The 27th Annual Southern Conservation Tillage Systems Conference

The Science of Conservation Tillage: Continuing the Discoveries

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Foreward

At the 2004 meeting in Raleigh, NC, the steering committee of *The Southern Conservation Tillage Conference for Sustainable Agriculture* changed the name to *The Southern Conservation Tillage Systems Conference.* This was done to emphasize the systems approach that is needed to optimize productivity and profitability while protecting and enhancing environmental resources with conservation tillage management. Though the name of the conference has changed several times since its inception in 1978, its purpose has remained constant: to serve as a means of communication among people interested in conservation tillage systems.

Times have changed in the South. Conservation tillage management has become common on southern farms. The theme of this year's conference, *The Science of Conservation Tillage: Continuing the Discoveries*, was chosen because as we begin this new era in crop production, we begin a new era of discoveries about how soils, the ecosystems surrounding fields, and the economics of production are affected with this new way of growing crop plants.

The 2005 *Proceedings* contains papers and abstracts of research and extension projects on a number of different aspects of conservation tillage. It contains reports on animal production, animal waste, pests, fertility and liming, soil water and irrigation, and soil physical and chemical responses to conservation tillage management. Although there are papers about most of the agronomic crops of the southern region, prominent this year is the large number of papers on conservation tillage production of peanuts. Special to this year's conference was a session on site-specific farming and those papers are included.

We in South Carolina appreciate the opportunity of hosting the conference. We thank the authors, sponsors, and participants who contributed to this conference.

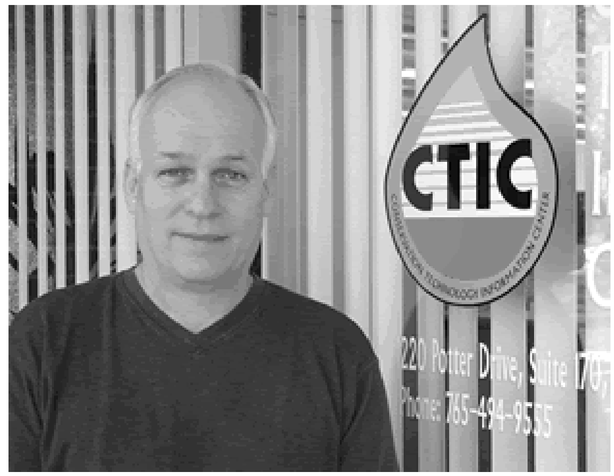
2005 Southern Conservation Tillage Planning Committee

CONFERENCE KEYNOTE SPEAKER

John A. Hassell

Executive Director, Conservation Technology Information Center

Executive Director of the Conservation Technology Information Center since 1999, Mr. Hassell has been working in the field of water quality and conservation for over twenty years. Mr. Hassell is responsible for CTIC's overall operations including the budget, programs and marketing. Prior to joining CTIC, Mr. Hassell was Director of Water Quality Programs for the Oklahoma Conservation Commission where he oversaw Oklahoma's nonpoint source water quality program including six Clean Water Act grants, the state's nonpoint source monitoring program and public information and education programs. Mr. Hassell has extensive experience with conferences and workshops. While with the Oklahoma Conservation Commission, Mr. Hassell put on an Off-site Assessment Workshop, Stream Bank Stabilization Workshop, National Nonpoint Source Monitoring and Evaluation Conference, Pre-Conference Water Quality Workshops, the First Annual Nonpoint Source Conference, and An Applied Fluvial Geomorphology Short Course. At CTIC, Mr. Hassell makes numerous presentations each year. Events have included national watershed, nonpoint source and wetland conferences. Mr. Hassell also assists CTIC staff in organizing and conducting the Annual Nonpoint Source Monitoring and Modeling Conference, as well as several other events each year.



WHERE HAS ALL THE PASSION GONE?

John A. Hassell

Executive Director, Conservation Technology Information Center

Changes to conservation and environmental policy within the United States have been driven by crisis. An early example occurred during the 1930s with the onset of the Dust Bowl. This, a major environmental crisis to affect the livelihood of so many, led to the establishment of the Soil Conservation Service (now the Natural Resources Conservation Service) and conservation districts. Then, during the late ‘60s and early ‘70s, when headlines broadcast massive fish kills and rivers catching on fire, the environmental movement was driven by considerable water pollution issues. Changes quickly followed with the establishment of the Environmental Protection Agency (EPA) and the passage of the Clean Water Act of 1972. Later, many other laws were passed to address safe drinking water, hazardous materials and other environmental issues. History proves that change occurs when passionate citizens of our country demand action to address environmental crises.

Where is our passion today? The majority of Americans are not aware of the current crisis in conservation and environmental stability. Increasing populations demand safe, inexpensive food, fiber and energy. Decreasing cropland acreages are expected to produce greater yields to satisfy the consumptive nature of our population. Depleted water supplies are stretched thin to satisfy agricultural production, industrial processing and municipal use. Soil quality is being compromised because of the way our lands are managed. Yes, a crisis exists, but are people aware?

The evidence is in the data. In 1982, 420.4 million cropland acres were planted. In 2004, 276.8 million acres were planted. Water quality issues associated with agriculture account for 40% of the reported problems according to EPA's Office of Water, Oceans and Wetlands. The problems identified include sediment, nutrients and bacteria. World population has grown from 2.5 billion in 1950 to 6.4 billion today. The United States population growth has gone from 120 million in 1950 to 293 million today, with a growth rate of approximately 3.2 million per year. The United States is the fastest growing industrialized county in the world. Rivers that once drained into our oceans have ceased to reach them because of the tremendous water withdrawals by hungry cities, industry and agriculture. Since 1950, the Ogallala Aquifer, a huge fossil aquifer stretching from the panhandle of Texas to the Dakota's, has lost 30% of its available water, which is equivalent to 50% of the water in Lake Erie. Our conservation efforts continue to address managing for soil erosion, rather than managing for soil quality. Yet in the United States, we still have 103 million acres of land eroding excessively, yielding 1.9 billion tons of soil loss annually. Our soil quality efforts are minimal, with only 22.6% of cropland acreage in a no-till system and less than 10% of those acres are continuously no-till. There is a crisis and no passion on the landscape demanding a change to protect the consumptive life that we all enjoy.

The presentation will discuss changes that need to be made in order for agriculture to continue to provide the safe, inexpensive products produced that society demands. The presentation will address the role that conservationists need to have in future agricultural programs. One of the ways to accomplish change is to renew the passion to promote changes that have positive benefits for our natural resources. There needs to be a revival of a conservation ethic by all who work in the area of conservation. And we need to remember that, "Conservation is more than just a word – it's a way of life – and it's forever."

Sod Based Rotations-The Next Step after Conservation Tillage

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Abstract

Conservation tillage techniques have been worked out over the past 30 years for the agronomic crops currently grown in the U.S. Many scientists have shown the value of conservation tillage on different aspects of crop production including economics, soil and water quality, and the environment. The advent of genetic technology for corn, soybean, and cotton increased the transition from conventional tillage (plow, harrow, etc.) to various forms of conservation tillage. This has allowed farmers to farm more land by allowing them to use broadcast sprayers where row tillage or directed sprays were done before. While conservation tillage has resulted in many benefits, farmers still struggle since yields have not necessarily increased by to converting to minimum tillage. There is a next step in increasing yields. Years of research in the southeast have shown that perennial grasses such as bahiagrass can help improve soil structure and reduce pests such as nematodes and increase crop yields, sometimes dramatically. Research in the southeast with perennial grasses grown in rotation with crops has shown higher yields (50% higher peanut yields than under conventional annual cropping systems), increased infiltration rates (more than 5 times faster), higher earthworm numbers (thousands per acre vs. none in some cases), and a more economically viable (potential 3-5 times more profit) cropping system. Diversification into livestock can add another dimension to the farming system making it more intensive and offer risk aversion benefits as well as provide a readily available use for perennial grasses. Verification of this concept is underway and is being moved onto farms.

Introduction

Conservation tillage has been widely accepted across the U.S. as a way to increase soil organic matter, one of the keys to productive soils, while enhancing water holding capacity, and reducing erosion, fuel and labor use. Sod based rotations should be coupled with conservation tillage for maximum benefits using integrated pest management and genetic technology (Reeves, 1997). The development of precision planters, subsoilers, and varieties resistant to herbicides and insects has enabled widespread adoption of conservation tillage practices in many farming systems. Conservation tillage techniques are still not widely used for peanut production and have had a slower adoption rate than for most of the row crops (CTIC, 1994). Even where conservation tillage has been widely adopted, yields of cotton and peanut have been stagnant for the last 20 or more years with spikes occurring when weather conditions are favorable. Conversion of crop land to perennial grasses in rotation with annual crops provides great potential to mitigate these problems. The native perennials protect the soil from erosion while increasing soil organic matter (SOM). Research efforts have shown several practices that lead to increased SOM or at least slower degradation. These practices include: including perennial grass and legume production in rotation or permanent pastures, manure or other organic additions, year round cover crops, return of high levels of plant residues, crop diversity, reduced tillage, use of stress resistant crops or varieties, and application of needed mineral fertilizer to promote higher yields and increased biomass production. The ultimate goal of agriculture is to be economically profitable while conserving and even enhancing natural resources for future generations. Seldom have all of these practices been used over wide areas. Increased SOM would have a major impact on agriculture by increasing soil fertility, improving water relations and soil structure, and eventually increase productivity and return higher rates of organic matter to the soil. Recent farm programs (Conservation Reserve Program) in the U.S. has led the effort to convert some of these cropped areas and once native grass areas back into perennial grasslands and forests. Diversified farming will become more common in the future which will mean more perennial grasses in rotation with annual crops allowing farmers to maintain or enhance quality of the soil resulting in long term sustainability of SOM and economic viability.

A wide range of grasses have been used for grazing and improving soil structure under different soil conditions. These include drought and salt tolerant wheatgrass (*Agropyron spp*.), flood tolerant reed canarygrass (*Phyalaris spp*.). Adapted perennial grasses generally develop a deep rooting system which can improve soil conditions. Pavlychenko (1942) noted that native grasses such as porcupine grass (*Stipa spartea Trin*) and blue grama (*Bouteloua gracilis*) were most effective in improving soil structure at depths of 60 cm as compared to creasted wheatgrass. In the Southeast, much of the farmland suffers from a natural compaction layer starting at 15-20 cm depth and continuing to 30 cm (Kashirad et al., 1967). This results in a shallow root system which confines root development to a small soil volume which is a small reservoir for both water and nutrients and consequently has dramatic effects on crop management and yield. The shallow rooted crops are susceptible to short periods of moisture stress under the sandy conditions typical of the southeast. Perennial grasses such as bahiagrass and Bermuda grass, which are adapted to the southeast, develop a deep root system which penetrates through the compaction layer (Elkins et al., 1977). When the roots die, they decay and leave root channels which positively impacts soil structure, water infiltration and available water (Elkins et al. 1977; Wright et al., 2004). Long and Elkins (1983) compared cotton following 3 years of bahiagrass sod with continuous cotton. They found a seven fold increase in pore sizes greater than 1.0 mm in the dense soil layer below the plow depth. They concluded that the dense soil layer had been penetrated by the bahiagrass roots and that, after the decay of the roots, pores were left that were large enough for the cotton roots to grow through. Perennial grasses can reduce the need for irrigation in the following crop. Elkins et al. (1977) calculated that given an evapotranspiration rate of 0.45 cm of water per day, available water of 2.54 cm per 30 cm of soil, and plant rooting depth of 15 cm, plants will experience water stress after 3 days without rainfall. However, if the rooting depth is 152 cm, the plant would not experience water stress for 30 days without rainfall.

The Southeast is one of the most diverse crop production areas in the U.S. and has a climate that is conducive to multi-cropping. All of the major crops as well as pasture grasses can be grown. Native vegetation was initially hardwood and pine forest with grass encroachment in cleared areas. As these small patches of bluestem and switch grass were overgrazed, they were replaced with broomsedge and other less desirable grasses. Continuous row cropping has continued to degrade these soils. It is known that rotation with perennial sod crops will increase soil carbon, water infiltration, improve soil structure, and decrease erosion to a higher level than the winter annual cover crops which have been shown to be better than summer annuals. Winter annual cover crops do not do much to enhance soil quality because of their short duration and fast degradation. Living roots have a tremendous impact on soil quality with annual crops only having active roots for about 3 to 4 months each year. Much of the research in the 20th century has looked at cover crops as green manure crops to be turned under for nitrogen benefit or nematode suppression. Perennial grasses all over the world have been shown to have a major impact on yield. Florida farmers will testify that peanut, watermelon, and soybean will all yield substantially higher after bahiagrass. Cooper and Morris, 1973, put it in context when they described a wheat- sod based rotation by saying that the primary function of sod is to put “heart back into the land”. Virginia research showed that winter annual cover crops did not contribute to improved water holding capacity while perennial grasses did. Agriculture has a history of depletion of SOM and subsequent loss of soil fertility and productivity as a result of poor management. At times this is a result of lack of knowledge about agricultural practices or a lack of proper resources to maintain productivity. Farmers are often financially strapped to the point of maximizing short term productivity at the expense of long term productivity. There are often other factors such as environmental conditions, marginal soils or marginal crops that result in minimum income resulting in growers doing the minimum to continue farming at the expense of long term productivity. Extensive cultivation done throughout the Corn Belt, Great Plains, and the Southeast Cotton Belt of the U.S. over the past 150 years resulted in loss of high amounts of SOM, soil nitrogen, and influenced atmospheric CO_2 levels as well as resulting in abandonment of large areas due to erosion. Cultivation and cropping resulted in losing ¼ to ¾ of the SOM that was present 100 years ago as seen from long term plots (Magruder, Sanborn, and Morrow plots). Many of these long term fertility sites had a rapid decrease in SOM until the 1940’s and 50’s when fertilizer use started to become a normal practice resulting in more biomass being produced and returned to the soil. Data from Georgia shows that SOM may be increased when put back into perennial crops but is degraded more rapidly. Soil quality is of major concern to the farming community while SOM or carbon sequestration concerns both agricultural and environmental scientists. A model (Imhoff et. al, 1990) currently in use for SOM by EPA and Natural Resource Conservation Service’s Natural Resources Inventory shows a decline between 1910 and 1950 to about one half the original levels. This model predicted some stability until about 1970 and predicted an increase in the next 30 years due to a higher cropping intensity and use of commercial fertilizer. Other reasons for a predicted increase in SOM are government programs that have promoted grass set aside of crop land and economic benefits of conservation tillage. The economic conditions of rising labor and fuel costs are expected to continue indefinitely. Growing continuous annual crops not only results in a decrease of SOM but in a buildup of nematodes and diseases (Dickson and Hewlett, 1989), a depletion of certain nutrients, less organic material left in the soil as compared to perennial crops, and compaction of the soil so roots cannot explore large areas for water and nutrients. Rotation is always at the top of the list as an important component of producing crops profitably (Edwards et. al., 1988). It is generally known that legumes will add nitrogen to the soil and improve soil health.

