II. Chemical and Micro-biological Properties. American Society of Agronomy, Madison, WI, pp. 539-579.

Paustian, K., Collins, H.P. and Paul, E.A. (1997). Management controls on soil carbon In: E.A. Paul, K. Paustian, E.T. Elliot and V.V. Cole (Eds.), Soil Organic Matter in Temperate Agroecosystems: Long-Term Experiments in North America. CRC Press, Boca Raton. FL, USA. pp 15-49.

Six, J., Elliott E.T., Paustian, K. and Doran, J.W. (1999). Aggregation and soil organic matter accumulation in cultivated and native grassland soils. Soil Sci. Soc. Am. J. 62: 1367-1377.

MULTIVARIATE CROP PRODUCTIVITY ZONES IN THE ALABAMA COASTAL PLAIN

H. D. Stone[1], J. N. Shaw[1], D. Rodekohr[1], K.S. Balkcom[2], R.L. Raper[2], and D.W. Reeves[3]
Department of Agronomy and Soils, Auburn University, 201 Funchess Hall, Auburn, AL 36849
Presenter: Hunter D. Stone (stonehd@auburn.edu)

Abstract.

Various data are used to develop management zones for site-specific crop production. Most evidence indicates that the technique used for zone development is crop and management dependent. The objective of this research is to evaluate which field-scale data are most appropriate for developing management zones for characterizing crop productivity and variability over multiple growing seasons and managements. Specifically, we are evaluating: 1) if field-scale crop yield variability is better described in zones derived from temporal or static data, and 2) the relationships between zone development approach and soil management system. This study was conducted on a field-scale (20 acre) experiment evaluating the interaction of soil management systems (conventional versus conservation) with soil landscapes on a site in the Alabama Coastal Plain. Six replications in a cotton (*Gossypium hirsutum L.*) - corn (*Zea mays L.*) rotation traverse the landscape. Soil landscapes range from Typic Paleudults on well drained uplands to imperfectly drained Oxyaquic Paleudults in drainageways. Field-scale data include satellite remote sensing imagery, terrain attributes generated from a LiDAR derived digital elevation model (DEM), field-scale electrical conductivity, and a first-order soil survey (1:5000). Management zones were developed using fuzzy k-means clustering, and geo-referenced crop yield data have been collected (2001-2006). Our results indicate that all evaluated data were generally suitable for characterizing crop productivity and variability using a clustering approach. As expected, satellite remote sensing data collected in season were more highly related to yield compared to terrain and soil variables. The relative effectiveness of these data for describing yield variability is most dependent on crop, and somewhat dependent on management.

INTRODUCTION

Multiple data are used in the development of site-specific crop management zones. Remote sensing imagery, terrain attributes generated from elevation models, field-scale electrical conductivity and soil surveys are among typical data. Each of these data has a demonstrated

---

[1] Department of Agronomy and Soils, Auburn University, 201 Funchess Hall, Auburn, AL 36849.

[2] USDA-Agricultural Research Service, National Soil Dynamics Laboratory, 411 S Donahue Drive, Auburn, AL 36832.

[3] USDA-Agricultural Research Service, J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA 30677

ability to describe crop productivity and variability. However, the effectiveness of these data is soil management dependent, and some of these data are highly temporally variable, requiring multiple acquisitions. These interactions complicate the optimum utilization and combination of these data for crop management zone development.

We are evaluating the relationship of field-scale data to crop productivity on an experiment investigating interactions of soil landscapes and management systems in the Alabama Coastal Plain. Multiple managements at this scale provide an opportunity to evaluate the performance of zone development data across both management system and landscape. Details on the first three years (2001-2003) of cotton productivity (as a function of landscape and management) and soil C sequestration for this experiment have been published elsewhere (Terra et al., 2005; Terra et al., 2006). The management and landscape effects on productivity have now been evaluated across six years. The specific objectives of this paper are to:

1) evaluate static and temporal data suitability for characterizing crop productivity and variability over multiple growing seasons, and
2) further develop relationships between zone development technique and soil management.

MATERIALS AND METHODS

Research Site and Experimental Design

The research site is located at the E.V. Smith Research Center, near Shorter, AL. The experiment is a joint undertaking between the USDA-ARS National Soil Dynamics Laboratory (NSDL) and the Alabama Agricultural Experiment Station (AAES). The experiment's 20 acre landscape is representative of the Alabama Coastal Plain region. Soils on the site range from Typic Paleudults in well-drained uplands to Oxyaquic Paleudults in drainageways. Cotton and corn yields have been collected and geo-referenced with a yield monitor since 2001. Various other data have been collected on this site between 2001 and 2006 (see Terra et al., 2004; Balkcom et al., 2005).

The treatments consist of a cotton-corn rotation in conservation and conventional management systems with and without manure amendments. The four treatments are replicated six times in strips (21.3-ft wide) that traverse the landscape. Experimental cells along each strip (21.3-ft wide by 59.1-ft long) have been developed for sampling efforts. The conservation system consists of winter cover crops before the summer cash crop (cotton and corn); conventional systems do not have cover crops. Conventional system tillage consists of chisel plow, disking and in-row subsoiling, while the conservation system utilizes strip-tillage (in-row subsoiling) that results in a narrow (4-6 inch) zone of surface disruption in heavy residue. Dairy manure amendments were applied as solids at 8 tons per acre. Both phases of the rotation exist in each year. Further details on treatments and experimental design for this test can be found in Terra et al. (2006).

Temporal Data

Remote sensing satellite imagery was collected in July 2004 and August 2005 by the Quickbird (Digital Globe, Longmont, CO) multi-spectral imaging satellite. The four band (blue, green, red and near infrared), 8.0-ft resolution images were subsequently geo-referenced and ortho-rectified. The images were calibrated using coefficients provided by Digital Globe.

Normalized Difference Vegetation Indices (NDVI) were generated and averaged by cell for both cotton and corn crops in 2004 and 2005:

$$rNDVI=(NIR-red) / (NIR+red) \quad (eq. 1)$$

$$gNDVI=(NIR-green) / (NIR+green) \quad (eq. 2)$$

where rNDVI and gNDVI are the red and green NDVI, and NIR, red and green are reflectance values in the near infrared, red and green regions, respectively.

Field-scale electrical conductivity (EC) measurements were taken on the research site in March 2001 using the Veris ® 3100 (Veris Technology, Salina, KS). This method uses direct contact sensors to measure soil electrical resistivity, which is converted to apparent electrical conductivity (EC_a) (mS m^{-1}). Estimated depths of data resolution are 0-11.8 inches [(EC shallow)] and 0-35.4 inches [(EC deep)] (Veris Technologies, 2003). Data points were interpolated (kriging method) in ArcGIS (ESRI, Redlands, CA) to create continuous map surfaces at 16.4-ft resolution.

Static Data

An order 1 soil survey (1:5000 scale) of the research site was developed to characterize soil spatial variability. Selected soil samples from type pedons were analyzed to facilitate soil classification. The soil observations were overlaid with a maximum downhill slope raster (from an RTK-GPS derived DEM) to develop digitized map units across the landscape (Figure 1).

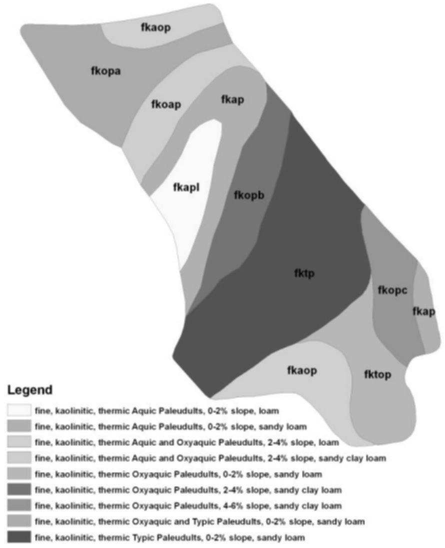


Figure 1 – Order 1 soil survey (1:5000) of the Coastal Plain research site.

LiDAR data were collected in spring 2006, and a 16.4-ft digital elevation model (elev) was developed. Terrain attributes including maximum downhill slope percentage (MDS), hydrologic flow direction and accumulation, specific catchment area (SCA) and compound topographic index (CTI) were generated using ArcGIS. The SCA and CTI (Moore et al., 1993) were calculated according to standard approaches. As a result of 'noise' artifacts (erroneous portions of a model not representative of the actual landscape) in the ArcGIS curvatures, landscape curvatures (plan, profile and mean) were modeled in ERDAS Imagine (Leica Geosystems GIS & Mapping, Atlanta, GA) using ArcGIS curvature formulas and an expanded neighborhood size (5x5 matrix with a 36.1-ft lag distance).

Management Zone Development

Selected terrain attributes – elevation, maximum downhill slope, CTI, flow direction and accumulation, and profile curvature – were utilized for terrain management zone development. These values were normalized and processed by the Management Zone Analyst (MZA) software (Fridgen et al., 2004), which employs fuzzy k-means clustering to create multivariate management zones or clusters. The output clusters were rasterized to a 16.4-ft image (Figure 2).

An identical process was used for the creation of field-scale electrical conductivity clusters using both depth intervals (i.e. EC shallow and EC deep) (Figure 3). Terrain attribute clusters, field-scale electrical conductivity clusters, and the order 1 soil survey were used to characterize landscape variability (i.e. three different approaches) and to relate to crop productivity.

Figure 2 – Terrain attribute management zones created using fuzzy k-means clustering of LiDAR derived terrain attributes.

Figure 3 – Field-scale electrical conductivity management zones created using fuzzy k-means clustering of shallow (EC 0-30 cm) and deep (EC 0-90 cm) EC measurements.

RESULTS

Both cotton and corn yields are highly temporally variable from year to year (Table 1). 2002, 2005 and 2006 were dry during the critical periods for corn yield, while 2002 and 2006 were dry during the first flower to peak flower cotton stages, and thus yields are relatively low for those years. Adequate rainfall for cotton was received in 2004, but damage from Hurricane Ivan at harvest negatively impacted yields. Although annual effects vary, averaged over all years of this experiment, conservation system yields are approximately 10% higher than conventional system yields for both crops.

Table 1. Seed cotton and corn grain yields by year and treatment. CT=conventional management system, and NT=conservation management system.

Treatment	2001		2002		2003		2004		2005		2006		Average	
	Cotton	Corn	Cotton	Corn	Cotton	Corn	Cotton	Corn	Cotton	Corn	Cotton	Corn†	Cotton	Corn

							lbs acre^{-1}							
CT	2467	8515	1128	6194	2655	10881	1325	7609	3198	5307	745	-	1906	7777
CT + Manure	2597	9015	1222	6127	2718	11150	1289	9166	3585	4484	932	-	2043	8065
NT	2778	8955	1456	7831	3045	11556	1594	9383	3423	5466	883	-	2182	8715
NT + Manure	2825	8943	1451	8135	3076	11738	1521	9997	3479	4688	735	-	2167	8776

† Due to extremely limited rainfall, no corn yield in 2006.

Highly significant differences in yields between clusters were evident for all clustering techniques (Table 2), with corn yield differences being slightly less significant. Furthermore, significant interaction between cluster technique (of the three clustering techniques) and management were found. All clustering techniques for corn had highly significant interactions with management, while these interactions in cotton were slightly less significant. No significant interactions were found between clusters and manure application. These findings support previous studies suggesting relationships between zone development technique and soil management system.

Table 2. Management zone effects on and crop yield variability.

Cluster Technique	Cluster		Cluster*manure		Cluster*management	
	Cotton	Corn	Cotton	Corn	Cotton	Corn
Map Unit	***	***	ns	ns	**	***
Terrain Attributes	***	**	ns	ns	**	***
Electrical Conductivity	***	***	ns	ns	***	***

** and *** significant at the 0.01 and 0.001 level respectively; ns= not significant

Pearson linear correlation coefficients (r) were measured to relate terrain and soil data (without remote sensing data) to crop yield for all years of the test (2001-2006), and again solely for 2004 and 2005 when remote sensing data were acquired (Table 3). Although several variables were related to yield, the temporally dependent variables rNDVI and gNDVI were most highly related to corn and cotton yields in the season of remote sensing acquisition. The fact that the NDVI correlation values are much higher than the other variables is not surprising, as these data were acquired within that particular growing season and thus provide a timely view of growth characteristics and level of plant stress related to crop yield. In addition, NDVI values were more highly related to corn than cotton yields.

The EC shallow and EC deep values were significantly related to crop yield in both approaches, even though several years have passed since this EC data collection (2001). Among static variables, the maximum downhill slope was significantly related to crop yield, but correlation values were much lower than observed with the NDVI values. The negative correlation between slopes, EC and yields is similar to what other researchers have found (Terra et al., 2006), and is likely due to a higher EC occurring on more clayey, eroded sidelopes (with higher slope) of generally lower productivity.

Table 3. Pearson linear correlation coefficients relating terrain attributes, field-scale electrical conductivity (EC shallow and EC deep) and NDVI to corn and cotton yields.

Variable	Pearson Linear Correlation Coefficient			
	2001-2006 (w/o NDVI)		2004 & 2005 (w/ NDVI)	
	Cotton	Corn	Cotton	Corn

Elev	ns	-0.077**	ns	-0.131**
MDS	-0.160***	-0.204***	-0.186***	-0.334***
CTI	ns	ns	ns	Ns
Flow Direction	-0.113***	ns	ns	-0.183***
Flow Accumulation	ns	0.113***	ns	0.180***
Profile Curvature	-0.077**	-0.123***	ns	-0.219***
rNDVI	-	-	0.416***	0.817***
gNDVI	-	-	0.336***	0.812***
EC shallow	-0.214***	-0.224***	-0.238***	-0.448***
EC deep	-0.129***	-0.183***	-0.159***	-0.323***

** and *** significant at the 0.01 and 0.001 level respectively; ns= not significant.

Similar to the correlation analyses, the temporally dependent NDVI values were highly significant in regression analyses (Table 4). In the absence of NDVI data for 2001-2006, the EC was more highly related to yield than the terrain factors. Regression analyses also indicated yield variability was better described for corn than cotton using the remote sensing, LiDAR derived terrain, and EC independent factors. Although the yield variability was generally better described in conservation management of corn, no definite trend was observed with respect to management in this regression approach.

Table 4. Linear regression relating independent variables to crop yield.

Treatment	2001-2006 (w/o NDVI)				2004 & 2005 (w/ NDVI)			
	Cotton		Corn		Cotton		Corn	
	R^2 †	Significant Variables ‡	R^2	Significant Variables	R^2	Significant Variables	R^2	Significant Variables
CT	0.134	EC30	0.073	EC90	0.544	rNDVI, gNDVI	0.712	rNDVI, EC30, Elev
CT + Manure	0.052	EC30	0.062	EC30	0.349	gNDVI	0.863	rNDVI, EC30
NT	0.090	MDS	0.114	EC30	0.485	rNDVI	0.829	rNDVI, EC30, Flow Direction
NT + Manure	0.130	EC30, CTI	0.106	EC30	0.233	rNDVI	0.870	gNDVI, EC30, Flow Direction

† Coefficient of Determination

‡ Partial Coefficient of Determination = 0.10

CONCLUSIONS

All data tested are generally suitable for characterizing crop productivity and variability over multiple growing seasons using a clustering approach. However, the relative descriptiveness of these data varies, and is greatly affected by crop and somewhat affected by management. For example, using a regression approach, corn productivity was better characterized by these soil, remote sensing and terrain variables than cotton productivity. The culmination of this suggests that an optimum combination of these data could be developed for a certain management system and crop to improve management zone delineation. The “in-season” remote sensing measures (NDVI) were far superior for that year as compared to the more static soil and terrain characterization (as expected). However, the timeliness and cost of acquiring these remote sensing data are such that seasonal acquisitions are sometimes impractical.