However, legumes contribute little to the long-term build up of organic matter and soil structure because of the rapid break down of the plant material and the flush of nitrogen available for plant growth (Frye et. al.1985). The U.S. Geological Survey has reported that 63% of North America that was previously in native grasslands is now cultivated. The reason for this is that most of these soils were highly productive and high in SOM when initially cultivated and many of these remain highly productive with ½ as much SOM as they started out with. Temperate grasslands have been estimated to contain 18% of the global SOM reserves (Atjay et al., 1979). This large storage of SOM is attributed to low decomposition rates relative to net production. Perennial grasses contribute little to the immediately available nitrogen pool, but add significantly to the organic base and long-term nitrogen pool as well as well as helping reduce pests normally found in annual grass or legume crops (Boman et.al., 1996, Elkins et. al. 1977). Annual ryegrass has been shown to contribute 3 to 4 times as much organic matter to the soil from its roots as crimson clover or vetch (McVickar, et.al.,1946). The nitrogen concentration of ryegrass roots is 1/3 to ½ that of legumes and yet ryegrass contributes more total nitrogen to the soil because it has considerably more root mass in the soil than any of the legumes. Likewise, animal manure and composts are more effective in building SOM than harvest residue, which is more effective than fresh plant material such as green manure crops. Paustian et al., 1992 showed that when the same rate of residue was added from 4 sources of organic material to the soil, soil organic carbon (SOC) was increased most by peat followed by manure, and then straw which contributed 3 times more SOC to the soil than alfalfa, which degrades rapidly. Likewise, relative soil carbon is 20-40% higher with grass/forage in a rotation as compared to continuous corn or soybean in rotation with corn. Areas with long growing seasons can have two to three crops planted each year adding to the organic matter base of the soil (Wright, et. al., 1998). However, continuous cropping of either annual grass or legume crops can result in nematode or disease build up to damaging levels as well as decreasing SOM. Hagan, et.al.,1995, noted that bahiagrass and to some degree, bermuda grass is resistant to all of the major nematodes of row crops in the Southeast and can contribute significantly to pest control and increased yields. Benefits of sod prior to row crop production can result in dramatic increases in yield at a lower cost of production with less pesticide use and less negative environmental impact than trying to alter all of these factors with chemicals and tillage tools. Water in the soil profile is conserved and utilized by the crops, since rooting depth is often 10 times deeper following bahia, or bermuda, as in conventional cropping systems, reducing irrigation needs from normal applications of about 30 cm of irrigation per year to as little as 5 cm with similar or higher yields. This could result in as little as 1/10 th the current water use for irrigation, alleviating some of the water problems for annual crops.

EXPERIMENTAL PROCEDURES

The multi-state project was has been underway since 2000 in Florida and 2001 in Alabama and Georgia to examine the influence of 2 years of bahiagrass on peanut and cotton as compared to a cotton/peanut rotation. The site at Marianna, FL was under a pivot and has a cow-calf operation in rotation with peanut and cotton and winter grazing after annual crops, while the large site at Headland has stocker cattle on winter grazing after peanut and cotton with the bahiagrass being used for hay in the stocker operation.

Small plots at Quincy, Headland, and Tifton utilized the grass as hay and the winter cover crop for planting the next crop into. 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 and various other measurements. The first four year cycle of this system was completed in small plots at Quincy in 2004 with data summarized over years and locations. The basic design of the study is shown below:

	Year 1		**Year 2**		**Year 3**		**Year 4**	
Field	Spring	Winter	Spring	Winter	Spring	Winter	Spring	Winter
1	Cotton	Wheat	Peanut	Wheat	Cotton	Wheat	Bahia	Bahia
2	Bahia	Bahia	Bahia	Bahia	Peanut	Wheat	Cotton	Wheat
3	Peanut	Wheat	Cotton	Wheat	Bahia	Bahia	Bahia	Bahia
4	Cotton	Wheat	Bahia	Bahia	Bahia	Bahia	Peanut	Wheat

RESULTS

The results obtained from the study have shown good advantages to the sod based system. Including bahiagrass in the cotton/peanut cropping system increases soil water infiltration rates in both the peanut and cotton phases of the cropping system. Higher infiltration rates reduce runoff and soil erosion and subsequently increase soil water content resulting in less plant stress. The bahiagrass rotation retained more soil moisture as compared to conventional cotton during both the 2003 and 2004 growing season. The increased moisture levels in the bahiagrass rotation were partially attributed to the increased infiltration rates observed in cotton after bahiagrass. Table 1 below shows the influence of the sodbased rotation on peanut with a 30-50% increase in peanut yield in 2003 and 2004 when the system was fully implemented. Bahiagrass was planted late the first year and did not have the advantage of 2 full years of bahiagrass.

Table 1. Peanut yields in a bahiagrass vs. a conventional Cotton/peanut rotation using conservation tillage techniques for both systems.

	2002		2003		2004		Mean	
	Irrigated	Non Irrigated	Irrigated	Non Irrigated	Irrigated	Non Irrigated	Irrigated	Non Irrigated
			(kg ha-1)					
B-B-P-C	3245a	3360a	2829 a	2737 a	3277 a	3287 a	3117a	3128a
C-P-C-C	3300a	3015b	2198 b	1719 b	2245 b	2584 b	2581b	2439b

* Means in columns followed by the same lower case letter are not significantly different.

Soil water nitrates were determined at the 15- and 30-cm depth in the conventional and bahiagrass rotated cotton. The cotton in the bahiagrass rotation had less soil water nitrate at both depths throughout the growing season. Bahiagrass has deep roots which penetrate through the compaction layer. When the grass dies, the roots decay, leaving root channels. Cotton may have exploited the channels and developed a more extensive rooting system, which utilize more N across a wider soil profile. Higher root biomass, root area and root length were observed in the bahiagrass rotated cotton. As with soil nitrate, the bahiagrass rotation had less ammonium nitrogen compared to the conventional cotton. Higher levels of N above the EPA recommended level have been reported in ground water in most states of the US. High levels of N in ground water are also responsible for algae blooms in fresh water bodies. Hence rotations which reduce N levels can be a good way to protect the environment.

Cotton in the bahiagrass rotation had less residual nutrients including P, Mg and B at the end of the season. The vigorously growing cotton in the bahiagrass rotation utilized more nutrients, leaving less residual nutrients being susceptible to leaching and erosion. However, the bahiagrass rotation had higher levels of both soil nitrate and ammonium at the end of the season. When the cotton roots died the decaying roots would have mineralized and released the NO3 and NH4. This would have resulted in more N being released from the bahiagrass rotation because it had the larger biomass. A solution to this would be to keep the land under crop cover, so that the residual soil N would be utilized. Cotton yields were significantly higher in 2002 and 2004 in the bahiagrass rotation (Table 2). All of the growth parameters were higher in cotton grown after peanuts in the bahiagrass system and yields were significantly higher 2 out of the 3 years.

Table 2. Cotton yields in bahia rotated vs. conventional rotations using conservation tillage techniques.

	2002	**2003**	**2004**	**Mean**
		Lint (kg ha^{-1})		
B-B-P-C	2317 a	1878	1979 a	2058
C-P-*C*-C	1613 b	2099	1829 b	1847
C-P-C-*C*	-	1934	1884 ab	1909

*Means in columns followed by the same letter are not significantly different

Earthworms were more numerous in sodbased rotated cotton by many folds in some cases. Earthworms are known to increase infiltration rates, aeration, soil nutrient cycling and help achieve good soil crumb structure. The higher organic matter and associated higher soil moisture in the bahiagrass rotation may have caused the increase in earthworm densities.

The bahiagrass rotated soils had less soil mechanical resistance compared to both cotton and peanuts in the conventional plots. High mechanical resistance impedes root growth and subsequently reduces cotton grade and yield. Higher mechanical resistance also retards water movement through the soil profile, thereby increasing the chances of water as runoff.

Soil from cotton in the bahiagrass rotation had lower bulk density compared to soil in conventional cotton. Bulk density is defined as the mass (weight) of a unit volume of soil.

Bulk density takes into consideration total pore space and is an indicator of porosity, infiltration and compaction.

Cotton grown after bahiagrass has improved yield component parameters including plant height, plant biomass and LAI in both 2003 and 2004. The cotton in the bahiagrass rotation was taller than cotton in the conventional system and had greater above ground biomass compared to conventional cotton. The taller plants in the bahiagrass rotated cotton also had greater total root length and root area. The more extensive rooting system in the bahiagrass rotation was able to utilize more soil nutrients across a larger volume of soil and in the process recycle nutrients from deeper soil depths. These nutrients would otherwise have been lost from the nutrient cycle.

Cotton in the bahiagrass rotation had higher LAI compared to the conventional cotton. The more developed plant canopy was able to effectively shade the weeds rendering them less competitive to the cotton. The reduced weed pressure in the bahiagrass rotated cotton will mean less herbicide application, thus reduce herbicides costs for the growers and also reduces, the potential for pesticide contamination to the environment. Bahiagrass contributed to the positive aspects of a health soil which in turn resulted in healthier and more vigorously growing plants which were better able to withstand stress conditions.

When combined over years, peanuts in the bahiagrass rotation had higher yields compared to the conventional peanuts at Quincy. Peanuts in the bahiagrass rotation are likely to have benefited from the positive soil health parameters following the bahiagrass, as described above. At Headland, peanuts in the conventional rotational had higher yield compared to the peanuts grown immediately after bahiagrass.

The beef industry has been doing well for the last several years. Forages are the backbone of the industry and the cheapest source of feed for livestock. Including bahiagrass in the traditional peanut/cotton cropping peanut increases the overall acreage of forage and provides risk aversion for that part of the farming operation that is then excluded from growing cash crops. Perennial grasses including bahiagrass can be produced at lower production costs compared to annual forages and row crops. Including bahiagrass in the traditional peanut/cotton cropping system will conserve and protect land from potential degradation. Perennial grasses protect land from erosion and help build up organic matter levels and increase water availability to following crops.

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SOIL RESPONSES UNDER INTEGRATED CROP AND LIVESTOCK PRODUCTION

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ABSTRACT

Integration of crops and livestock could be either detrimental or beneficial to soil properties, depending upon timing and intensity of animal traffic and initial condition of the soil surface. We evaluated the surface-soil properties of a Typic Kanhapludult in Georgia during the first three years of an experiment evaluating the effect of tillage [conventional (CT), conservation (NT)], cropping system (summer grain-winter cover, winter grain-summer cover), and cover crop utilization (none, grazed) variables. With initially high soil organic C (SOC) due to previous pasture management, depth distribution of SOC became widely divergent between CT and NT following cropping management. Soil bulk density during the first year was reduced with CT, but soil became reconsolidated below 12 cm, similar to that under NT. Soil penetration resistance was greater under NT than under CT, but larger differences occurred with low soil water content than with high soil water content. Ponded infiltration was lower under NT than under CT with low antecedent soil water content, but higher under NT than under CT with high antecedent soil water content. The interaction of tillage management with antecedent soil water content on penetration resistance and water infiltration indicates that long-term tillage effects on soil physical quality will be partly influenced by timing and intensity of tractor and cattle traffic loads. Although CT management could alleviate negative influences on compaction with periodic tillage, NT management may also have an advantage in pasture-crop rotation systems by preserving the organic matter-enriched surface soil to buffer against compactive forces. A longer term investigation is warranted to verify or strengthen these interpretations.

INTRODUCTION

Soil organic matter is a critical component in maintaining soil quality in the southeastern USA. Pastures are known to improve soil organic C and N, which leads to retention of organically-bound nutrients and improved water relations. Cropping systems that are appropriate in this region under conditions of high soil organic matter have not been evaluated since much of the cropland has been stripped of soil organic matter from previous degradative cropping practices.

The impact of grazing animals on the environment is more often than not viewed as negative. A large portion of the land area in the southeastern USA is devoted to pasture production of cattle. Our previous work has shown that grazing of warm-season grasses in the summer can have positive impacts on soil organic C and N accumulation and no observable detriment to surface soil compaction (Franzluebbers et al., 2001b). However, the role of grazing animals in pasture-crop rotations does not have to be limited to the medium- or long-term pasture phase alone. Cover crops following grain or fiber crops can be an excellent source of high quality forage to be utilized in mixed-use farming operations, which have the potential for adoption throughout the southeastern USA. A potential impact of animals grazing cover crops, however, could be compaction due to trampling, as was observed in two soils under relatively low soil organic matter conditions (Tollner et al., 1990). Surface residue cover may provide a significant buffer against animal trampling effects, such that no tillage crop production following long-term pasture could alleviate negative animal trampling effects.

A long-term pasture-crop rotation experiment was established in 2002 to determine the influence of tillage, cropping system, and cover crop management on productivity and environmental quality in the Southern Piedmont. Preliminary crop and animal productivity responses were reported in Franzluebbers and Stuedemann (2004).

Our objective was to quantitatively evaluate three management factors (tillage, time of cover cropping, and cover crop management) for their impacts on soil physical, chemical, and biological properties. The factorial arrangement of treatments allowed us to isolate interactions among management factors, which should lead to a better understanding of the processes controlling productivity and environmental quality. Other objectives during the course of this multi-year project will be to (1) quantify the responses in plant and animal productivity due to tillage management under cropping systems that include grazing cattle and high cropping intensity, (2) quantify the relative stability of plant production during winter versus summer growing seasons, (3) quantify cattle productivity and performance during short-term grazing alternatives to perennial pastures, and (4) evaluate the interrelationships among soil, plant, and animal properties following adoption of land management systems, which may uniquely alter soil organic matter dynamics and plant and animal productivity.

MATERIALS AND METHODS

Previous History

The experiment was located at the J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville GA on Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludult). A set of 18 experimental paddocks (1.7 acres each) were previously arranged as six cattle grazing treatments in three blocks. Previous treatments included low (120-30-60 lb $N\text{-}P_2O_5\text{-}K_2O$/acre/yr) and high fertilization rates (300-75-150 $N\text{-}P_2O_5\text{-}K_2O$/acre/yr) imposed upon four grass variables [‘Kentucky-31’ tall fescue (*Festuca arundinacea* Schreb.) with low and with high endophyte infection, ‘Johnstone’ tall fescue with low endophyte infection, and ‘Triumph’ tall fescue with low endophyte infection]. Previous treatments were part of a long-term experimental design initiated in 1981 to study tall fescue-endophyte effects on cattle productivity, performance, and other miscellaneous animal response variables until 1997. Fertilization was terminated prior to 1998 and forage grazed on an *ad hoc* basis thereafter. Pasture growth during the past five years without fertilization was expected to remove any differences among paddocks in residual inorganic soil N. All paddocks were limed (1 ton/acre) immediately prior to termination of the tall fescue. The 18 experimental paddocks were regarded as an excellent starting point for the proposed research because soil organic matter was at a high level (Franzluebbers et al., 1999) and grazing infrastructure was mostly in place at the site (fencing, gates, shades, mineral feeders, watering troughs, and animal handling facility).

Experimental Design and Management
The experimental design of the current investigation consisted of a completely randomized design with a split-plot arrangement within main plots. Main plots were a factorial arrangement of (a) tillage and (b) time of cropping and split plots within main plots were (c) cover crop management. Main plots were replicated four times. Grazed plots were 0.5 ha (1.1 acre) in size and ungrazed plots were 0.2 ha (0.6 acres). Two paddocks remained in perennial pasture to serve as uncropped controls.

Tillage management was with (1) conventional disk tillage (CT) following harvest of each grain and cover crop and (2) no tillage (NT) with glyphosate to control weeds prior to planting. Conventionally tilled plots were broken from sod with a moldboard plow to a depth of 25 to 30 cm (10 to 12") and disk plowed to approximately 15 cm (6") thereafter.

Cropping systems included (1) winter grain cropping [wheat (*Triticum aestivum* L.); November planting and May harvest] with summer cover cropping [pearl millet (*Pennisetum glaucum* (L.) R. Br.; June planting and October termination] and (2) summer grain cropping [grain sorghum (*Sorghum bicolor* (L.) Moench; May-June planting and October harvest] with winter cover cropping [cereal rye (*Secale cereale* L.); November planting and May termination]. ‘Tifleaf 3’ pearl millet was drilled in 6.75"-wide rows under CT and 7.5"-wide rows under NT at a rate of 14 lb/acre on 12 June 2002, at 13 lb/acre on 26 June 2003, and 15 lb/acre from 22-23 June 2004. Pioneer 83G66' grain sorghum was drilled in 13.5"-wide rows under CT and 15"-wide rows under NT at a rate of 5 lb/acre from 13-14 June 2002, at 6 lb/acre from 2-5 June 2003, and 6 lb/acre from 18-19 May 2004. Due to poor stand of sorghum in 2002, especially under NT, portions of plots were replanted on 17 July 2002. Ammonium nitrate was spread on sorghum and millet at 44 lb N/acre on 18 June 2002, on sorghum at 46 lb N/acre on 12 June 2003, on millet at 40 lb N/acre on 9 July 2003, on sorghum at 43 lb N/acre on 18 June 2004, and on millet at 45 lb N/acre on 19 July 2004. Sorghum was harvested for grain from 15-22 November 2002, 17-20 October 2003, and 5-6 October 2004. Wheat was drilled in 7.5"-wide rows at a rate of 106 lb/acre on 28 November 2002 (‘Crawford’), at 82 lb/acre (CT) and 116 lb/acre (NT) from 4-6 November 2003 (‘518W’), and at 106 lb/acre (CT) and 110 lb/acre (NT) from 10-16 November 2004 (‘Coker 9663’). Rye was drilled in 7.5"-wide rows at a rate of 111 lb/acre on 2 December 2002 (‘Hy-Gainer’), at 94 lb/acre (CT) and 111 lb/acre on 5 November 2003 (‘Hy-Gainer’), and at 103 lb/acre (CT) and 118 lb/acre (NT) from 10-16 November 2004 (‘Wrens Abruzzi’). Ammonium nitrate was spread on wheat and rye at 47 lb N/acre on 25 February 2003, at 36 lb N/acre on 20 February 2004, and at 45 lb N/acre on 3 March 2005. Wheat was harvested for grain from 11-19 June 2003 and 3-4 June 2004.