REFERENCES

Balkcom, K.S., J. A. Terra, J.N. Shaw, D.W. Reeves and R.L. Raper. 2005. Soil management system and landscape position interactions on nutrient distribution in a Coastal Plain field. J. Soil Water Cons. 60(6):431-437.

Fridgen, J.J., N.R. Kitchen, K.A. Sudduth, S.T. Drummond, W.J. Wiebold, and C.W. Fraisse. 2004. Management Zone Analyst (MZA): Software for subfield management zone delineation. Agron. J. 96:100–108.

Moore, I.D., P.E. Gessler, G.S. Nielsen, and G.A. Peterson. 1993. Soil attribute prediction using terrain analysis. Soil Sci. Soc. Am. J. 57: 443-452.

Terra, J. A., J.N. Shaw, D.W. Reeves, R.L. Raper, E. van Santen and P.L. Mask. 2004. Soil carbon relationships with terrain attributes, electrical conductivity, and a soil survey in a coastal plain landscape. Soil Sci.169:819-831.

Terra, J.A., D.W. Reeves, J.N. Shaw and R.L. Raper. 2005. Impact of landscape attributes on C sequestration during the transition form conventional to conservation management practices on a Coastal Plain field. J. Soil Water Cons.60(6): 438-445.

Terra, J.A., J. N. Shaw, D. W. Reeves, R. L. Raper, E. van Santen, E. B. Schwab, and P. L. Mask. 2006. Soil management and landscape variability affects field-scale cotton productivity. Soil Sci. Soc. Am. J. 70:98-107.

Veris Technologies. 2003. Frequently asked questions about soil electrical conductivity [Online]. [2 p.] Available at: http://www.veristech.com [cited 8 Oct. 2003; verified 15 Mar. 2005]. Veris Technologies, Salina, KS.

Furrow Diking: A Management Practice for Conserving Soil and Water Resources

R.C. Nuti[1] and C.C. Truman[2]

[1]USDA-ARS, National Peanut Research Lab
Dawson, GA 39842
[2]USDA-ARS, Southeast Watershed Research Lab
Tifton, GA 31793

Abstract

Crop production in the Southeastern U.S. is water limiting. Water capture and supplemental irrigation is needed to maintain soil water levels to sustain profitable crop production. Increased water capture would efficiently improve natural water use and reduce supplemental irrigation amounts and other input costs, thus improving producer's profit margin. Furrow diking is a cost effective management practice that is designed to create a series of depressional storage basins in the furrow between crop rows to catch and retain rainfall and/or irrigation water. The objective of this study was to compare water capturing and erosion control characteristics of furrow diking by comparing infiltration, runoff, soil loss, and soil water contents diked and non-diked tilled systems. In 2006, a field study (Faceville loamy sand) was established near Dawson, GA with diked and non-diked conventional tilled systems managed to irrigate cotton. Simulated rainfall (50 mm/h for 1 hr) was also utilizing on diked and non-diked plots (2x3 m) (n=3). Runoff and soil loss were measured continuously from each rainfall simulator plot. Diking reduced runoff and sediment yields by 3.5 times compared to the non-diked treatment. Diking increased infiltration by 38% resulting in 7.1 days of estimated plant available water for diked plots and only 3.9 days of estimated plant available water for non-diked plots.

Soil Microbial Community Dynamics as Influenced by Soil Properties and Landscape Position

D.B. Watts[1]*, H.A. Torbert[1], Y. Feng[2], and S.A. Prior[1]

[1]USDA-ARS National Soil Dynamics Laboratory, Auburn, AL 36832
[2]Department of Agronomy and Soils, Auburn University, 36849
*Corresponding author's email address: dwatts@ars.usda.gov

Abstract

Factors that affect plant growth, whether it is manure addition, season, or soil-type and landscape variability may provide insight on how to better manage agricultural fields through the evaluation of soil microbial activity, biomass and community structure. Thus, an *in situ* study was conducted to evaluate microbiological properties from three different soil types and landscape positions located in close proximity of each other during the summer and winter months. The three Coastal Plain soils investigated were Bama (Sandy loam), Lynchburg (Loam) and Goldsboro (Loam). Dairy-composted manure was incorporated into *in situ* soil cores at a rate of 350 kg N ha^{-1} and compared to unamended controls. Microbial properties were determined by microbial biomass N, dehydrogenase enzyme activity, and PLFA analysis. Dairy-composted manure addition greatly affected the microbial properties of the soil. An increase in microbial activity and immobilization of N was observed with the addition of manure, suggesting that a shift in microbial dynamics had occurred due to the changes in the available substrate. This was most evident during summer months, which suggests that warmer temperatures stimulated the microbial activities. Landscape and soil-type was also shown to affect microbial properties. The Lynchburg soil, a loam soil located in a depressed area of the field, was shown to have the highest microbial biomass and microbial activity. Canonical discriminate analysis (CDA) of the phospholipid ester-linked fatty acid (PLFA) profiles was utilized to confirm the results of microbial properties. This analysis indicated that a shift in microbial communities as indicated by PLFA profiles occurred between season, manure application, and soil landscape. Therefore, microbial properties could be a useful tool for providing insight into the long-term sustainability of the soil.

Introduction

In recent years, there has been a renewed interest in the use of manure for agricultural row crop production, resulting from large amounts of manure being generated in confined areas. The use of manure in row crop production can be viewed as having a two-fold affect: as a means of waste disposal and building up soil fertility through the addition of organic matter. The addition of organic matter in the form of manure promotes microbial activity. Soil fertility and microbial activity go hand in hand because it is through the microbial population that mineralization (C, N, P, S) of organic material occurs (Frankenburger and Dick, 1983), which is controlled by the soil microbial community structure. Also, the topography of a landscape can influence the fertility and microbial activity of a soil resulting from water movement and distribution of nutrients carried by water. Thus, information on the affect that manure application has on microbial parameters of soils from different soil-types and landscape positions during winter and summer months is needed to make predictions on the long-term sustainability of soil systems. The objectives of this study were to determine the effects of manure application on three different soils in close proximity to each other from different landscapes and soil textural classes on microbial parameters and community structure during two different seasons.

Materials and Methods

Soil samples were collected from an ongoing precision agriculture experiment located at Auburn University's E.V. Smith Experiment Station in Macon County, Alabama (Terra et al., 2006). Soils were collected from field plots that have not received manure within the last 10 years. The three soil series evaluated (Bama, Goldsboro, and Lynchburg) were chosen because they are located in close proximity to one another, yet different in texture. The Bama series is a fine-loamy, siliceous, subactive, thermic Typic Paleudults (sandy loam - summit). Goldsboro is fine-loamy, siliceous, subactive, thermic Aquic Paleudults (loam-backslope). The Lynchburg is fine-loamy, siliceous, semi-active, thermic Aeric Paleaquults (loam-depression). The farming practice was comprised of conventional tillage, which receives inorganic fertilizer in a continuous cotton/corn rotation.

The experiment was conducted using *in situ* soil cores (microplot cylinders) made of polyvinyl chloride (PVC) plastic cylinders (6.25 cm dia and 20.32 cm length). These cylinders were placed in the surface 20 cm of the soil profile. The soil cores were placed in each of the three soil types with half of the cores amended with manure the other half without manure. The appropriate amount of manure was added to the top 4 cm of the soil core in the microplot cylinders to give 350 kg N ha^{-1} applied to a 15 cm depth. Soil cores were collected and returned to the laboratory for analysis on 0, 7, 14, 21, 49, and 70 days after manure application by randomly selecting and removing six cylinders from each plot. On each sampling day microbial biomass N was determined similar to Runion et al. (2004) using the chloroform fumigation extraction method as described by Horwath and Paul (1994) and dehydrogenase activity was determined similar to Runion et al. (2002) from a modified procedures described by Tabatabai (1982). Phospholipid fatty acid analysis was determined on field moist samples as described by Feng et al. (2003) using a modified procedure of Findlay and Dobbs (1993) and Bossio and Scow (1998).

The study was a completely randomized factorial design with three soil types amended with and without manure for the summer and winter months. Statistical analysis was performed using the GLM procedure of SAS (SAS institute, 1985), and means were separated using least significant difference (LSD) at an a *priori* 0.10 level. To access specific effects of season (winter vs. summer), soil series, and manure application on microbial community structure, canonical discriminate analysis (CDA) was performed on FAME data. CDA was analyzed using the mole percentage distribution of PLFAs with SAS software version 9.13. Canonical discriminate analysis was performed on combined PLFA data from day 70 from winter 2004 and summer 2005. All samples were analyzed for PLFA profiles using a set of 33 fatty acids that were present in most of the samples.

Results and Discussion

Some of the basic soil properties of the three soil types utilized in this study are presented in Table 1 and 2. In general, the focus of this study was to access whether season and manure addition had an impact on microbial characteristics and the microbial community as a whole when applied to different soil types and landscape positions. Season, manure application, soil type and landscape position had an affect on the microbial properties. Seasonal effect (winter season compared to summer seasons) was shown to have the greatest affect on microbial properties compared to soil type and manure application. This is similar to the results of Bardgett et al. (1999) who reported greater microbial biomass C and N and microbial activity during summer months compared to winter months. The following discussion is a more in-depth look at the specifics of how the previously mentioned management decisions affect microbial properties.

Dehydrogenase

A significant increase in dehydrogenase activity was observed ($P<0.10$) on all sampling days except day 49 during the winter and day 7, 28, and 49 during the summer months (Figure 1). Although, not significant on each sampling day, an increase in dehydrogenase activity was observed with the addition of manure to the soil during the winter and summer, suggestings that changes in the size of microbial populations and respiratory activity occurred in response to the added available substrate. Season greatly impacted dehydrogenase activity. Significant differences were observed ($P< 0.001$) for every sampling day except day 14. Dehydrogenase activity measured during the summer was almost double that measured during the winter months. Higher dehydrogenase enzyme activity, which is a representation of microbial activity, was probably a result of higher soil temperature, which has been shown to stimulate microbial activity. Dehydrogenase activity was also greatly affected by soil type. Significant differences were observed ($P<0.10$) on all sampling days except day 7, 14 and 49 during the winter and day 28 and 49 during the summer season. The Lynchburg soil produced higher dehydrogenase enzyme activity ($P<0.10$) on all sampling dates except day 0, 49, and 70 during the winter and day 7 during the summer months. Although no significant differences were observed between the soil X amendment effects at any sampling days, there was a trend resembling the soil effect. The Lynchburg soil with manure produced the highest microbial activity compared to the other soils. The Lynchburg soil, located in a depression area, contains the highest organic C and N content. The observed difference in microbial activity was probably attributed to nutrients accumulating in the depressed area from water movement, thus, resulting in increased organic matter. This also corresponds with the higher organic C and N, CEC values observed from the initial soil characteristics from this soil.

Soil microbial biomass N

Similar to dehydrogenase activity, microbial biomass N also increased following the application of dairy compost (Figure 2). Significant differences were observed ($P<0.10$) on all sampling days except day 7 and 70 during the winter and day 49 during the summer. Although not significant on every sampling day, microbial biomass was higher in manure compared to no manure treatments. It is well know that changes in microbial biomass concentrations observed in the soil correspond to changes in the availability of decomposable substrate. The addition of manure provided the microbes with readily available C and N. This is consistent with the finding of Bohme et al. (2005) who reported that microbial biomass was greater in soil following the application of farmyard manure. The same trend was also shown for soil X season effect. During the summer more microbial biomass N was observed compared to the winter months at all sampling dates. This corresponds to dehydrogenase activity, suggesting that as microbial activity increased, more N was immobilized into microbial cells. A comparison of soil type shows that significant differences were observed on every sampling date for the winter and summer season ($P<0.10$). In the Lynchburg soil, which contained the highest initial soil organic C and N content, microbes were more efficient in immobilizing the N, suggesting that land-use and topography of a landscape could cause changes in soil C and N cycling rates and accumulation of organic matter (Chen and Stark, 2000). The microbial biomass was the lowest in the Goldsboro soil. This indicates that less N was being immobilized into the microbial cells. The reduced microbial biomass N occurring in the Goldsboro soil could be attributed to more nitrification occurring and less immobilization. This also corresponds with the low C:N ratio that was observed in the soil, thus suggesting that although the Goldsboro soil had a higher clay content, microbial biomass N was more closely related to the C, N, and C:N ratio of the soil. Also, the textural differences in these were not great enough to affect the microbial biomass N.

Soil microbial community structure

In this study, PLFAs analysis identified 48 fatty acids. However, of these, only 33 were present in most samples used in data analysis. CDA was carried out by comparing the summer and winter seasons to identify differences between the dairy compost additions and soil series. The first 3 canonical discriminate variants (CDV) accounted for a total of 84% of the total variance. The first CDV, which accounts for 48% of the variance, discriminated the with and without composted manure treatments, the second accounted for 25% of the variance, and discriminated the seasonal effect, and the third accounted for 11% of the variance, discriminated the soil type effect (Figure 3&4). PLFAs 16.1?5c, 18:3?6c, 18:1?7c, cy19:0, 20:4?6, 9,12 were identified by CDA as influential biomarkers for the CV1 and 16:1?7c / i15:0 2OH, 18:1?7c, 18:0, 18:3?6c for CV2, respectively (Table 3). The PLFAs i17:0, a18:0/18:2 ?6, 9c, 16:120H, cy17:0, and 17:0 10 methyl were influential biomarkers for CV3. The metabolic association of the fatty acids previously mentioned are described by Frostegard et al., 1993; Zelles, 1997; Fierer et. al, 2003; Feng et al, 2003. The PLFA 16.1?5c is associated with monounsaturated fatty acids, which have been shown to increase with manure addition. Also 16.1?5c, 18:1 ? 7c and cy19:0 are Gram-negative bacteria and which are associated with an increased readily-available substrate. On the other end of the spectrum 18:3?6c and 20:4?6, 9,12 are associated with fungi and were shown to decrease with the addition of available substrate. The PLFA identified for the second CV 16:1?7c, 18:1?7c accounted for most of the discrimination. Fatty acid 16:1?7c is associated with monounsaturated fatty acids and 18:1?7c is associated with gram-negative bacteria, both of which increased with the addition of manure. The biomarker 18:0 is a non-specific fatty acid, which is found in all organisms. The signature fatty acid biomarker a15:0 is associated with gram-positive bacteria and 18:3?6c is associated with fungi. The increase in soil temperature probably affected the PLFA concentrations, thereby causing a shift in lipid composition between seasons. The PLFAs identified for the third CV i17:0 is a gram-positive bacteria, 18:0 gram-negative bacteria, 16:1 2OH non-specific bacteria, cy17:0 and 17:0 10 methyl were all found in more abundance in the Lynchburg and Goldsboro soil, which are both loam soils. These fatty acids played an integral role in discriminating the loam two soils from the sandy loam soil suggesting that lipid composition changed due to texture and available substrate.

Conclusions

Microbial parameters evaluated in the study suggest that season, addition of manure, and changes in the topography of a landscape can greatly affect soil microbial community structure.