Cover crops were managed to assess the impact of grazing cattle on crop production as (1) without cattle by mowing (CT) and mechanical rolling (NT) at maturity and (2) stocking with cattle for 60-90 days to consume available forage produced. Cover crops were stocked with yearling Angus steers in Summer 2002 (initial weight 578 $\pm$ 48 lbs) and in Spring 2003 and with cow/calf pairs in Summer 2003 (initial cow weight 1107 $\pm$ 88 lbs and initial calf weight 370 $\pm$ 33 lbs), Spring 2004, Summer 2004, and Spring 2005. Ungrazed cover crops were grown until 2-4 weeks prior to planting of the next crop and either (1) mowed prior to conventional tillage operations or (2) mechanically rolled to the ground in the no-tillage system.

Each grain and cover crop received a top-dressing application of ammonium nitrate shortly after planting and no other fertilizer amendment. The basal application of N assured early plant growth and development with further growth dependent upon the mineralization of stored nutrients in soil organic matter. Extractable P and K concentrations in the surface 3 inches of soil were greater than 100 mg $P \cdot kg^{-1}$ soil and 400 mg $K \cdot kg^{-1}$ soil (Schomberg et al., 2000), levels considered adequate for crop production.

Soil Sampling and Analyses

Soil was sampled in May 2002 and in November/December 2002, 2003, and 2004. Soil was sampled at depths of 0-3, 3-6, 6-12, and 12-20 cm in May 2002 and additionally at 20-30 cm depth thereafter. A composite sample of 8 cores in grazed plots and 5 cores in ungrazed plots was collected with a 4-cm diameter probe following surface residue collection from a 0.04 m^2 area at each subsampling location. Soil was dried at 55 °C for $\geq$3 days and passed through a 4.75-mm screen to remove large stones. Soil bulk density was determined from the total dry weight prior to sieving and volume of coring device. A subsample was ground in a ball mill for analysis of total C and N with dry combustion. Soil microbial biomass C was determined from 25- to 65-g subsamples following rewetting of dried soil using a chloroform fumigation-incubation technique (Jenkinson and Powlson, 1976; Franzluebbers et al., 1996). Mean-weight diameter of water-stable aggregates was determined by summing the dry-weight components of four aggregate sizes (1-4.75, 0.25-1, 0.053-0.25, and <0.053 mm) following immersion of a 100-g subsample in water and oscillated for 10 minutes at a 20-mm stroke length with a frequency of 31 cycles/minute (Kemper and Koch, 1966; Franzluebbers et al., 1999).

Penetration resistance was determined with an impact penetrometer (Herrick and Jones, 2002). A 2-kg hammer was dropped 0.74-m distance repeatedly onto a 0.23 cm-diameter cone with a 30° tip. The number of strikes required to reach a depth of 10, 20, and 30 cm was recorded. Each strike contained the equivalent kinetic energy of 14.5 J. Penetration resistance was determined in four locations of each grazed plot and in two locations of each ungrazed plot on 9 May 2003, 5 August 2003, 9 October 2003, 7 May 2004, 27 July 2004, and 22 October 2004. Soil water content was determined at a depth of 0-20 cm with time-domain reflectrometry from the average of five measurements within a 2-m radius of each penetrometer sampling.

Water infiltration was determined from the linear rate of water intake during 1 hour within a 30-cm diameter steel ring inserted approximately 4 cm into the ground. Water was supplied with a Mariotti system and volume of water recorded every 10 minutes. Linear regression was used to determine rate of water infiltration. Accounting for a 5-cm head of water, the intercept from the linear regression allowed estimation of air-filled macroporosity. Infiltration was determined from two locations in each grazed and ungrazed plot on 15 October 2003, 3 May 2004, 27 July 2004, and 20 October 2004. Soil water content was determined in the same manner as described earlier.

Significance of difference in soil properties among management systems was assessed with the general linear model procedure of SAS and non-linear relationships of penetration resistance and water infiltration with antecedent soil water content.

RESULTS AND DISCUSSION

Soil Organic C and Microbial Biomass

Soil organic C (SOC) concentration was initially very high at the soil surface and declined rapidly with depth (Fig. 1). There were no differences in SOC between tillage systems before treatment implementation, indicating an equal starting point for this long-term comparison. At the end of one year of cropping, SOC under NT remained highly stratified with depth, similar to that at initiation. Under CT however, SOC became relatively uniformly distributed due to moldboard plowing that inverted soil within the surface 30 cm and subsequent disk tillage that mixed residues throughout the tillage layer. Similar SOC results were obtained at the end of two years of cropping. Although SOC was removed from the soil surface with CT, SOC concentration became enriched lower in the plow layer relative to that under NT.

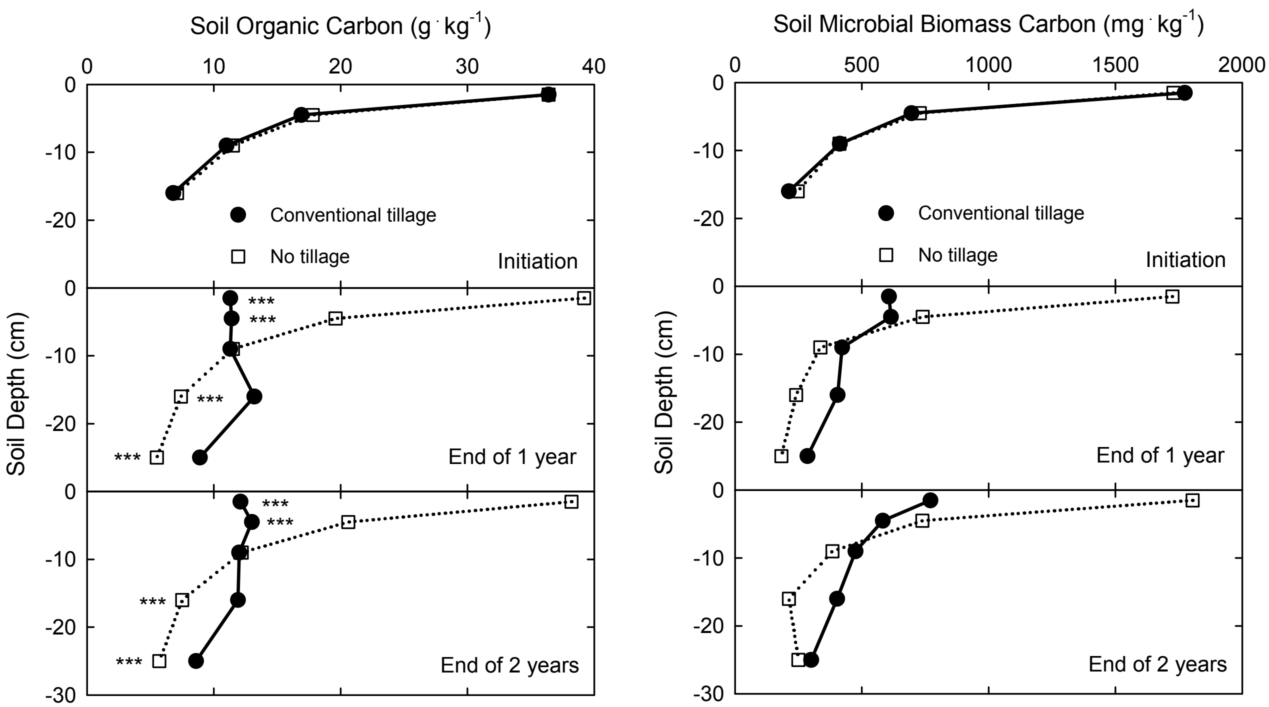

*Figure 1. Soil organic C and microbial biomass C concentration with depth as affected by tillage management and year of sampling. *** denotes significance between tillage means within a depth at P = 0.001. Statistical evaluation was not available for soil microbial biomass C.*

Soil microbial biomass C followed a similar development pattern in response to time of sampling and tillage management as occurred for SOC (Fig. 1). Soil microbial biomass C was 3.9 $\pm$ 0.9% of SOC, somewhat lower than percentages reported using similar measurement techniques in another study in Georgia (6.7 $\pm$ 0.5%; Franzluebbers et al., 1999) and from cropping systems in eastern Texas (5.1 $\pm$ 0.7%; Franzluebbers et al., 1995), but more similar to soils in northern Alberta and British Columbia (3.3 $\pm$ 0.8%; Franzluebbers and Arshad, 1996). The portion of SOC as soil microbial biomass C is often interpreted as an index of biologically active soil organic matter. Higher values suggest aggrading management influence under similar environmental conditions. Available data suggests that the portion of SOC as soil microbial biomass C is higher in warmer than in cooler climate zones and in drier than in wetter climate zones (Franzluebbers et al., 2001a). These same climatic conditions are also reflected in soil depths, where surface soil layers tend to be warmer and drier on average than deeper layers, and have the highest portion of SOC as soil microbial biomass C.

Soil Bulk Density and Penetration Resistance

Soil bulk density following long-term pasture and prior to this cropping experiment was relatively low at the soil surface (1.1 Mg/m^3) and increased dramatically with depth to about 6 cm, at which point maximum bulk density occurred (~ 1.5 Mg/m^3), similar to lower depths (Fig. 2). With initial moldboard plowing of pasture, soil bulk density was reduced during the first year, but returned to high values below 12 cm in later years. Tillage operations following the breaking of sod were limited to approximately the surface 15 cm, which led to reconsolidation without subsequent mechanical loosening in the 12 to 30 cm zone. Under NT, soil bulk density did not appear to change with time compared to the initial pasture condition. Maintenance of the low bulk density at the soil surface with NT was likely possible only with the high concentration of SOC present. Subsequent animal and equipment traffic did not cause any further obvious compaction to soil.

Soil penetration resistance was highly related to antecedent soil water content at the time of sampling (Fig. 3). Soil water content averaged across sampling events was 0.171 $m^{3/}$ m^3 under

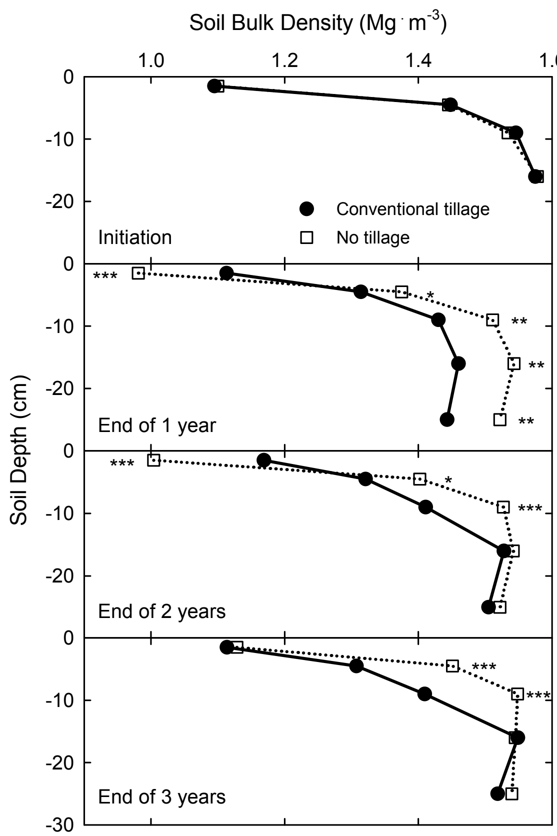

*Figure 2. Soil bulk density with depth as affected by tillage management and year of sampling. *, **, and *** denote significance between tillage means within a depth at P = 0.1, 0.01, and 0.001, respectively.*

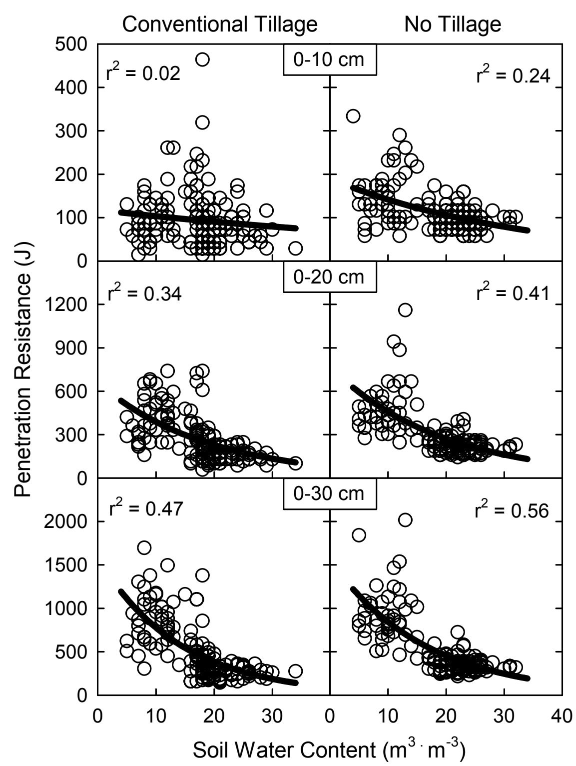

Figure 3. Penetration resistance of soil in relationship to soil water content as affected by tillage management and depth of sampling. Regression lines represent the best fit to the equation: $Y = a\ e^{-b\ SWC}$, where a and b are derived constants and SWC is soil water content.

CT and 0.184 $m^{3/} m^3$ under NT ($P < 0.001$). Despite the higher soil water content under NT, penetration resistance was greater ($P < 0.05$) under NT than under CT at all three sampling depths (i.e., 113 vs. 94 J at 0-10 cm, 316 vs. 278 J at 0-20 cm, and 544 vs. 508 J at 0-30 cm). Maximum absolute difference in penetration resistance between tillage systems occurred at the driest soil water content. Therefore when dry, soil under NT would likely be more resistant to root penetration than under CT, a situation that could be partly overcome by the high surface residue condition under NT to maintain higher soil water content than under CT. Statistically, most significant differences in penetration resistance between tillage systems occurred at higher soil water content ($\geq$0.20 $m^{3/} m^3$). Overall, difference in penetration resistance between tillage systems was relatively small. Busscher et al. (1997) previously demonstrated a strong relationship between penetration resistance and soil water content on Coastal Plain soils.

Although the effect of cover crop management was not strong, soil penetration resistance tended to be greater under grazed than ungrazed cover crops under CT (292 vs. 248 J at 0-20 cm depth). Under NT, penetration resistance averaged 308 J with grazing and 338 J when ungrazed at a depth of 0-20 cm. Although these results are preliminary, it appears that grazing of cover crops would be more detrimental to penetration resistance under CT than under NT. More data are needed to verify this conclusion.

Soil Aggregation and Infiltration

Mean-weight diameter of soil aggregates was greatly affected by tillage management during the first year of CT (Fig. 4). With CT, soil aggregates became less stable and formed smaller units, resulting in smaller mean-weight diameter of water-stable aggregates. Less stable aggregates would eventually lead to (1) SOC loss through more rapid oxidation, (2) fewer macropores to allow rapid water infiltration, and (3) surface crust development that could prevent seed germination and rainfall percolation.

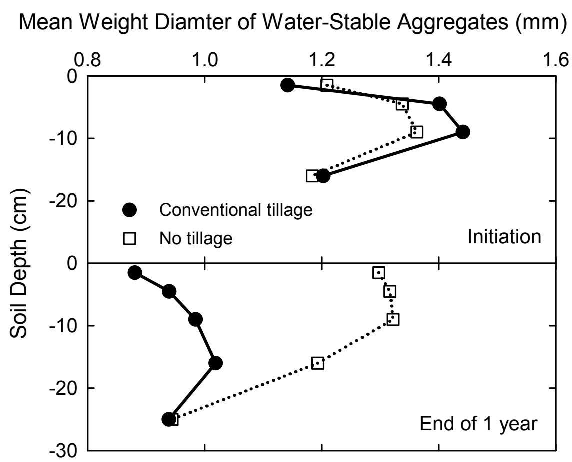

Figure 4. Mean-weight diameter of soil with depth as affected by tillage management and year of sampling. Statistical analysis was not yet available.

Steady-state water infiltration and air-filled macroporosity were also negatively related to antecedent soil water content (Fig. 5). Steady-state water infiltration tended to be lower under NT than under CT under relatively dry soil conditions, but higher under NT than under CT under wetter soil conditions. These results indicate a dominating influence of antecedent soil water conditions on additional water infiltration. These results also indicate that tillage management can modify water infiltration, but that tillage interacts with antecedent soil water content. The timing of tractor and cattle traffic operations during the year could greatly impact the development of physical soil quality in the long-term.

As an estimate of air-filled macroporosity, the initially rapid water infiltration that created a positive intercept (b) in the equation: $Y = m \cdot X + b$, was influenced by antecedent soil water

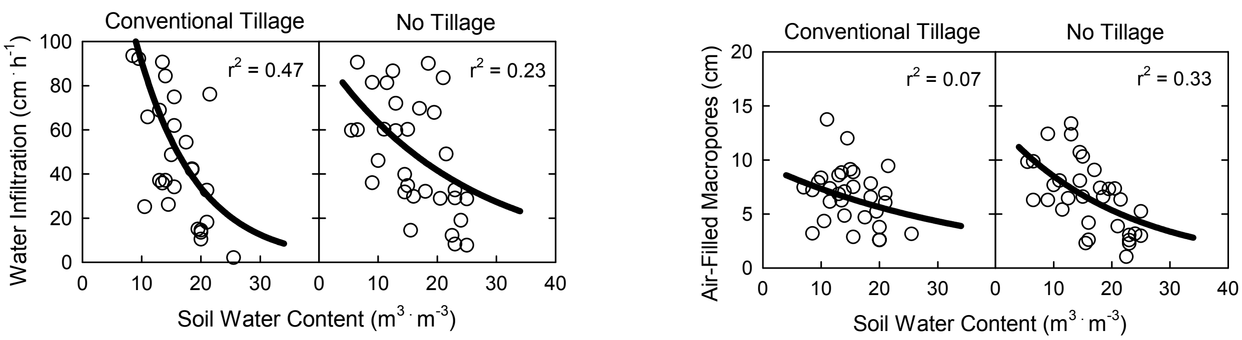

Figure 5. Steady-state water infiltration from 10 to 60 minutes and initial rapid infiltration during the first 10 minutes of ponded percolation representing air-filled macroporosity in relationship to soil water content as affected by tillage management.

content, but also by tillage management (Fig. 5). Air-filled macroporosity tended to be higher under NT than under CT at relatively dry soil condition and lower under NT than under CT at wetter soil condition. These results illustrate that soil water content is an important factor for understanding the impact of tillage system and cover crop management on soil physical condition that develops with time. The timing of tractor and cattle traffic during the year could greatly impact the development of soil physical quality in the long-term.

SUMMARY AND CONCLUSIONS

Crop management following termination of long-term pasture resulted in significant changes in soil properties during the first three years. Termination of pasture with moldboard plowing and subsequent disking (CT) for seedbed preparation led to relatively uniform distribution of SOC and soil microbial biomass C within the plow layer. Termination of pasture with herbicide and subsequent NT management of crops maintained a highly stratified distribution of organic matter in soil. Although CT loosened soil initially throughout the plow layer (0-30 cm), soil at lower depths became reconsolidated after the first year, resulting in less dense soil with CT compared with NT only at a depth of 3-12 cm thereafter. Mean-weight diameter of water-stable aggregates was greatly reduced with CT during the first year after pasture termination. Penetration resistance and steady-state water infiltration were highly related to antecedent soil water content. Tillage system interacted with antecedent soil water content, such that firmer soil and lower water infiltration occurred at low soil water contents, but differences between tillage systems were minimal at wetter soil water contents. Whether cover crops were grazed by cattle or left unharvested for biomass input had relatively minor effects on soil properties, but additional analyses are being conducted to strengthen this conclusion. Although there were indications that soil organic matter, microbial biomass, and soil aggregation could be retained with long-term NT management following rotation with long-term pasture, other soil physical properties (i.e., bulk density, penetration resistance, and water infiltration) indicated equal or poorer conditions for crop growth potential than with CT management, at least during the first three years.

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MANURE NITROGEN MANAGEMENT ISSUES IN CONSERVATION TILLAGE

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ABSTRACT

A new model of ammonia volatilization losses following application of animal manure and granular fertilizer has been developed based on data from the literature and new data obtained by researchers at Clemson University. The new ammonia-N loss model was combined with a range of organic-N mineralization factors from the literature to provide estimates of the plant available nitrogen (PAN, lb/ac), ratio of PAN to total nitrogen (TN), and the mass of ammonia-N lost per acre following application of fertilizer and animal manure to a field covered with crop residue.

The new model was compared to the current estimates provided by Clemson University Extension. It was determined that current Clemson Extension estimates of ammonia-N loss differ from the new model by 2% to 95%. The differences in estimates in the value of PAN/TN ranged from -23% to 21%.

The new model was used to estimate the ammonia-N losses following application of granular fertilizer, lagoon supernatant, broiler litter, and untreated dairy manure to a no-till field. Broadcast application resulted in ammonia-N losses ranging from 0.4 lb NH_3-N/ac for lagoon supernatant to 48 lb NH_3-N/ac for dairy manure. The ammonia-N loss for granular fertilizer (25 lb NH_3-N/ac) was greater than for poultry litter (7.4 lb NH_3-N/ac).

The influence of application methods such as band spreading, band spreading with immediate soil coverage, direct injection, immediate incorporation with light tillage, and incorporation with irrigation was studied using the model. The results indicated that these practices could reduce the mass of ammonia-N lost per acre by 51% to 94%. Model results indicate that the time lag between application and incorporation should be no more than 24 h for granular fertilizer, 6 h for poultry litter, and 12 h for dairy manure.

INTRODUCTION

Current conservation tillage practices generally do not include the use of tillage to incorporate granular fertilizers or animal manure. In all cases, nitrogen will be lost to the atmosphere by ammonia volatilization to some extent. Ammonia volatilization loss of nitrogen equates to a financial loss to the farmer. Ammonia volatilization is also of environmental concern due to the potential for acid rain formation and deposition into sensitive ecosystems that are a significant distance from the farm.

The economic and environmental impacts associated with ammonia losses have given rise to a need for better estimates of the amount of ammonia-N lost from no-till fields. Better estimates of ammonia-N losses can be used to evaluate practices to reduce the release of ammonia to the atmosphere.

A significant amount of work has been conducted at Clemson University to better quantify ammonia volatilization losses following land application of animal manure. Recent data by Montes (2002) and analysis presented elsewhere in these proceedings by Chastain and Montes (2005) have indicated that ammonia volatilization losses during irrigation of animal manure is insignificant at the 95% level of probability. In addition, new data have been obtained to quantify ammonia-N losses following application of lagoon supernatant and poultry litter on forestland. Pooled analysis of the new data with data from the literature indicated that ammonia-N loss from the plant residue on the forest floor, hay, grass, and crop residue were not significantly different. All available data were combined to develop a new model that represents ammonia volatilization losses following application of granular fertilizer and animal manures.

The objectives of this paper are to: (1) provide a summary of the new ammonia volatilization model, (2) compare the new model to current Clemson University Extension estimates, and (3) compare the ammonia-N losses from no-till fields fertilized with lagoon supernatant, poultry litter, dairy manure, and granular ammonium fertilizer using various application methods.

METHODS

Nitrogen can be present in manure as ammonium-N, ammonia-N, organic-N, and nitrate-N. Not all of the nitrogen in manure is immediately available for plant use. The nitrogen that is available for plant use is called the plant available nitrogen (PAN).

Most animal manure contains very little nitrate-N and as a result it is typically not measured. However, manure that receives aerobic treatment, i.e. composting or aeration, should be analyzed for nitrate-N.

Most laboratories measure the total ammoniacal nitrogen content (TAN) of animal manure, which is NH_4^+-N + NH_3-N. The total ammoniacal nitrogen concentration is reported as ammonium-N (NH_4^+-N) by many university laboratories.

The plant available nitrogen in animal manure, compost, or sludge can be estimated as:

$$\text{PAN} = A_f\,\text{TAN} + m_f\,\text{Organic-N} + \text{Nitrate-N}. \tag{1}$$

Where:

A_f= the ammonium-N availability factor, and

m_f= the organic-N mineralization factor.

Therefore, the plant available nitrogen is the sum of the TAN that is not lost by volatilization, the portion of the organic-N that is mineralized during the growing season, and all of the nitrate nitrogen.

The fraction of the TAN that can be used by a crop is expressed as the ammonium-N availability factor (A_f). The ammonium-N availability factor is calculated from the ammonia-N lost as:

$$A_f = (1\text{-}\,AL(\text{t}))/100. \tag{2}$$

Where,

$AL(t)$ = the ammonia-N lost following application expressed as percentage of TAN applied = 100 (NH_3-N(t) /TAN-applied).

The current recommendations by Clemson University Extension for A_f are (CAMM, 2005):

- 0.5 for surface applied manure with no incorporation,
- 0.8 for surface application followed by incorporation within 24 hours
- 0.8 for irrigation of lagoon supernatant or liquid manure, and
- 1.0 for direct injection or immediate incorporation.

A new model of ammonia-N loss following application of animal manure has been under development at Clemson University over the past few years. The relationship to describe the ammonia-N loss following application of animal manure or granular fertilizer is:

$$AL(t) = f_S\, f_A\, AL_{\max}\left(1 - e^{-Kt}\right). \quad (3)$$

Where,

f_S = a soil factor that ranges from 1.0 for application to a standing crop, grass, or crop residue down to 0.7 for application of high TS manure to bare soil,
f_A = application method factor that depends on the method of application,
AL_{max} = the maximum ammonia-N loss possible ,100 (NH_3-N/TAN-applied), and
K = a rate constant that is a function of manure type and wind speed (h^{-1}).

Values and relationships for f_S, f_A, AL_{max}, and K are tabulated in Appendix A for a variety of application methods, several types of animal manure, and granular fertilizer.

At the present, Clemson University Extension recommends that a value of 0.6 be used for the mineralization factor for all types of animal manure. Therefore, 60% of the organic-N is assumed to be available in all cases using Clemson Extension's recommendations.

The actual amount of organic-N that will be mineralized depends on manure type, level of treatment, soil pH, soil temperature, soil moisture content, and soil type. Evanylo (2000) provided a detailed review of the research related to the factors that effect mineralization of animal manure. Evanylo determined that animal species and manure treatment were the main factors that could be practically considered to estimate values for m_f.

The new model includes the results of Evanylo's review and a few other reviews of the literature. The values of m_f used with the new model are given in Table 1. The ranges of m_f are also given to indicate the large amount of variation in the available data.

Animal manure contains all 13 of the essential plant nutrients that are used by plants. These include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe), and molybdenum (Mo). Plant nutrients originate from the feed, supplements, medications, and water consumed by the animals. Using animal manure as a fertilizer for crops may provide a portion, or all, of the plant requirements. The amount of nutrients provided depends on the nutrient content of the manure (lb of nutrient / 1,000 gal of manure or lb / ton) and the amount of manure applied (gal/ac or tons/ac). The amount of manure applied per acre, or application rate, is typically based on the nitrogen needs of the crop. However, phosphorous requirement can also be used to determine the application rate.

Table 1. Estimates of organic-N mineralization factors for use in the new model (Evanylo, 2000; Mikkelsen, et al., 1995; and Rynk et al., 1992).

Material	Recommended value of m_f (range)
Dairy and beef manure (untreated)	0.4 (0.13 to 0.51)
Swine manure (untreated)	0.5 (0.25 to 0.50)
Poultry manure (litter and untreated layer manure)	0.6 (0.47 to 0.90)
Lagoon supernatant	0.7 (0.5 to 0.9)
Anaerobically treated manure or sludge	0.6 m_f (based on species)
Compost	0.12 (0.06 to 0.12)

The nutrient content of animal manure varies significantly based on species, amount of water added for handling, and level of treatment. Representative animal nutrient data are provided for common types of animal manure used in the Southeastern US in Table 2. Additional information on the nutrient content of animal manure is provided in the manuals of the Confined Animal Manure Managers Program (CAMM, 2005).

The material application rate (MAR, ton/ac or gal/ac), or the amount of manure needed per acre to provide the N requirement, is calculated as:

$$\text{MAR} = \text{N requirement (lb/ac)} \div \text{PAN}. \tag{4}$$

Where,

PAN = lb PAN / ton or lb PAN / gal.

The amount of ammonia-N lost per acre following application of animal manure or fertilizer was calculated as:

$$M_{AL} = (AL(\text{t})/100) \cdot \text{TAN} \cdot \text{MAR}. \tag{5}$$

Where,

M_{AL} = mass of ammonium-N lost (lb/ac), and
TAN = lb TAN/ ton or lb TAN / gal.

Table 2. Nutrient and solids content of selected types of animal manure (Chastain et al. 2001; broiler litter data from Coloma, 2005).

Moisture	99.63%	98.0%	93%	24.4
Total Solids	0.37%	2%	7%	75.6
Manure Type	Swine Lagoon Supernatant	Untreated Swine Manure[1]	Untreated Dairy Slurry	Broiler Litter
Constituent	------------- lb/1,000 gal		--------------	lb / ton
TAN [2]	3.4	11.4	9.4	10
Organic - N	1.4	5.6	13.6	44
TN [3]	4.8	17.0	23.0	54
P_2O_5 [4]	2.8	13.4	14.0	66
K_2O [5]	6.1	14.2	21.0	57
Ca	0.86	3.7	10.0	44
Mg	0.46	2.4	4.8	9
Zn	0.03	0.28	0.21	0.6
Cu	0.02	0.26	0.05	0.6
Mn	0.01	0.12	0.18	0.6
S	0.31	1.3	3.1	10.6
Na	1.8	2.5	3.2	13.4

[1] The total solids content from flush and pit-recharge buildings will vary from 1.5% to 2.6% depending on building design and animal weight. A mean value of 2% is shown.
[2] TAN = NH_4^+-N + NH_3-N
[3] TN = Organic-N + TAN
[4] Total phosphorus expressed as P_2O_5. To get elemental P multiply by 0.44.
[5] Total potassium expressed as K_2O. To get elemental K multiply by 0.83.

ANALYSIS AND RESULTS

Comparison of Clemson Extension Recommendations with the New Model

Estimates of the plant available N in animal manure depends on the estimates of the ammonia-N availability factor and mineralization factor, and measurements of TAN and organic-N content of the material (equation 1). The ratio of PAN to TN is the fraction of the total nitrogen that can be used to meet crop needs.

The estimates of A_f, m_f, and PAN/TN based on Clemson University Extension recommendations and the new model are compared for four types of animal manure and ammonium-N fertilizer in Table 3. In all cases, the manure or fertilizer was assumed to be spread on a field with crop residue with no tillage, rain or irrigation for 7 days. Therefore, these results reflect the maximum ammonia-N loss.

The greatest difference between the two methods is in the estimate of ammonium-N availability. The differences in A_f range from 2% for untreated dairy slurry to -86% for untreated swine manure. The Clemson Extension value over predicts ammonia-N losses, (1- A_f), for irrigation of swine lagoon supernatant by 95% as compared to the new model.

Table 3. Comparison of ammonia availability factors (A_f), mineralization factors (m_f), and PAN/TN values for application of animal manure and fertilizer on no-till fields (no incorporation, irrigation or rain for 7 days).

Material	Clemson Extension [1]			New Model [2]		
	A_f	m_f	PAN/TN	A_f	m_f	PAN/TN
Untreated Dairy Slurry (TS = 7%)	0.50	0.6	0.56	0.49	0.4	0.44
Untreated Swine Manure (TS = 2%)	0.50	0.6	0.53	0.93	0.5	0.79
Broiler Litter (TS = 75.6%)	0.50	0.6	0.58	0.75	0.6	0.63
Lagoon Supernatant (TS = 0.37%)	0.80	0.6	0.74	0.99	0.7	0.91
Granular Fertilizer	1.0	NA[3]	1.0	0.80	NA	0.80

[1] Based on current recommendations from Clemson University Extension (CAMM, 2005).
[2] Based on a new model of ammonia volatilization under development at Clemson University (equation 3 and Appendix A).
[3] Not applicable

Mineralization rates differed between the two methods by 0% to 33%. The best agreement was for broiler litter and the worst agreement was for dairy slurry.