The addition of dairy compost manure resulted in a diverging microbial community structure probably by increasing soluble C in soil. Season also increased the microbial parameter resulting in increased metabolic activity during the summer compared to the winter. Soil landscape positions that have resulted in a buildup of organic matter were observed to enhance and alter the microbial community. The significant changes in microbial parameters were evident by observing increases in microbial biomass N, dehydrogenase (microbial activity), total PLFAs, as well as changes in microbial community structure. Canonical discriminate analysis clearly discriminated PLFA profiles by season, manure addition, and soil type and landscape, thus confirming that changes in microbial community structure diverged, resulting from the agronomic management practices evaluated. Thus, consideration of microbial parameters should be taken into account when developing management practices in order to maximize the use of plant nutrients contained in manure without negatively affecting the environment.

Acknowledgements

The authors acknowledge Barry G. Dorman, and Sheryl A. Morey (USDA-ARS National Soil Dynamics Laboratory) for technical assistance.

References

Bardgett R.D., R.D. Lovell, P.J. Hobbs, and S.C. Jarvis. 1999. Dynamics of below-ground microbial communities in temperate grasslands: influence of management intensity. Soil Biol. Biochem. 31: 1021-1030.

Bohme, L., U. Langer, and Bohme. 2005. Microbial biomass, enzyme activities and microbial community structure in two European long-term field experiments. Agric. Ecosyst. Environ. 109: 141-152.

Bossio, D.A., and K.M. Scow 1998. Impacts of carbon and flooding on soil microbial communities: phospholipids fatty acid profiles and substrate utilization patterns. Microbial Ecology 35: 265-278.

Chen J., and J.M Stark 2000. Plant species effects and carbon and nitrogen cycling in a sagebrush-crested wheatgrass soil. Soil Biol.Biochem. 32: 47-57.

Feng Y., A.C. Motta , D.W. Reeves, C.H. Burmester, E. van Santen, and J.A. Osborne. 2003. Soil microbial communities under conventional-till and no-till continuous cotton systems. Soil Biol.Biochem. 35: 1693-1703.

Fierer N., J.P Schimel, and P.A. Holden. 2003. Variations in microbial community composition through two soil depth profiles. Soil Biol. Biochem. 35: 167-176.

Findlay, R.H., and F.C. Dobbs. 1993. Quantitative description of microbial communities using lipid analysis, p 777. In P.F. Kemp, B.F. Sherr, E.B. Sherr and J.J. Cole (eds), Handbook of Methods in Aquatic Microbial Ecology. Lewis Publishers, Boca Raton.

Frankenberger Jr., W.T., and W.A. Dick 1993. Relationship between enzyme activities and microbial growth and activity indices in soil. Soil Sci. Soc. Am. J. 47: 945-951.

Frostegard, A., E. Baath, and A. Tunlid,. 1993. Shifts in the structure of soil microbial communities in limed forests as revealed by phospholipid fatty acid analysis. Soil Biol.Biochem. 25: 723–730.

Horwath, W.R., and E.A. Paul. 1994. Microbial biomass pp. 753-773. In R.W. Weaver, J.S. Angle, and P.S. Bottomley (eds.) Methods of Soil Analysis. Part 2 Microbiological and Biochemical Properties. SSSA Book Series No. 5, Soil Science Society America Inc., Madison, WI.

Runion, G.B., Prior, S.A., Reeves, D.W., Rogers, H.H., Reicosky, D.C., Peacock, A.D., White, D.C. 2004. Microbial responses to wheel-traffic in conventional and no-tillage systems. Commun Soil Sci. Plant Anal. 35: 2891-2903.

Tabatabai, M.A., 1982. Soil enzymes; Dehydrogenases. Pp937-940. In A.L. Page, R.H. Miller and D.R. Kenney (eds) Methods of Soil Analysis. Part 2 Chemical and Microbiological Properties. 2nd Edition, Agronomy Monograph 9. ASA and SSSA, Madison, WI.

Terra J.A., J.N. Shaw, D.W. Reeves, R.L. Raper, E. van Santen, E.B. Schwab, and P.L. Mask. 2006. Soil management and landscape variability affects field-scale cotton productivity. Soil Sci. Soc. Am. J. 70:98-107.

Zelles, I., Q.Y. Bai, R.X., Ma R. Rackwitz, K. Winter, and F. Beese. 1994. Signature fatty acids in phospholipids and lipopolysaccharides as indicators of microbial biomass and community structure in agricultural soils. Soil Biol.Bioch.em 24: 317-323.

Table 1. Characteristics of soil properties used in the in situ field study reported on a dry wt basis.

Soil Series	pH	CEC	Total C	Total N	C:N Ratio
		cmol kg^{-1}	-----------g kg^{-1}	-----------	
Spring 2004					
Bama	6.31	5.84	4.42	0.48	9.21
Lynchburg	6.1	5.46	5.57	0.51	10.92
Goldsboro	6.24	6.09	3.77	0.41	9.2
Summer 2005					
Bama	6.26	5.7	3.77	0.39	9.67
Lynchburg	6.25	7.79	6.12	0.58	10.56
Goldsboro	6.86	5.12	4.02	0.54	7.41

Table 2. Soil physical characteristics of soils used in this study

	BD	Sand	Silt	Clay
	g cm^{-3}	-----------------	%	-----------------
Bama	1.68	66.25	21.25	12.50
Lynchburg	1.64	46.25	41.25	12.50
Goldsboro	1.61	33.75	48.75	17.50

Table 3. PLFAs of the first five scores accounting for the variance of the first three canonical axes

Fatty acid	Score	Score	Specificity as a biomarker
Canonical variable 1			
16.1? 5c		0.82	Bacteia (Gram-positive and Gram-negative)
18:3 ? 6c		-0.43	Fungi
18:1? 7c		0.42	Aerobic bacteria, Gram-negative
cy19:0		0.40	Anaerobes, Gram-negative bacteria
20:4? 6,9,12		0.39	Fungi
Canonical variable 2			
16:1? 7c/i15:0 2OH		-0.70	Nonspecific
18:1? 7c		-0.53	Aerobic bacteria, Gram-negative
18:0		0.50	Biomass all organisms
a15:0		-0.38	Gram positive bacteria
18:3? 6c		0.37	Fungi
Canonical variable 3			
i17:0		0.38	Gram-postive bacteria
a18:0/18:2? 6,9c		-0.42	Grampositive/ Fungi
16:1 20H		0.37	Nonspecific
cy 17:0		0.37	Gram-negative
17:0 10 methyl		0.36	Actinomycetes

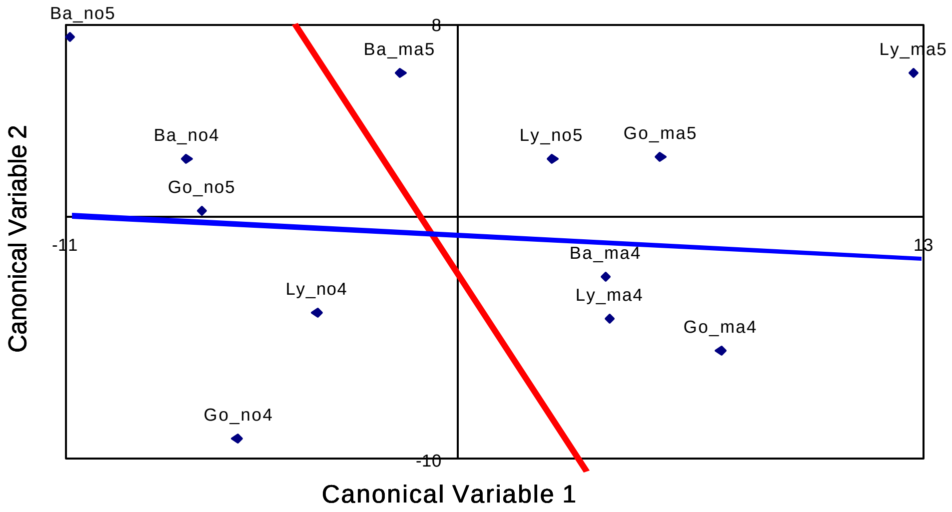


Figure 3. Canonical discriminant analysis (CDA) of phospholipid fatty acid profiles of the canonical variables (CV). Plot of ordination of CV1 against CV2 during the summer (05) and winter (04) months for the Bama (Ba), Lynchburg (Ly) and Goldsboro (Go) soil with (ma) and without dairy compost manure (no).