The value of PAN/TN encompasses the overall differences in the two methods to estimate PAN and is directly related to the economic value of manure. The differences in PAN/TN estimates ranged from -23% for lagoon supernatant to 21% for dairy manure. The best agreement in PAN/TN estimates was for broiler litter.

At the present, ammonia volatilization losses following application of fertilizer-N are ignored. The new model uses a mean value from the literature for A_f of 0.80. Therefore, 20% of the purchased N would be lost following broadcast application onto a no-till field. The economic importance of this loss depends on the price of N.

Variation in Ammonia Loss with Time Following Application to No-Till Fields

The new model provides a method to estimate the rate of ammonia-N loss as well as the total amount of N lost following application of manure and granular fertilizer. The rate of ammonia-N loss is controlled by the rate constant, K, in equation 3. The value of K varies with the material and wind speed. At the present, variation in wind speed is not included in the model. However, as wind speed increases, K increases. Recommended values for the rate constant for different types of manure and granular fertilizer are given in Table A4.

The influence of the rate constant on the rate of ammonia-N loss is shown in Figure 1 for animal manure and granular fertilizer. The ammonia-N loss was normalized to the maximum ammonia-N loss as: fraction of maximum ammonia-N Loss = $AL(t) / AL_{max}$.

The results in the figure indicate that the rate of ammonia-N loss is slowest for granular fertilizer. Therefore, substantial nitrogen savings can be obtained by providing incorporation by either a light tillage operation or irrigation of 0.5 in. of water 6 to 24 hours following a broadcast application.

Ammonia volatilization occurs more quickly for animal manure than granular fertilizer and the rate depends on manure consistency and the amount of liquid that can infiltrate into the soil. Lagoon supernatant quickly infiltrates into the soil and as a result, the volatilization only occurs for about 6 hours. The high porosity of poultry litter permits ammonia to be released more slowly than lagoon supernatant, but still much faster than a slurry (TS = 7%). Incorporation of litter must occur within 6 hours following application if any real benefit is to be obtained. Incorporation of untreated dairy manure (slurry) should occur 8 to 12 hours after a broadcast application to cut volatilization losses by 40% to 50%.

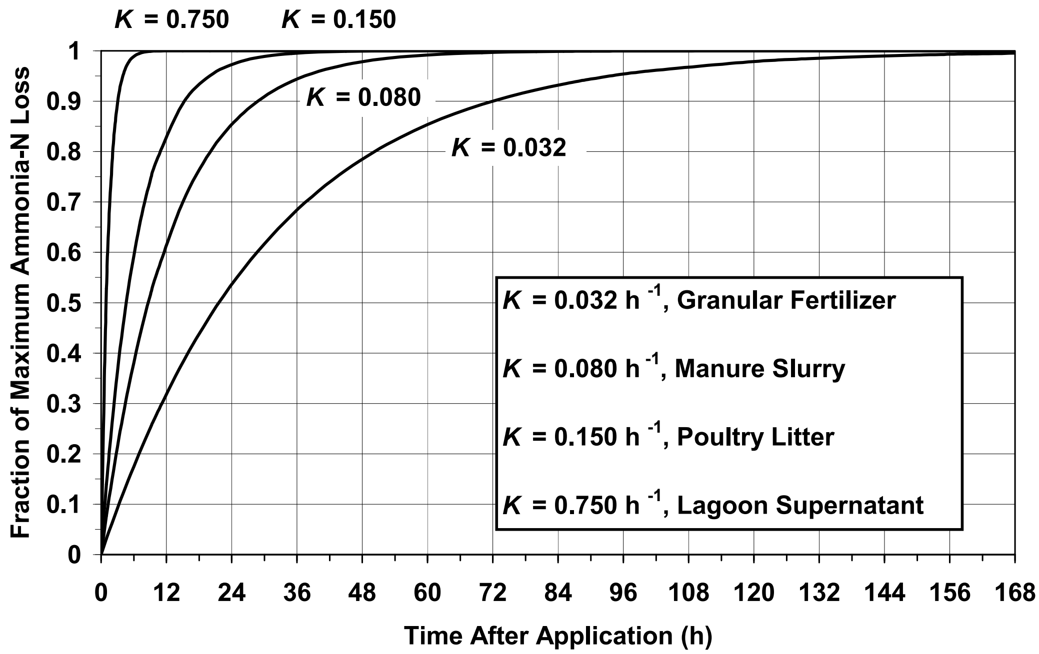

Figure 1. Rate of ammonia-N loss as determined by the value of the rate constant (K).

Influence of Land Application Techniques on Ammonia-N Loss per Acre

Several application techniques can be used with granular fertilizer and animal manure to reduce ammonia-N losses from no-till fields. No-till drills that plant, spread a band of fertilizer, and cover with coulters can provide immediate incorporation. Spreaders that place bands of fertilizer (drop/side dress) or manure (trail hose) on the surface can be used. Irrigation with a least 0.5 in. of water within a few hours of spreading manure or fertilizer can also wash ammonium-N into the soil and greatly reduce volatilization losses. Towed hose or tank injectors are available to allow immediate incorporation of bands of liquid or slurry manure with minimal disturbance of crop residues.

The new ammonia volatilization model was used to calculate the ammonia-N lost following application of 100 lb of plant available nitrogen per acre for several application methods. Model results are compared for application of fertilizer, lagoon supernatant, broiler litter, and dairy slurry to no-till fields in Table 4. The values of f_A used in equation 3 are given in Table A3. Nutrient data used were from Table 2. The granular fertilizer was assumed to be 17% ammonium-N.

The material that had the highest ammonia nitrogen loss was a broadcast application of dairy manure. The losses were the highest because dairy manure had the lowest ammonium-N availability and the lowest organic-N mineralization rate (Table 3). Any method to reduce volatilization losses should be considered if untreated dairy manure is used as a plant nutrient source in conjunction with conservation tillage. Direct injection is one of the best options currently available for use with dairy manure. However, other implements that can provide the benefits of direct injection, but with lower tractor power requirements are needed.

Table 4. Comparison of ammonia nitrogen loss estimates following application of granular fertilizer and animal manure to provide 100 lb PAN/ac to fields covered with crop residue.

Description of Application Method	Granular Fertilizer	Lagoon Supernatant (TS = 0.37%)	Broiler Litter (TS = 75.6%)	Untreated Dairy Slurry (TS = 7%)
	------------------ Ammonia-N Loss (lb N/ac) ------------------			
Broadcast [1]	25	0.4	7.4	48
Band / trail hose	11	0.2	3.6	19
Trench with sliding foot	N/A	N/A[2]	N/A	4.0
Shallow injection	N/A	N/A	N/A	3.4
Injection or immediate incorporation	1.6 [3]	N/A	0.6	2.7

[1] Assumes no rain or irrigation for 7 days.
[2] Not applicable.
[3] No-till drill with band spreading and soil coverage with coulters.

The quantity of ammonia-N lost per acre following application of lagoon supernatant or litter to provide 100 lb PAN/ac was much lower than expected. The new model predicts a much lower value of A_f than many extension publication would suggest (e.g. Chastain et al., 2001; MWPS, 1993; NRAES, 1999). However, the model includes new data that was obtained in 2002 (Montes, 2002).

Many professionals often forget to include the affects of organic-N mineralization when the mass of ammonia-N lost per acre is computed. Available organic-N is a significant fraction of the PAN for these materials and is not subject to loss by volatilization yet influences the total amount of TAN applied (equations 4 and 5).

Data and model results indicate that little development is needed to reduce ammonia-N loss following irrigation of lagoon supernatant. However, new equipment or litter treatments are needed to make poultry litter more compatible with no-till production systems.

Broadcast application of granular NH_4^+-N fertilizer is a poor choice for conservation tillage systems. For every 100 lb of PAN spread, 25 lb of nitrogen is wasted. The results given in the table indicate that band or side dress spreading, or use of a no-till drill that band spreads and covers fertilizer with soil should be used. Incorporation could also be achieved by providing 0.5 in. of water soon after a broadcast application.

Influence of Time Lag between Broadcast and Incorporation on Ammonia-N Loss per Acre

If irrigation or some sort of light tillage operation will be used to reduce nitrogen losses following application of fertilizer, poultry litter or dairy manure the rate of volatilization needs to be considered. If too much time elapses between application and incorporation, no benefit will be attained.

The affect of time lag between application and incorporation of fertilizer, broiler litter, and dairy manure is shown in Table 5. Assuming that incorporation must reduce nitrogen losses by half, model results indicate that incorporation should occur with 24 h for fertilizer, 6 h for poultry litter, and 12 h for dairy manure. On a very windy day, the maximum allowable time lag between application and incorporation will be much lower than indicated by the current model.

Table 5. Affect of time lag between application and incorporation on ammonia nitrogen loss from no-till fields fertilized to provide 100 lb PAN/ac.

Time between broadcast and incorporation or irrigation [1] (hr)	Granular Fertilizer	Broiler Litter (TS = 75.6%)	Untreated Dairy Slurry (TS = 7%)
	----- Ammonia-N Loss (lb N/ac) -----		
0	1.6	0.6	2.7
4	2.5	3.2	9.8
8	4.7	5.1	18
12	6.8	6.1	25
24	12	7.2	38
36	16	7.4	44
48	19	7.4	47
No incorporation [2]	25	7.4	48

[1] Irrigation of at least 0.5 in. is considered incorporation.
[2] Assumes no rain or irrigation for 7 days.

Incorporation of dairy manure or poultry litter within 24 h is a common recommendation to reduce nitrogen loss. However, the results given in Table 5 indicate that such a practice is of minimal benefit. Using an irrigation system to stop volatilization losses may also be impractical. Immediate incorporation using a second tractor with a light tillage implement or use of an implement that places the manure beneath the soil surface (injection) would be preferred. Many producers are reluctant to use a second tractor due to increased equipment and labor costs.

Additional research related to the quantification of soil conservation impacts of using minimum tillage with animal manure as compared to no-till is needed. New types of spreading equipment are also needed to minimize the equipment and operating cost associated with ammonium-N loss reduction techniques.

CONCLUSIONS

A new model of ammonia volatilization losses following application of animal manure and granular fertilizer has been developed based on data from the literature and new data obtained by researchers at Clemson University. The model includes the affects of manure type, total solids content, characteristics of the soil surface (bare or covered with a crop or residue), application method, and rate of ammonia-N loss.

The new ammonia-N loss model was combined with a range of organic-N mineralization factors from the literature to provide estimates of the plant available nitrogen (PAN, lb/ac), ratio of PAN to total nitrogen (TN), and the mass of ammonia-N lost per acre.

The new model was compared to the current estimates provided by Clemson University Extension. It was determined that compared to the new model, current Clemson Extension recommendations over predict ammonia-N losses following irrigation of lagoon supernatant by 95%. The best agreement in the estimate of ammonia-N loss was for dairy slurry (2%). The difference in mineralization factors used by the two methods ranged from 0% to 33%. The differences in estimates in the value of PAN/TN ranged from -23% to 21%.

The new model was used to estimate the ammonia-N losses following application of granular fertilizer (17% ammonium-N), lagoon supernatant, broiler litter, and untreated dairy manure to a no-till field. Calculations were performed to determine the amount of material required to provide 100 lb PAN/ac. Broadcast application, with no rain or irrigation for 7 days, resulted in ammonia-N losses ranging from 0.4 to 48 lb NH_3-N/ac. The highest loss was for dairy manure (48 lb NH_3-N/ac), and the lowest loss was for irrigation of lagoon supernatant (0.4 lb NH_3-N/ac). The ammonia-N loss for granular fertilizer (25 lb NH_3-N/ac) was greater than for poultry litter (7.4 lb NH_3-N/ac).

The influence of application methods such as band spreading, band spreading with immediate soil coverage, direct injection, immediate incorporation with light tillage, and incorporation with irrigation was studied using the model. The results indicated that these practices could reduce mass of ammonia-N lost per acre by 51% to 94% for all materials. Irrigation of lagoon supernatant was shown to be equivalent to immediate incorporation.

The model was also used to determine the affect of time lag between application and incorporation of fertilizer, broiler litter, and dairy manure. Assuming that incorporation must reduce nitrogen losses by half, model results indicate that incorporation should occur within 24 h for fertilizer, 6 h for poultry litter, and 12 h for dairy manure.

These short time periods may not be practical in many situations. New types of spreading equipment are needed to minimize the equipment and operating cost associated with immediate incorporation of poultry litter and slurry manure to achieve ammonium-N loss reduction.

APPENDIX A

Values of AL_{max}, f_S, f_A, and K for the Ammonia Volatilization Model

Table A1. Recommended values for the maximum ammonia-N loss following surface application of animal manure and granular fertilizer on grass, stubble, forestland, or crop residue (based on data from Montes and Chastain, 2003, Montes, 2002, and literature reviews by Chastain et al., 2001 and Montes, 2002).

Material	Recommended Values for AL_{max} (%)	Variable Range
Lagoon Water	$AL_{max} = 14.30\ TS - 4.74$ ($R^2 = 0.791$, n = 12, $SE_y = 0.57\%$)	$0.39\% \le TS \le 0.57\%$
Swine Manure	$AL_{max} = 3.284\ TS$ ($R^2 = 0.875$, n = 23, $SE_y = 7.35\%$)	$0.57\% < TS \le 19\%$
Dairy Manure	$AL_{max} = 20.87\ TS^{0.461}$ ($R^2 = 0.811$, n = 18, $S_{RES} = 10.45\%$)	$0.9\ \% < TS \le 22\%$
Poultry Litter (bedded)	$AL_{max} = 4.387\ TS - 306.5$ ($R^2 = 0.658$, n = 10, $SE_y = 8.92\%$)	$71\% \le TS \le 79\%$
Poultry Manure (Layer or unbedded)	$AL_{max} = 85.1 - 0.938\ TS$ ($R^2 = 0.584$, n = 5, $SE_y = 18.2\%$)	$16\% \le TS \le 61\%$
Urea, $(NH_4)_2SO_4$	$AL_{max} = 20$ (S = 14.3%, n = 13)	$3.5\% \le AL_{max} \le 50\%$

Table A2. Ammonia-N loss reduction factors for animal manure or granular fertilizer applied to bare soil (based on literature review by Montes, 2002).

Material	f_S
Fertilizer or manure with $TS \le 2\%$	1.0
Manure with TS = 3.5%	0.9
Manure with TS =5.0%	0.8
Manure with $TS \ge 10\ \%$	0.7

Table A3. Application method factors (based on literature review by Chastain et al., 2001 and Montes, 2002).

Application Method	f_A
Broadcast or Irrigation	1.0
Band spreading (drop or trail hose)	0.5
Trenching with sliding foot	0.12
Shallow injection	0.10
Direct injection or immediate incorporation	0.08

Table A4. Recommended rate constants (*K*) for ammonia-N loss following surface application of animal manure and granular fertilizer (based on data and literature review from Montes, 2002).

Material	Recommended Values for *K* (h^{-1})	Range (h^{-1})
Lagoon Water	0.750 (S = 0.119, n = 12)	$0.528 \leq K \leq 2.09$
Animal Manure (Swine, Dairy, Poultry)	$K = 0.073 + 0.00103$ TS ($R^2 = 0.960$, n = 5, $SE_y = 0.007$)	$0.019 < K \leq 0.18$ ($3.9\% \leq TS \leq 74\%$)
Poultry Litter	0.150 (S = 0.119, n = 9)	$0.105 < K \leq 0.184$
Urea, $(NH_4)_2SO_4$	0.032	$0.02 < K < 0.20$

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CONSERVATION TILLAGE CORN, COTTON AND TOMATO SYSTEMS IN CALIFORNIA

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ABSTRACT

Conservation tillage (CT) is not widely practiced in California's Central Valley row crop production systems today. Current estimates of CT acreage in the region are less than 2% for major crops such as corn, cotton and tomatoes. A range of economic and environmental drivers have resulted in interest in alternative tillage systems throughout this area and local networks of farmers, equipment companies and researchers are now beginning to develop and refine CT cropping systems for these crops. The University of California / USDA Natural Resources Conservation Services CT Workgroup has grown to over 490 members in the past five years. Over 70 CT demonstration evaluations have been conducted during this time and a CT annual conference series has attracted over 1200 participants since 1998. A very wide range of CT approaches are being explored according to the specific environmental and crop rotation context of the various production regions throughout the Valley. In addition to cutting production costs, improving air quality and reducing surface water runoff are important potential benefits of CT production systems that are currently being investigated.