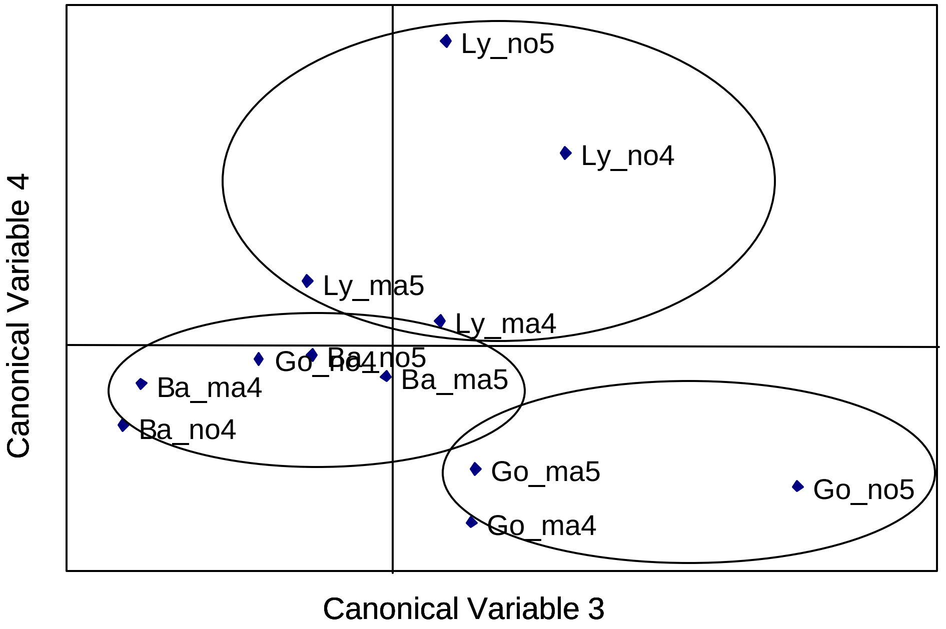


Figure 4. Canonical discriminant analysis (CDA) of phospholipid fatty acid profiles of the canonical variables (CV). Plot of ordination of CV3 against CV4 during the summer (05) and winter (04) months for the Bama (Ba), Lynchburg (Ly) and Goldsboro (Go) soil with (ma) and without dairy compost manure (no).

PEANUT YIELD RESPONSE TO BAHIAGRASS KILL TIME AND TILLAGE METHOD IN THE SOUTHEAST

Duli Zhao, David Wright, Jim Marois, and Tawainga Katsvairo

IFAS-North Florida Research and Education Center
University of Florida, Quincy, FL 32351
E-mail: dzhao@ufl.edu

ABSTRACT

Experiments were conducted in 2006 at two locations (Marianna and Quincy) of the North Florida Research and Education Center, FL to investigate effects of bahiagrass (*Paspalum notatum*) kill time and tillage practices on peanut yield and market grade. The experiments included two bahiagrass kill times (fall kill and spring kill) and six tillage methods [(1) strip till, (2) disk+turned, (3) disk+chisel, (4) paratill+strip till at planting, (5) disk+strip till, and (6) strip till+40 lbs N acre^{-1}] within each kill time. Peanut (cv. AP 3) was seeded on 15-16 May 2006 with a row space of 3 feet and six seeds per foot row. During the growing season, insects and diseases were controlled and irrigation was scheduled based on peanut production practices in the region. Pod yield and market pod grade characteristics were determined. Neither kill time of bahiagrass nor tillage methods affected peanut yield at both locations ($P > 0.05$). There was no interactive effect of the bahiagrass kill time and tillage type on peanut yield. In the strip till, peanut yield did not respond the N application. Averaged across the locations and tillage methods/bahiagrass kill times, peanut yields of the fall kill and spring kill were 4077 and 4173 lbs acre^{-1}, respectively; and the yields of the six tillage methods were 4199, 4201, 4281, 4072, 4162, and 3843 lbs acre^{-1}, respectively. These results indicate that (i) in the sod-based rotation systems in Florida, farmers may have a wide window of time period to kill bahiagrass and to prepare seedbed for following peanut crop; (ii) N nutrient may not be a factor of limiting peanut yield or make a difference in crop residue decomposition in the strip till system of peanut following bahiagrass in the region; (iii) there is potential to make the sod-based crop rotation system more profitable by reducing energy input and tillage requirements; and (iv) high yields of peanuts may be expected when planting peanuts after bahiagrass.

INTRODUCTION

Studies have shown that sod-based rotation of peanut (*Arachis hypogea* L.) and cotton (*Gossypium hirsutum* L.) in the Southeast US can significantly reduce disease pressure (Dickson and Hewlett, 1989; Johnson et al., 1999; Marois and Wright, 2003a; Wright et al., 2004a), improve crop growth and development, and increase crop yield and profitability (Norden et al., 1980; Brenneman et al., 1995; Katsvairo et al., 2006) compared with conventional cropping systems. The value of bahiagrass (*Paspalum notatum*) in rotation with peanuts is clear in many field experiments (Brenneman et al., 1995; Marois and Wright, 2003b; Wright et al., 2004a; Wright et al., 2004b). However, most growers have not see the system as being out of crop production for a year or more and the cost of breaking up the land to get it back to peanut production. With rising fuel prices as well as input cost, it has become more important to find ways of reducing costs and increasing profitability while increasing peanut yields. Studies suggest that there are considerable differences among tillage methods in input cost, soil impact or crop yields (Jordan et al., 2002). In order to make the sod-based crop rotation system more profitable by reducing energy input and tillage requirements, we conducted this research at three states of Florida, Alabama, and Georgia in 2006 and 2007. The specific objectives of this study were to investigate effects of bahiagrass kill time and tillage practices on peanut yield, market grade, and net return and to test if fungicide application has different effects on peanut yield. In this report, we summarize the results of peanut yield responses to bahiagrass kill time, tillage, and fungicide application in 2006 at two locations (Marianna and Quincy) of the North Florida Research and Education Center.

MATERIALS AND METHODS

Marianna location

The experiment included two levels of bahiagrass kill time (fall kill and spring kill) and six tillage treatments within each kill time. The dates of bahiagrass fall kill and spring kill were 26 October 2005 and 20 March 2006, respectively with 3 qts. of Rundup Weather Max per acre. The six tillage treatments were: (1) Strip till, (2) Disk+turned, (3) Dick+chisel, (4) Paratill+strip till at planting, (5) Disk+strip till, and (6) Strip till+40 lbs N acre^{-1}. A rate of 40 lbs N fertilizer of Ammonium N per ace was forecasted on April 15 for the strip till+40 lbs N treated plots.

Peanut (cv. AP 3) was seeded with a 2-row planter on 15 May 2006 with a row space of 3 feet and six seeds per foot row. During the growing season, insects and diseases were controlled and irrigation was scheduled based on peanut production practices in the region. When crop reached maturity stage on 4 October 2006, the two middle rows in each plot were mechanically dogged and reversed and harvested on 9 October. Pod samples were placed a forced-air dryer at 113°F for 72 hours to ensure for a constant weight. Pod yield and market pod grading characteristics, including percentages of sound mature kernels (SMK), sound split kernels (SSK), other kernels (OK), Hulls, and TSWV were determined.

Quincy location

Similar to the Marianna experiment, the experiment at Quincy was also composed with two levels of bahiagrass kill time (fall kill and spring kill) and six tillage treatments. The fall kill date was 26 October 2005 with 3 qts. of Rundup Weather Max per acre and the spring kill was two times of applying Glyphomax Plus on 29 March and 10 April 2006 with the rate of 3 qts. acre^{-1} each time. The six tillage treatments were the same as that in Marianna and they were: (1) Strip till, (2) Disk+turned, (3) Dick+chisel, (4) Paratill+strip till at planting, (5) Disk+strip till, and (6) Strip till+40 lbs N acre^{-1}. Seeds of peanut cultivar AP 3 were planted on 16 May 2006. Measurements of Soil mechanical resistance were taken in all plots using a CP20 Cone Penetrometer on 18 May, 5 June, 25 July, and 15 August. Except for the kill time and tillage treatments, other field management practices, such as irrigation and herbicide and insecticide application, were scheduled for all plots based on peanut production practice recommendations in the region during the growing season. At maturity, the two middle rows in each plot were mechanically harvested. Pod samples were dried to determine yield and market pod grading parameters using the similar methods described above.

Experimental design and data analysis

The experiments were a split plot design with four replications. The bahiagrass kill times were main plots and tillage treatments were sub-plots. The sub-plot size was 50 feet long and 18 feet wide. Analysis of variance (ANOVA) was carried out using SAS procedures of GLM to determine the main and interactive effects of bahiagrass kill time and tillage type. The least significant difference (LSD) tests were used to distinguish the treatment difference at *P* = 0.05 level.

RESULTS AND DISCUSSION

Soil mechanical resistance

Studies have confirmed that soil compaction directly affects crop root growth and limits use of deep soil water and nutrients, resulting in a reduced crop growth and low yields (Atwell, 1990; Alakukku and Elonen, 1995). Measurements of soil mechanical resistance in Quincy indicated that the fall kill treatment had less soil resistance from 20 to 30 cm of soil depth than the spring kill treatment (Figure 1A). Less resistance in soil compaction layer for the fall killed than the spring killed bahiagrass is not surprised because fall kill treatment had more time to decompose bahiagrass biomass, especially roots. When roots decay, they leave root channels which can improve soil penetration (Katsvairo et al., 2006) and field infiltration (Katsvairo et al., 2007). However, this soil penetration advantage from fall kill of bahiagrass did not result in yield benefit of the following peanut in the present study (Tables 1 and 2). Reduced soil mechanical resistance in the fall killed treatment may save horse power for seedbed preparation although peanut yield did not respond soil resistance. Types of tillage greatly affected soil mechanical resistance. Averaged across measurement dates and the bahiagrass killed times, the Disk+strip till treatment had the greatest and the Paratill+strip till had lowest soil resistance (Figure 1B).

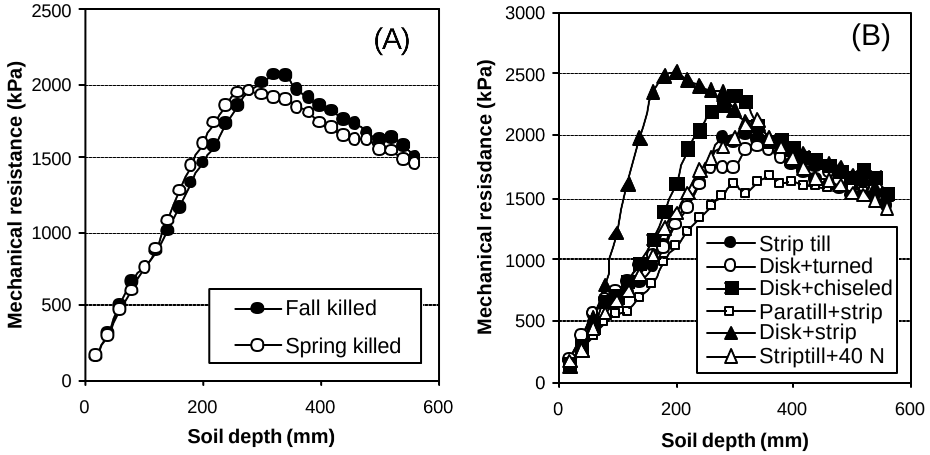


Figure 1. Soil mechanical resistance for (A) plots of fall kill vs. spring kill bahiagrass and (B) the six tillage types. Data are means of four times of measurements in Quincy, Florida.

Peanut yield responses to bahiagrass kill time and tillage

Peanut yields in Marianna and Quincy were 4273 and 3978 lbs acre^{-1}, respectively, averaged across the bahiagrass kill time and tillage treatments. Overall, the peanut yield in the present study is 60 to 70% higher than State average yield (about 2500 lbs acre^{-1}) of peanut in the Southeast. The good yields are attributable to being after 2 years of bahiagrass (Brenneman et al., 1995; Marois and Wright, 2003b; Wright et al., 2004a; Wright et al., 2004b). Statistical analysis indicated that there was significant difference ($P < 0.05$) in peanut yield between the two experimental locations. Therefore, yield data were analyzed independently for each location. In Marianna, neither the kill time nor tillage statistically affected pod yield. The interaction between replication and the kill time was significant ($P < 0.05$, Table 1). In Quincy, the kill time did not, but the tillage did affect peanut yield ($P < 0.10$). There was no any interaction of the kill time and tillage in yield at the experimental location of Quincy (Table 1).

Table 1. Analysis of variance (ANOVA) for peanut yield responses to the kill time of bahiagrass and tillage at Marianna and Quincy, Florida in 2006.

Source	DF	*P* value	
		Marianna	Quincy
Replication	3	0.1458	0.5663
Kill time	1	0.9122	0.3616
Rep × Kill time	3	0.0274	0.6685
Tillage	5	0.4843	0.0910
Rep × tillage	15	0.2323	0.4061
Kill time × tillage	5	0.7473	0.2334

Peanut yields from bahiagrass kill date and tillage treatments at two locations are given in Table 2. Averaged across the tillage treatments, peanut yields of the fall kill and spring kill of bahiagrass were 4264 and 4280 lbs acre^{-1}, respectively in Marianna and 3890 and 4066 lbs acre^{-1}, respectively in Quincy. Peanut yield did not differ between the fall kill and the spring kill of bahiagrass at the both locations. Our unpublished data in a corn following bahiagrass experiment also indicate that there are no differences in corn growth and physiological parameters between the fall kill and the spring kill of bahiagrass. Thus, farms have a great time window or flexibility from fall to spring to kill bahiagrass for the following row crops without any yield reduction. In Marianna, tillage did not affect peanut yield in the fall kill, but the strip till had higher yield than the disk+chiseled treatment in the spring kill of bahiagrass ($P < 0.05$). Although yield did not differ between the fall kill and spring kill treatments when averaging yield across tillage treatments at Quincy, yield of the strip + 40 lb N/acre treatment was significantly lower than that of the disk+turned treatment in the fall kill of bahiagrass and that of the disk+chiseled treatment in the spring kill of bahiagrass. The yield of the paratill+strip till at planting time was also lower than that of the disk+chiseled (Table 2).

Strip till was the most simple tillage method among the six tillage treatments, but its peanut yield was equivalent to that of other tillage treatments. This indicates that in sod-based peanut-cotton rotation systems in the southeast, the conservation tillage of strip till can reduce input and increase profitability. Theoretically, row crops may face N limitation when they follow bahiagrass because decomposition of bahiagrass roots and residues requires a period of time. Our results revealed that N nutrient was a factor of limiting peanut yield in the sod based rotation system with strip till in both the fall kill and the spring kill of bahiagrass (Table 2).