YIELD AND ECONOMIC SUSTAINABILITY OF REDUCED IRRIGATION CAPACITY ON THREE TILLAGE SYSTEMS IN THE SOUTHEASTERN COASTAL PLAIN

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ABSTRACT

The interaction between reduced irrigation capacity and tillage, including the possible conservation of water with reduced tillage systems, is of vital interest to growers. A field study was initiated in the fall of 2001 to determine crop response under a simulated reduction in irrigation. Three tillage systems were replicated three times each under one of four irrigation levels (100% of a recommended amount, 66%, 33%, and 0% or dryland). Tillage systems were conventional tillage, wide-strip tillage and narrow-strip tillage. The test area was planted in triplicate, in a peanut-cotton-corn rotation, with each crop being present each year. Tillage was significant for peanut yield and net return at the 0% irrigation level only. No trend in yield was evident, however, net return was consistently high with narrow-strip tillage in all years. Irrigation, at any level greater than 0%, masked tillage effects in both yield and net return. These data confirm the suitability of peanut to conservation tillage practices, including both wide- and narrow-strip tillage.

INTRODUCTION

Crop production in the Southeastern Coastal Plain is generally water-limiting. Because these highly-weathered soil systems tend to be drought-prone and susceptible to compaction and erosion, they present water management challenges. To complicate this, abundant rainfall is poorly distributed, and producers commonly utilize supplemental irrigation to sustain crops during extended dry periods. A major problem facing producers in the region is maintaining crop yield, while maximizing current water resources through efficient water use. Lamb et al. (1997) reported significant increases in yield, quality, net returns, and a reduction in aflatoxin contamination for peanuts produced under irrigation compared to dryland peanut production systems. These findings illustrate the importance of irrigation and demonstrate the potential negative impacts future water restrictions may have on growers in the region. Interstate litigation regarding water rights has focused much attention on agricultural water use in the Southeast in recent years. Moratoria on agricultural withdrawal permits in certain watersheds and voluntary auctioning of agricultural water rights have occurred in Georgia; thus the future expansion of irrigated acreage may be limited unless alternative methods of irrigation are adopted or current practices are made more efficient.

Surface residue management coupled with conservation tillage is a viable management tool for producers (Brown et al. 1985). The positive impact of conservation tillage, strip-tillage in particular, on infiltration, runoff and soil quality has been well-researched (Bosch et al. 2002; Lascano et al. 1994; Truman et al. 2005a and 2005b). It is also suspected that conservation tillage increases the amount of plant available water, thus increasing the efficiency of rainfall or irrigation (Sullivan et al. 2005). Conservation tillage systems for peanut have been successful, although not always increasing yield when compared with conventional tillage systems (Baldwin and Jones 2003; Hartzog and Adams 1989; Wright and Porter 1995). Objectives of this field study were to quantify the yield effect of reduced irrigation amounts on three tillage systems and ultimately, to understand how reductions in irrigation water may affect the economic sustainability of crop production in the southeast.

MATERIALS AND METHODS

An experimental site was established on a Greenville fine sandy loam (fine, kaolinitic, thermic Rhodic Kandiudults) at the Hooks-Hanner Environmental Resource Center, near Dawson, GA in the fall of 2001. The site was fallow the previous 5 yr with an occasional disking or mowing to limit weed growth.

The following three tillage systems were implemented: conventional tillage, wide-strip tillage, and narrow-strip tillage. Conventional tillage consisted of multiple diskings, subsoiling (year one only) and moldboard plowing, field cultivation, and bedding prior to planting. Wide-strip tillage consisted of a single-pass tillage operation with an implement consisting of a coulter ahead of a subsoil shank, followed by two sets of fluted coulters ahead of a rolling basket and a drag chain assembly. An area approximately 18 in. wide was tilled over the row. Narrow-strip tillage consisted of a coulter ahead of a subsoil shank followed by two parallel press wheels that firm the disturbed area in one pass. An area approximately 12 in. wide was tilled over the row.

The three tillage systems were replicated three times each under one of four irrigation levels (100% of a recommended amount, 66%, 33%, and 0% or dryland) in a randomized block design. Plot dimensions were 6-36 in. rows wide by 120 ft. long. Irrigation timing was based on plant evapotranspiration (ET) measurements (2002) and on Irrigator Pro®, an irrigation decision support system that uses atmospheric ET and plant growth stage (2003-2004). Irrigation levels were obtained using a lateral move overhead sprinkler irrigation system with three spans, each span nozzled for the appropriate reduction in volume. The dryland area lay just beyond the third span of the lateral.

The study was planted in triplicate with each of the following three crops present and in rotation: peanut (*Arachis hypogea* L. var. ‘Georgia Green’), followed by cotton (*Gossypium hirsutum* L. var. ‘DPL 555RR’), followed by corn (*Zea mays* L. var. ‘DK 6760RR’). Best management practices for each crop were followed with regards to seeding rates, fertility, pest management, growth regulation, and harvest timings. Peanut only was planted in a twin row pattern, with the center of each twin row spaced 36 in. apart. A wheat (*Triticum aestivum* L. var. ‘AGS 1000’) cover crop was drill-seeded each fall on conservation tillage plots. Cover crop termination was performed approximately three weeks prior to planting of each crop species.

The center two rows by 100 ft. were machined harvested in each crop to determine yield. Peanut plots were subjected to soilborne and foliar disease evaluations, aflatoxin analysis, FSIS grade, and digging loss analysis. Net returns were calculated using enterprise budgets with the following adjustments: variable cost of irrigation, \$6.50 acre^{-1} inch^{-1}; irrigated land rent, \$100 acre^{-1}; dryland rent, \$50 acre^{-1}; cost (variable plus fixed costs) of machinery and fuel for conventional tillage, \$83.67 $acre^{-1}$; cost of machinery and fuel for strip tillage, \$28.45 $acre^{-1}$; selling price, \$380 ton^{-1} (2002, 2004) and \$390 ton^{-1} (2003). Yield and net returns for tillage systems were analyzed within a given irrigation level using Mixed Models analysis. Orthogonal contrasts were performed to further distinguish between tillage systems. Peanut yield response and net returns from 2002-2004 are presented.

RESULTS AND DISCUSSION

ANOVA revealed that tillage was a significant effect at the 0% irrigation level, and then only by year (Table 1). All remaining irrigation levels showed no differences between tillage systems, only differences by year. Accordingly, both yield and net return data will be presented by year only for the 33-100% irrigation levels. Yield and net return are presented by tillage and year for the 0% (dryland) irrigation level.

Although a statistical comparison may not be made, yield increased numerically with an increase in irrigation level in two of three years (Table 2). Rainfall in 2002 was very near the 30-yr average for the research site (Table 3). Both 2003 and 2004 had approximately four more inches of rainfall than the 30-yr average. Yield in 2003 showed no trend with irrigation and is likely due to the even distribution of rainfall during that growing season (Figure 1). Compared with 2004, rainfall recorded during a 9 week period starting at week 9 was three-fold greater during 2003. This time period, from 63 to 119 days after planting corresponds to the pegging and pod fill stages of peanut development, when crop water use is at its greatest. A similar drought occurred in 2002 beginning at week 11 and continuing through week 17. This corresponds to a four-fold increase in rainfall during that time. Irrigated yields in 2003 were less than both 2002 and 2004 due to excessive vine growth which caused digging problems (data not shown).

Tillage effects were evident at the 0% irrigation level only (Table 4). Yields ranged from 2700 to 3350 lb $acre^{-1}$ in 2002, with maximum yield in the narrow-strip tillage system. Net return corresponded closely with yield, with the highest return (\$102.00 $acre^{-1}$) found also in the narrow-strip tillage. Contrasts revealed no significant difference between the narrow-strip tillage system and the conventional tillage system. However, a significant decrease in both yield and net return was found for the wide-strip tillage system. This decrease cannot be attributed to any certain factor. No significant differences were determined for 2003, with maximum yield of 3810 lb $acre^{-1}$ and net return of \$203.00 $acre^{-1}$. Both strip tillage systems had greater yield and net return compared to the conventional tillage system in 2004. Highest yield and net returns were with wide-strip tillage (3940 lb $acre^{-1}$ and \$214.33 $acre^{-1}$), but these were not significantly greater than those for narrow-strip tillage. With the exception of wide-strip tillage in 2002, all treatments had positive net returns for dryland production.

These initial findings indicate that dryland fields may be more responsive to choices in tillage system compared to irrigated fields. No clear trend in yield can be related to tillage at this time. Conservation tillage adoption in peanut has lagged compared with other crops such as corn and cotton, due to producer reluctance and concern for digging problems. Our data further indicate that either wide- or narrow-strip tillage can be used successfully in the southeast in both favorable (2003-2004) and marginal production years (2002). Narrow-strip tillage production was among the highest in net return per acre regardless of year. No significant differences in tillage were determined at any level of irrigated peanut production for either yield or net returns, indicating that water continues to influence peanut production in the southeastern coastal plain. The interaction between tillage and irrigation level will continue to be monitored, with special emphasis on the temporal effects of conservation tillage.

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Table 1. ANOVA results for peanut yield and net return within irrigation level[†].

Effect	0% (dryland) Yield	0% (dryland) Net return	33% Yield	33% Net return	66% Yield	66% Net return	100% Yield	100% Net return
	P > F							
Year	0.0011	0.0021	0.0293	0.0265	0.0252	0.0142	0.0328	0.0201
Tillage	0.0207	0.0031	0.9961	0.9957	0.8501	0.8039	0.9674	0.9547
Year * tillage	0.0207	0.0031	0.9961	0.9957	0.8502	0.8038	0.9673	0.9545

[†] Main effects considered significant if $P \leq 0.05$. Interactions considered significant if $P \leq 0.10$.

Table 2. Mean peanut yield and net return by year (across tillage systems) at three irrigation levels.

Irrigation level	2002 Yield	2002 Net return	2003 Yield	2003 Net return	2004 Yield	2004 Net return
	--lb/A--	*--$/A--*	*--lb/A--*	*--$/A--*	*--lb/A--*	*--$/A--*
0%[†]	3100	33.67	3680	161.22	3700	146.89
33%	4250	183.56	3710	112.33	3780	96.00
66%	4760	262.33	3460	59.44	4040	130.78
100%	4820	254.00	3660	94.89	4140	135.44

[†] 0% (dryland) means presented for comparison purposes only.

Table 3. Total rainfall and supplemental irrigation applied to the 2002-2004 peanut crops at the Hooks-Hanner Environmental Research Center, Dawson, GA.

Source	2002	2003	2004	30-yr average
	------------ *inches* ------------			
Rainfall	24.01	27.83	28.06	24.82
Irrigation†	8.4	1.76	7	--
Total water	32.41	29.59	35.06	--

† Irrigation amounts are those in the 100% irrigation level.

Table 4. Mean peanut yield and net return of three tillage systems at the 0% (dryland) irrigation level†.

	2002		2003		2004	
Tillage system	Yield	Net return	Yield	Net return	Yield	Net return
	--lb/A--	*--$/A--*	*--lb/A--*	*--$/A--*	*--lb/A--*	*--$/A--*
Conventional	3260	19.67	3810	141.33	3340	33.33
Wide-strip	2700	-20.67	3460	139.33	3940	214.33
Narrow-strip	3350	102.00	3780	203.00	3830	193.00
Contrast	------------ *P > F* ------------					
Conventional vs. strip	0.1536	0.6973	0.2670	0.3560	0.0435	0.0059
Wide-strip vs. narrow-strip	0.0021	0.0845	0.1136	0.1141	0.6682	0.6676
Wide-strip vs. conventional	0.0104	0.5225	0.0943	0.9556	0.0052	0.0087
Narrow-strip vs. conventional	0.7970	0.2151	0.8979	0.1237	0.0427	0.0149

† Contrasts considered significant if $P \leq 0.05$.

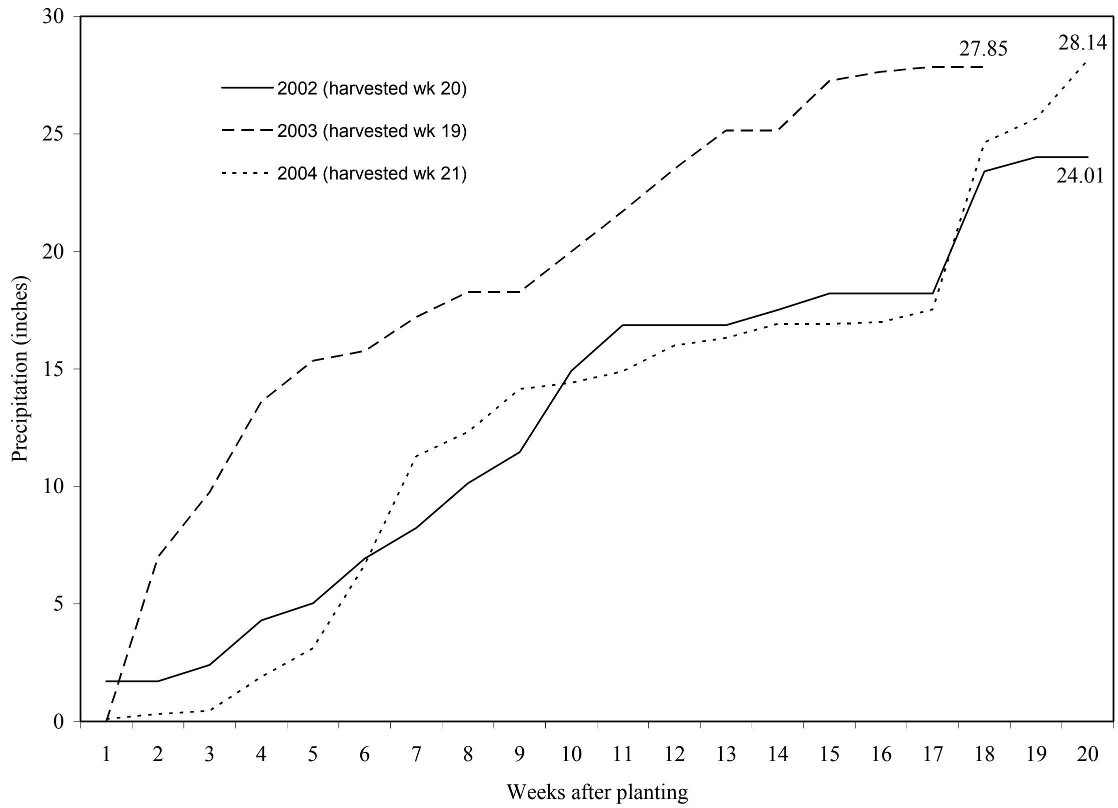

Figure 1. Rainfall distribution with cumulative totals during the 2002-2004 cropping seasons, Dawson, GA.

The Use of Bayes' Theorem to Explore the Adoption of Herbicide-Tolerant Cotton Seed and No-Tillage Production Practices

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Abstract

This paper examines the relationships between the adoption of no-tillage production practices in cotton and the adoption of herbicide-tolerant seed. Using Bayes' theorem, time series data on cotton tillage practices are compared to the planting of herbicide-tolerant cotton seed. Farmers who have already adopted no-tillage production practices have a higher probability of adopting herbicide-tolerant seed and farmers who have already adopted herbicide-tolerant seed have a higher probability of adopting no-tillage production practices. This result suggests that adoption of no-tillage production practices facilitates the adoption of herbicide-tolerant seed and that adoption of herbicide-tolerant seed facilitates the adoption of no-tillage production practices.