Table 2. Effects of bahiagrass kill time and tillage on peanut yield (lbs acre^{-1}) at Marianna and Quincy, Florida in 2006.

Tillage	Marianna			Quincy[†]		
	Fall kill	Spring kill	Mean	Fall kill	Spring kill	Mean
Strip till	4078 a[†]	4499 a	4289 a	3776 ab	4441 ab	4109 ab
Disk+turned	4115 a	3806 b	3960 a	4516 a	4369 ab	4442 a
Disk+chiseled	4331 a	4364 ab	4348 a	3731 ab	4697 a	4214 ab
Paratill+strip till	4353 a	4442 ab	4398 a	3983 ab	3508 b	3746 bc
Disk	4521 a	4316 ab	4420 a	4049 ab	3759 ab	3904 abc
Strip till+40 lb N	4187 a	4253 ab	4220 a	3285 b	3634 b	3465 c
LSD $_{0.05}$	1114	648	622	875	1023	650

[†] Means within a column followed by the same letter are not significantly different at the level of *P* = 0.05.

Peanut market grade characteristics

Bahiagrass kill time and tillage method did not affect any grading parameters of percent sound mature kernels (SMK), percent sound split kernels (SSK), percent other kernels (OK), percent hulls, or percent kernels with tobacco spot wilt virus (TSWV) infection (data not shown). There were no statistical differences between the two locations in SMS, SSK, OK, and percent hulls (Table 3). However, peanut kernels at Quincy had significantly higher TSWV compared to peanuts at Marianna in all tillage methods (Table 3). Averaged across kill times of bahiagrass and tillage types, the TSWV was 0.53% at Marianna and 0.81% at Quincy.

Table 3. Percentages (%) of sound mature kernels (SMK), sound split kernels (SSK), other kernels (OK), hulls, and TSWV of peanuts at Marianna and Quincy, Florida in 2006.

System	Marianna					Quincy				
	SMK	SSK	OK	Hull	TSWV	SMK	SSK	OK	Hull	TSWV
Strip till	60.0	6.82	4.25	28.6	0.48	59.7	7.39	4.18	28.0	0.83
Disk+turned	60.0	6.71	4.18	28.5	0.61	59.0	7.69	4.54	28.1	0.86
Disk+chiseled	60.4	6.22	4.84	28.3	0.51	59.3	7.06	4.46	28.4	0.85
Paratill+strip till	59.8	5.70	4.80	29.0	0.34	61.0	6.08	4.66	28.0	0.73
Disk	59.3	7.19	4.68	28.3	0.63	59.4	6.89	4.52	28.5	0.86
Strip till+40 lb N	59.9	6.03	5.14	28.9	0.64	60.0	6.16	5.10	28.0	0.71
Mean	59.9	6.44	4.65	28.6	0.53	59.7	6.88	4.57	28.2	0.81

[†] Data are means of the fall kill and spring kill of bahiagrass.

CONCLUSIONS

Preliminary results of this study at the two locations (Marianna and Quincy) of the North Florida Research and Education Center in 2006 indicated that:

1. Peanut yield and grading variables did not differ between the bahiagrass fall kill and spring kill treatments at both locations although soil penetration was improved by the fall kill bahiagrass compared to the spring kill bahiagrass. Therefore, in the sod-based rotation systems in the southeast, farmers may have a wide window to kill bahiagrass and to prepare seedbed for following peanut crop. Bahiagrass may be killed at anytime from the fall until 4-5 weeks prior to planting. However, soil compaction is higher if bahiagrass is killed in the spring as compared to the fall and may require more horse power to pull tillage implements due to more compacted soil.

2. Peanut yield response to tillage treatments depends upon the experimental location. At Marianna, the six tillage treatments did not affect peanut yield in the fall kill of bahiagrass, but in the spring kill, yield of the strip till was significantly higher than the disk+turned treatment. At Quincy, the disk+turned treatment had significant higher yield than the strip till+40 lb N treatment in fall kill of bahiagrass. In the spring kill of bahiagrass, the treatment of disk+chiseled had the highest, but the disk+strip till at planting and the strip till+40 lb N treatments had the lowest yield. More studies are required for further investigating tillage effect on peanut yield.

3. Application of N fertilizer did not improve peanut yield, when peanut followed bahiagrass in strip till system at both locations in this study. Therefore, N nutrient may not be a factor of limiting peanut yield or make a difference in cover crop decomposition in the strip till system of peanut following bahiagrass in Florida.

4. High yields of peanuts can be expected when planting peanuts after bahiagrass in conservation tillage.

REFERENCES

Alakukku, L., and Elonen, P. 1995. Long-term effects of a single compaction by heavy field traffic on yield and nitrogen uptake of annual crops. Soil Tillage Res, 36: 141-152.

Atwell, B.J. 1990. The effect of soil compact on wheat during early tillering. I: Growth, development and root structure. New Phytol., 115: 29-35.

Brenneman, T.B., Sumner, D.R., Baird, R.E., Burton, G.W., and Minton, N.A. 1995. Suppression of foliar and soilborne peanut diseases in bahiagrass rotations. Phytopathology 85:948–952.

Dickson, D.W., and Hewlett, T.F. 1989. Effects of bahiagrass, and nematicides on Meloidogyne arenaria on peanut. Suppl. J. Nematol. 21, 4S:671–676.

Johnson, A.W., Milton, N.A., Brenneman, T.B., Burton, G.W., Culbreath, A.K., Gascho, G.J., and Baker, S.H. 1999. Bahiagrass, corn, cotton rotations, and pesticides for managing nematodes diseases, and insects in peanuts. J. Nematol. 31:191–200.

Jordan, D.L., Bailey, J.E., Barnes, J.S., Bogle, C.R., Bullen, S.G., Brown, A.B., Edmisten, K.L., Dnphy, E.J., and Johnson, P.D. 2002. Yield and economic return of ten peanut-based cropping systems. Agron. J., 94: 1289-1294.

Katsvairo, T.W., Wright, D.L., Marois, J.J., Hartzog, D.L., Rich, J.R., and Wiatrak, P.J. 2006. Sod–livestock integration into the peanut–cotton rotation: A systems farming approach. Agron. J. 98: 1156-1171.

Katsvairo, T.W., Wright, D.L., Marois, J.J., Hartzog, D.L., Balkcom, K.B., Wiatrak, P.P., and Rich, J.R. 2007. Cotton roots, earthworms, and infiltration characteristics in sod–peanut–cotton cropping systems. Agron. J. 99:390-398.

Marois, J.J., and Wright, D.L. 2003a. Effect of tillage system, phorate, and cltivar on tomato spotted wilt of peanut. Agron. J. 95: 386-389.

Marois, J.J., and Wright, D.L. 2003b. A working business model for cattle/peanuts/cotton. Proc. Sod Based Cropping Syst. Conf., North Florida Research and Education Center-Quincy, University of Florida, Feb. 20-21, 2003, pp. 180-186.

Norden, A.J., Perry, V.G., Martin, F.G., and NeSmith, J. 1980. Effect of age of bahiagrass sod on succeeding peanut crops. Peanut Sci. 4:71–74.

Wright, D.L., Katsvairo, T.W., Marois, J.J., and Wiatrak, P.J. 2004a. Introducing bahiagrass in peanut/cotton cropping systems-effects on soil physical characteristics. In Annual Meeting Abstracts of ASA, CSSA, and SSSA. Madison, WI.

Wright, D., Marois, J., Katsvairo, T., Wiatrak, P., and Rich, J. 2004b. Value of perennial grasses in conservation cropping systems. Proc. 26th Southern Conserv. Tillage Conf. Sustain. Agric., Raleigh, NC, 8-9 June 2004. p. 135-142.