Introduction

The area under no-tillage production practices in the United States experienced steady growth and increased from 5.4 million acres in 1973 to 11 million acres in 1983 to almost 55 million acres in 2002 (International Soil Tillage Research Organization). In 1989, 5.1 million acres of corn and 4.8 million acres of soybean were planted using no-tillage production practices. By 2002, 15 million acres of corn and 26 million acres of soybean were planted using no-tillage technology. Adoption rates of no-tillage corn and soybean increased to 19.1% and 34.9%, respectively, in 2002 from around 7% in 1989. In Tennessee, diffusion of no-tillage increased to 61% of cropland acreage from 1983 to 2002, and rose more rapidly during the 1997-2002 period.

Weed control is a vital step for no-till adoption. Failure to control weeds when using no-tillage production systems will result in decreased output and lower quality and may even impact crop harvest. Herbicide-tolerant cotton varieties have been developed using genetic engineering techniques. Crops that carry herbicide-tolerant genes were developed to survive certain herbicides that previously would have destroyed the crop along with the targeted weeds. With herbicide-tolerant crops, farmers have a wider range of chemical herbicides from which to select (Fernandez-Corne and Mcbride, 2002).

Herbicide-tolerant cotton varieties provide farmers with effective weed control programs that eliminate some of the problems associated with conventional programs. Until 1995, cotton farmers did not have any broadleaf herbicides that could be used over a growing cotton crop without causing crop injury. With the introduction of herbicide-tolerant cotton, farmers could use a broad-spectrum herbicide over the growing cotton with minimal cotton injury. The introduction of herbicide-tolerant cotton varieties has led to a reduction in the number of herbicide applications made by cotton farmers (Janet E. Carpenter, 2001). Thus, farmers who use no-tillage production practices may benefit if adopting herbicide-tolerant crops allows them to use a more effective herbicide treatment system (Robbin Shoemaker, 2001).

Jaffe et al (2000) pointed out that diffusion is the process by which a successful innovation gradually becomes broadly used through adoption by firms or individuals. This process generally results in an S-shaped diffusion curve (Griliches 1957). After a slow start in which only a few farmers adopt the innovation, adoption expands at an increasing rate. Eventually, the rate of adoption tapers off as the number of adopters begins to exceed the number of potential adopters who have not yet adopted the innovation. Finally, the adoption rate approaches its asymptotic maximum and the process ends. No-tillage production practices and herbicide-tolerant cotton seed adoption both follow the well-known diffusion process. However, compared with the diffusion curve for herbicide-tolerant (HT) cotton seed, diffusion curve for no-tillage cotton is flatter and the rate of diffusion was slower (Figure 1).

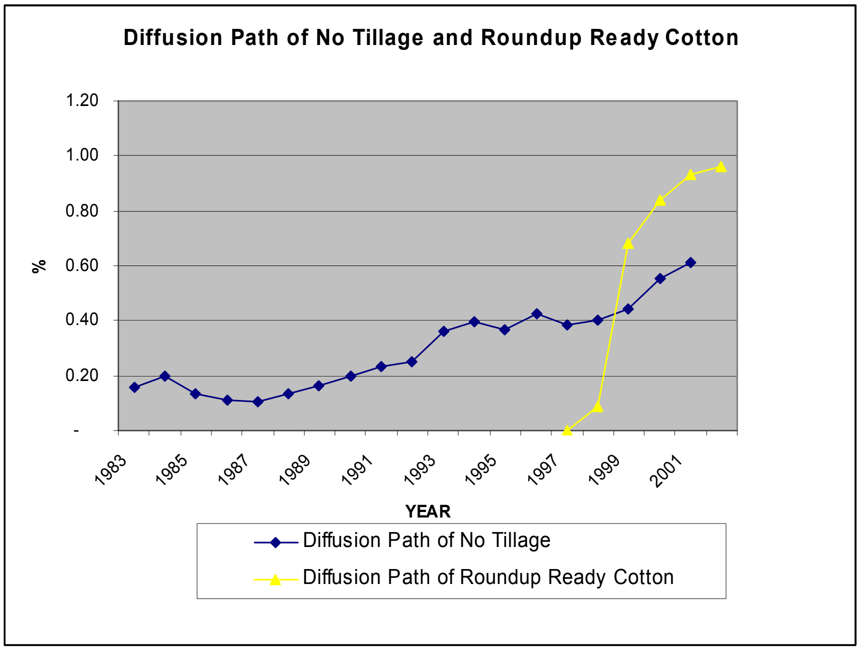

Figure 1. No-tillage and herbicide-tolerant crop technology adoption by cotton farmers

METHODS

A conditional probability is defined as the probability of an event given that another event has occurred, the probability that event B occurs, given that event A has already occurred is stated mathematically in equation (1),

$$P(B|A) = P(A \text{ and } B)/P(A) \qquad (1)$$

where P(B|A) is the probability of event B occurring given the fact that event A has already occurred, P(A and B) is the probability of events A and B occurring together, and P(A) is the probability of event A occurring. Bayes' Rule allows the order of conditional probabilities to be reversed. Many (but not all) conditional probability problems are of this type. Bayes' Rule states that

$$P(B|A) = \frac{P(B)P(A \mid B)}{P(B)P(A \mid B) + P(\bar{B})P(A \mid \bar{B})} \qquad (2)$$

where $P(\bar{B})$ is the probability of the complement to event B occurring. And according to Bayes' Rule, a posterior probability exists, P (A|B) = $\dfrac{P(A)P(B \mid A)}{P(A)P(B \mid A) + P(\bar{A})P(B \mid \bar{A})}$ (3)

In this analysis, attention is given to two events, the adoption of no-tillage production practices and the adoption of herbicide-tolerant seed. A conditional probability of P (H|N) is the probability that a farmer adopts herbicide-tolerant seed (H), given that the farmer has already adopted no-tillage practices (N). Another conditional probability exists (P (H| $\overline{N}$) and is defined as the probability that a farmer adopts herbicide-tolerant seed, given that the farmer has not adopted no-tillage practices. Thus, the two conditional probabilities can be written as,

P (H|N) = $\dfrac{P(H)P(N \mid H)}{P(H)P(N \mid H) + P(\bar{H})P(N \mid \bar{H})}$ (4)

and

P (H| $\overline{N}$) = $\dfrac{P(H)P(\overline{N} \mid H)}{P(H)P(\overline{N} \mid H) + P(\bar{H})P(\overline{N} \mid \bar{H})}$ (5)

If the two conditional probabilities are the same, the adoption of no-tillage practices did not influence the adoption of herbicide-tolerant seed. If the first conditional probability is greater than the second, the farmer who adopts no-tillage practices is more likely to adopt herbicide-tolerant seed than a farmer who does not adopt no-tillage practices.

According to Bayes' Rule, the posterior probabilities, P (N|H) and P (N| $\overline{H}$) can be calculated as,

P (N|H) = $\dfrac{P(N)P(H \mid N)}{P(N)P(H \mid N) + P(\bar{N})P(H \mid \bar{N})}$, (6)

and

P (N| $\overline{H}$) = $\dfrac{P(N)P(\overline{H} \mid N)}{P(N)P(\overline{H} \mid N) + P(\bar{N})P(\overline{H} \mid \bar{N})}$, (7)

where P (N|H) is the probability of adopting no-tillage practices given adoption of herbicide-tolerant seed and P (N| $\overline{H}$) is the probability of adopting no-tillage practices given non-adoption of herbicide-tolerant seed. The Bayes' posteriors will be used to evaluate whether adoption of herbicide-tolerant seed has an influence on adoption of no-tillage production practices.

Data used in the analysis were taken from Doane AgroTrak for 1998 through 2002. The Doane AgroTrak data contain information about the number of Tennessee cotton acres in no-tillage production practices and herbicide-tolerant seed, as well as the number of cotton acres in both no-tillage production practices and herbicide-tolerant seed.

RESULTS

The results show that over the years the percentage of cotton acres in herbicide-tolerant seed that was also no-tilled (P (H|N)) is greater than the percentage of cotton acres in herbicide-tolerant seed that was not no-tilled (P (H| $\overline{N}$). This result suggests that farmers who have adopted no-tillage practices have a higher probability (.96 < .71 in 2000) of adopting herbicide-tolerant cotton seed, which further suggests that the diffusion of herbicide-tolerant cotton seed has been faster with farmers who have adopted no-tillage practices that farmers who have not

Table 2. Comparison between herbicide-tolerant cotton adoptions given no tillage and given non-no-tillage practice

	1998	1999	2000	2001	2002
RR Pct ---P(H)	0.09	0.68	0.84	0.93	0.96
No-tll Pct---P(N)	0.10	0.47	0.51	0.72	0.67
RR No-till Pct--P(HN)	0.05	0.38	0.49	0.71	0.66
Non-RR No-till Pct	0.05	0.09	0.02	0.01	0.01
P(H|N)	**0.50**	**0.81**	**0.96**	**0.99**	**0.99**
P(H| $\overline{N}$)	**0.04**	**0.56**	**0.71**	**0.78**	**0.90**

adopted no-tillage practices.

The posterior probability P (H|N) suggests that farmers who have adopted herbicide-tolerant seed have a higher probability of adopting no-tillage practices than do farmers who have not

Table 3 Comparison between No-tillage adoption given herbicide-tolerant cotton seed and given non- herbicide-tolerant cotton seed adoption

	1998	1999	2000	2001	2002
RR Pct ---P(H)	0.09	0.68	0.84	0.93	0.96
No-till Pct---P(N)	0.10	0.47	0.51	0.72	0.67
RR No-till Pct--P(HN)	0.05	0.38	0.49	0.71	0.66
Non-RR No-till Pct	0.05	0.09	0.02	0.01	0.01
P(N|H)	**0.56**	**0.56**	**0.58**	**0.76**	**0.69**
P(N| $\overline{H}$)	**0.05**	**0.28**	**0.12**	**0.14**	**0.25**

adopted no-tillage practice (.58 > .12 in 2000).

CONCLUSIONS

In general, the probability analysis explores the relationship between adoption of herbicide-tolerant seed and adoption of no-tillage production practices. The data indicate that farmers who have already adopted no-tillage production practices have a higher probability of adopting herbicide-tolerant seed and farmers who have already adopted herbicide-tolerant seed have a higher possibility of adopting no-tillage production practices. The results suggest that no-tillage production practices encourage farmers to adopt herbicide-tolerant seed and herbicide-tolerant seed technology facilitates the adoption of no-tillage production practices.

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NARROW AND WIDE STRIP TILLAGE PRODUCTION FOR PEANUT

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ABSTRACT

Increased production costs and potential benefits of maintaining surface residue has renewed interest in conservation tillage systems for peanut (*Arachis hypogaea* L.) production. We initiated a study to determine surface residue cover following two strip tillage systems (narrow vs wide), compare yields and sound mature kernels (SMK) of three peanut cultivars (Anorden, AP-3, and GA 02-C) across each strip tillage system with two row spacings (single vs twin), and evaluate soil moisture between these treatments. Two experimental sites were established on a Malbis fine sandy loam (Fine-loamy, siliceous, subactive, thermic Plinthic Paleudults) in Fairhope, AL and a Dothan loamy sand (Fine-loamy, kaolinitic, thermic Plinthic, Kandiudults) in Headland, AL during the 2004 growing season. First year results indicated that the narrow strip tillage system produced higher surface residue cover at the Fairhope location. Yield differences between cultivars showed that GA 02-C and AP-3 yielded higher than Anorden at Fairhope, while no yield differences were observed at Headland. GA 02-C had higher SMK at both locations, but AP-3 SMK were higher than Anorden at Fairhope, while Anorden SMK were greater compared to AP-3 at Headland. Strip tillage system or row pattern had no effect on yield or SMK at either location. Although not significant, soil moisture contents measured at Headland followed the same trend as measured peanut yields, while row spacing had no effect on soil moisture contents. Preliminary results indicated that peanut conservation tillage practices may not require a wide tillage strip regardless of row pattern.

INTRODUCTION

Peanut tillage operations have typically involved moldboard plowing followed by several other tillage operations to create a smooth seedbed, bury crop residues that may potentially increase disease pressure, and bury weed seeds to inhibit their germination (Colvin and Brecke, 1988; Hartzog and Adams, 1989). However, concerns related to soil and wind erosion and the need to reduce production costs has prompted interest in conservation tillage methods for peanut production (Jordan et al., 2001b; Jordan et al., 2003).

Conservation tillage benefits have been widely reported to enhance soil physical properties and these benefits can be attributed to the build-up of organic matter at the soil surface by maintaining crop residue and planting a cover crop. Residues retained on the soil surface have been shown to improve moisture management by decreasing evaporation and increasing infiltration (Lascano et al., 1994). A typical peanut conservation tillage system involves planting a winter annual cereal cover crop, chemically terminating the cover crop in the spring, utilizing an in-row subsoiler with coulters and baskets (strip tillage) to prepare a seedbed, followed by the planting operation. However, this strip tillage operation typically disrupts approximately 1/3 of the row width.

Some peanut producers in the Southeast have shifted from single row patterns to twin row patterns spaced 7 to 9 in. apart, centered on 36 to 40 in. rows (Jordan et al., 2001a). This shift to twin rows has been attributed to a decreased incidence of tomato spotted wilt tospovirus (TSWV) compared to single row patterns (Baldwin et al., 1998), which may contribute to increased peanut yields of twin row over single row patterns (Jordan et al., 2001a). Twin row peanuts in a conservation system typically utilize the strip tillage system described above which disrupts a wider portion of the row to accommodate the twin rows. A smooth seedbed is created, but the incorporation of beneficial surface residue occurs.

Another form of strip tillage has been utilized for row crops that produce their fruit above ground, such as cotton (*Gossypium hirsutum* L.). The same in-row subsoiler is used, but the coulters and baskets are replaced with rubber pneumatic tires to close the slit created by the subsoiler shank. This type of tillage operation provides belowground disruption of any compacted zones present beneath the row, while maximizing the amount of residue on the soil surface. Therefore, our objectives are to determine surface residue cover following two strip tillage systems, compare yield responses of three peanut cultivars across each strip tillage system with two row spacings, and evaluate soil moisture between these treatments.

MATERIALS AND METHODS

An experimental site was established at the Gulf Coast Research and Extension Center (GCS) in Fairhope, AL and the Wiregrass Research and Extension Center (WGS) in Headland, AL during the 2004 growing season. Treatments consisted of three peanut cultivars, two tillage systems, and two row spacings with a split-split plot arrangement in a randomized complete block design with four replications at GCS and three replications at WGS. Main plots were peanut cultivars, (AP-3, Anorden, and GA 02-C) sub-plots were tillage systems (narrow strip consisting of a coulter, shank, and press wheels; wide strip consisting of a coulter, shank, two sets of coulters, rolling basket, and drag chain), and sub sub-plots were row spacings (single and twin rows). Sub sub-plot dimensions were 12.7 ft. wide (4-38 in. rows) at GCS and 12 ft. wide (4-36 in. rows) at WGS with 30 ft. long rows.

A rye (*Secale cereale* L.) cover crop was established in fall 2003 with a no-till drill on a Malbis fine sandy loam at GCS and an oat (*Avena sativa* L.) cover crop was established with a no-till drill on a Dothan loamy sand at WGS. Both cover crops were seeded at 90 lb ac^{-1} and chemically terminated the following spring. Biomass samples were determined from each plot, immediately prior to termination, by cutting all aboveground tissue from two areas, each measuring 2.7 ft^2.

Approximately 3 wk after cover crop termination, each strip tillage configuration was performed in the appropriate plot and subsequent peanut cultivars were planted at 6 seed ft^{-1} for single and twin rows. Surface residue was determined for each plot using the line transect method (Morrison et al., 1993), prior to peanut emergence. Soil water content was monitored during the growing season using ECH_2O-20 probes (Decagon Devices Inc., Pullman, WA[1]) at WGS. The probes were installed vertically in the row centers, with measurements taken between 3- and 11-in of depth from the soil surface. Data was collected every 15-min using self-contained dataloggers.

Peanuts were mechanically harvested from the two center rows of each plot to determine yield and SMK. Yield was determined by weighing freshly harvested nuts in the field and adjusting the weight based on a subsample that was dried to 10% moisture. That subsample was shelled and graded to determine SMK. Cultural practices to control weeds, diseases, and insects were based on Alabama Cooperative Extension recommendations.

Data were analyzed using a mixed model procedure provided by the Statistical Analysis System (SAS Institute, 2001). Treatment differences were considered significant if P > F was less than or equal to 0.05. Comparison among more than three treatment means were separated by the least significant difference (LSD).

RESULTS AND DISCUSSION

Surface residue cover was higher for the narrow strip tillage system at both locations; however, the difference was only significant at GCS (Fig. 1). Residue cover was greater for both strip tillage systems at GCS compared to WGS (Fig. 1). This may be attributed to higher amounts of biomass produced by rye at GCS compared to oat biomass at WGS. Previous research has shown that rye was superior to other cereal and legume cover crops, as well as, selected mixtures of cereals and legumes (Daniel et al., 1999).

Peanut populations measured 3 wk after planting were between 3.5 and 4.0 seeds ft^{-1} (data not shown). No interactions were observed for peanut yields or SMK between cultivars, strip tillage systems, and row pattern, therefore each of these effects will be presented separately.

Peanut yields of AP-3 and GA 02-C were superior to Anorden at GCS, but they were not different from each other (Table 1). These two cultivars also produced higher yields compared to Anorden at WGS, but no significant differences were observed (Table 1). Peanut yields of all cultivars were higher at WGS than yields observed at GCS, although SMK were generally higher at GCS than WGS (Table 1). The cultivar GA 02-C produced the highest SMK at both locations, but AP-3 SMK were higher than Anorden at Fairhope, while Anorden SMK were greater compared to AP-3 at Headland (Table 1).

The strip tillage system utilized at each location had no effect on peanut yields or SMK (Table 2). These preliminary results indicate that the row pattern should not dictate which type of strip tillage system is used. Coulters and baskets used behind the shank for a wide strip tillage system may not be necessary for twin row peanuts, allowing beneficial residue to remain on the soil surface.

First year results indicated no differences existed between yields or SMK for single and twin rows at either location (Table 3). Jordan et al. (2001a) showed inconsistent yield responses for twin rows over single rows across seven site-years, but seeding rates were higher for twin rows and all plots were planted with conventional tillage practices. The lack of yield response for twin rows compared to single rows in our study may be attributed to the two conservation tillage systems used in the experiment. Conventional tillage practices that leave the soil bare may attract thrips, which vector TSWV compared to soil covered with crop residue (Marois and Wright, 2003). Since cover crop residues were retained in all plots, yield reductions associated with TSWV were diminished.

Soil moisture was affected by peanut variety (Fig. 2). Greater soil water contents were recorded with the AP-3, followed by the GA 02-C and Anorden, respectively. Although yield differences were not significant, the soil water contents corresponded to observed yields at this location (Table 1). These differences in soil water content possibly reflect differences in water use efficiency by the three peanut cultivars.

Seeding rates were the same for the single and twin row, and plant populations measured 3 wk after planting were between 3.5 and 4.0 seed ft^{-1}. For this reason the plant water demand should have been similar for both treatments. This was apparent in the soil water content between the single and twin row spacing, which showed no differences (Fig. 3).

CONCLUSION

Preliminary results indicate that the narrow strip tillage system produced higher surface residue cover at GCS. Yield differences between cultivars showed that GA 02-C and AP-3 yielded higher than Anorden at GCS, while no yield differences were observed at WGS when averaged over tillage systems and row patterns. The highest percentage of SMK for both locations were found in GA 02-C, but AP-3 SMK were higher than Anorden at GCS, while Anorden SMK were greater compared to AP-3 at WGS. Yield and SMK were not influenced by strip tillage or row pattern at either location. Although not significant, soil moisture contents measured at WGS followed the same trend as measured peanut yields, while row spacing had no effect on soil moisture contents. First year results indicate that peanut conservation tillage practices may not require a wide tillage strip, regardless of row pattern, but continuing research will help confirm these findings.

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Table 1. Peanut yields and sound mature kernels (SMK) measured for three cultivars averaged across two tillage systems and two row patterns at two locations during the 2004 growing season.

Cultivar	Gulfcoast†		Wiregrass	
	Yield	SMK	Yield	SMK
	---lb ac^{-1}---	---%---	---lb ac^{-1}---	---%---
Anorden	2690	67.3	3330	66.6
AP-3	3530	68.2	4750	64.0
GA 02-C	4080	70.2	4550	71.3
$LSD_{0.05}$	580	1.9	NS	1.6

† Four replications for Gulfcoast; three replications for Wiregrass.

Table 2. Peanut yields and sound mature kernels (SMK) measured for two tillage systems averaged across three peanut cultivars and two row patterns at two locations during the 2004 growing season.

Strip tillage	Gulfcoast†		Wiregrass	
	Yield	SMK	Yield	SMK
	---lb ac^{-1}---	---%---	---lb ac^{-1}---	---%---
Narrow	3430	68.1	4290	67.8
Wide	3440	69.0	4130	66.7
P > F	0.9944	0.2612	0.4697	0.0911

† Four replications for Gulfcoast; three replications for Wiregrass.

Table 3. Peanut plant populations and yields measured for two row patterns across three peanut cultivars and two strip tillage systems at two locations during the 2004 growing season.

Row pattern	Gulfcoast†		Wiregrass	
	Yield	SMK	Yield	SMK
	---lb ac^{-1}---	---%---	---lb ac^{-1}---	---%---
Single	3600	69.0	4160	67.7
Twin	3270	68.1	4260	66.9
P > F	0.1313	0.2612	0.5688	0.2291

† Four replications for Gulfcoast; three replications for Wiregrass.

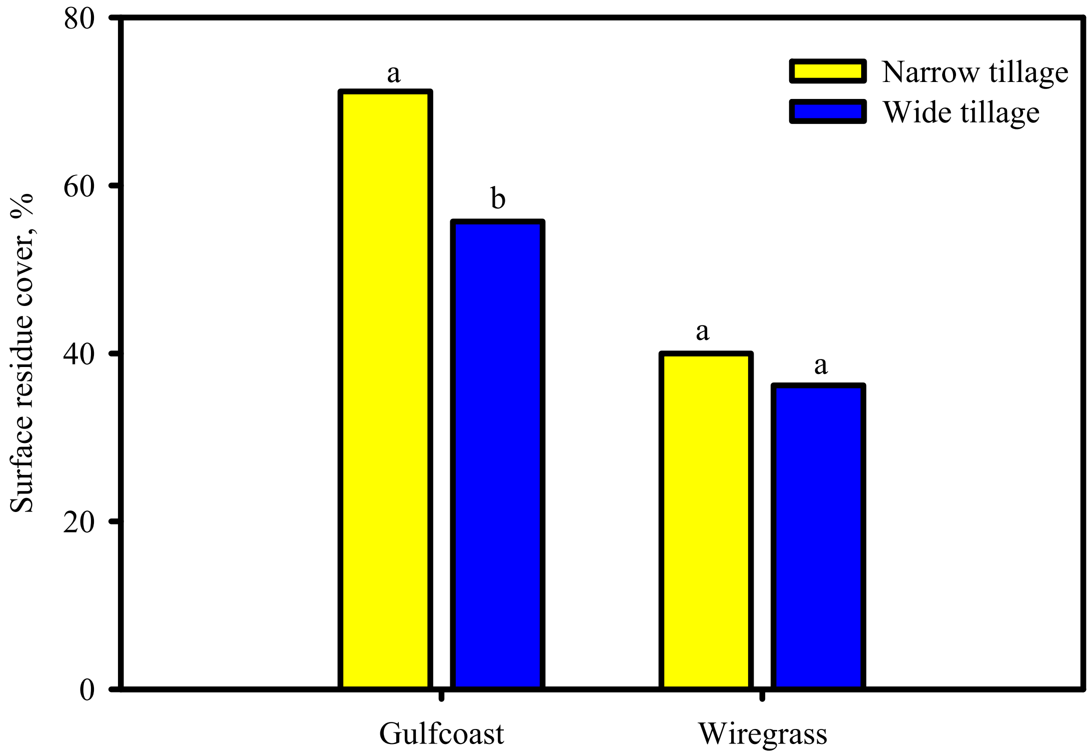

Figure 1. Surface residue cover measured immediately after peanut planting in narrow and wide strip tillage systems for a rye cover crop at the Gulfcoast Research and Extension Center in Fairhope, AL and an oat cover crop at the Wiregrass Research and Extension Center in Headland, AL during the 2004 growing season. Means followed by the same letter within a location are not significantly different from each other at the 0.05 significance level.

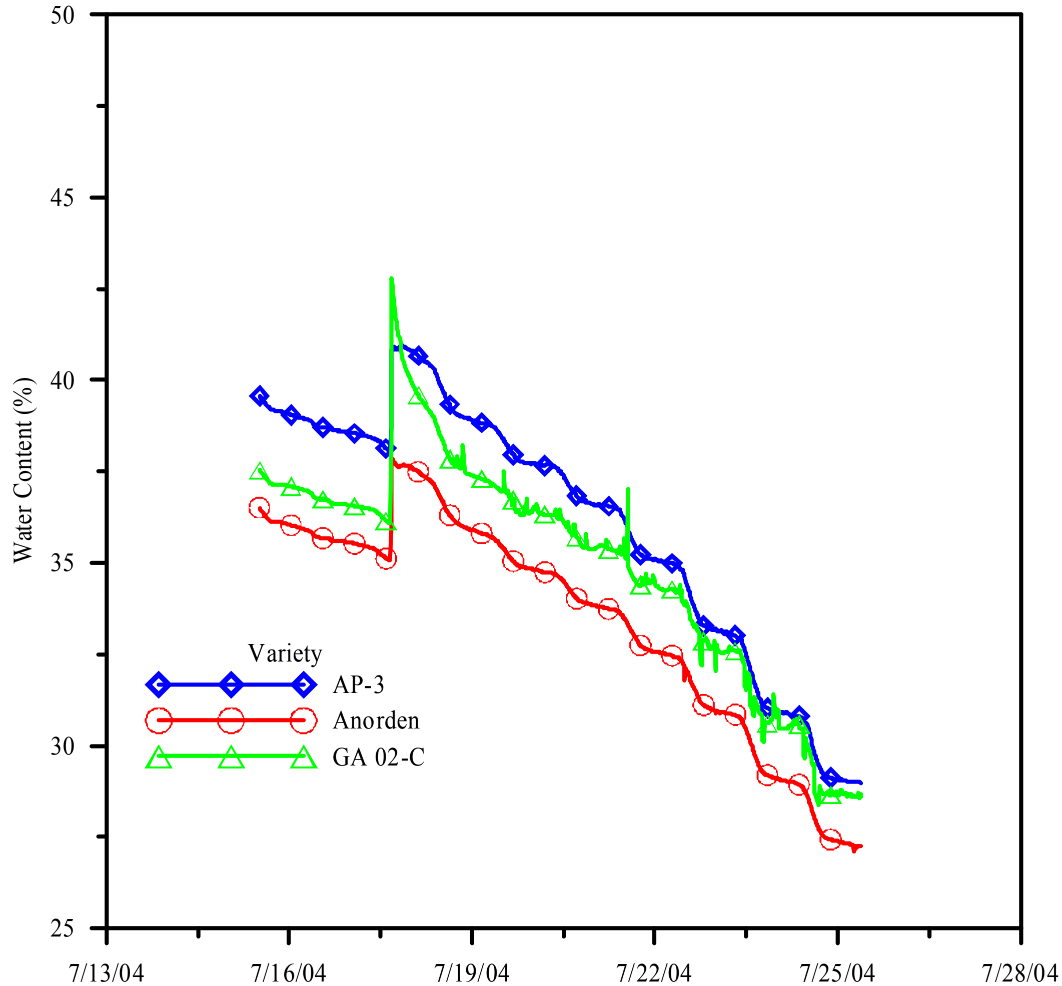

Figure 2. Soil water content measured during the growing season of 2004 for three peanut cultivars at the Wiregrass Research and Extension Center.

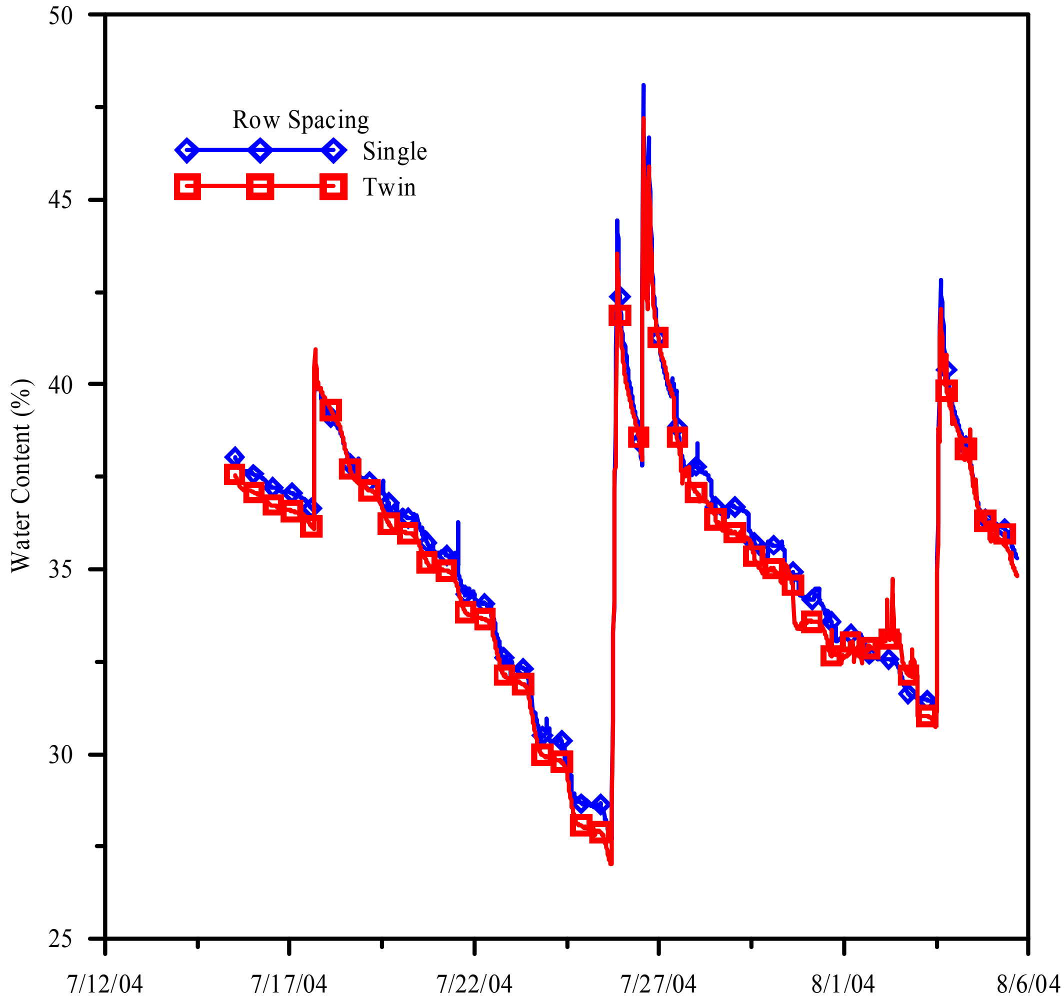

Figure 3. Soil water content measured during the 2004 season for single and twin row patterns at the Wiregrass Research and Extension Center.

INTERACTIONS OF TILLAGE WITH OTHER COMPONENTS USED TO MANAGE TOMATO SPOTTED WILT OF PEANUT

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ABSTRACT

Conservation tillage is a cultural practice that can be used to minimize tomato spotted wilt of peanut (*Arachis hypogaea* L.). Other practices that influence incidence of tomato spotted wilt include: in-furrow insecticides to control thrips (*Frankliniella fusca*), cultivar selection, planting date, planting pattern, and plant population. Tomato spotted wilt was generally lower when the peanut cultivar Gregory was seeded at higher plant populations in strip tillage systems, or when phorate was applied in the seed furrow. However, when *Cylindrocladium* black rot [caused by *Cylindrocladium crotalarie* (Loos) Bells and Sobers] was present, disease incidence was higher and peanut pod yield lower when the cultivar Gregory was planted rather than the cultivar Perry. While supporting the current tomato spotted wilt index in North Carolina and Virginia, these data also indicate that response to specific components of the index can be inconsistent, and that distinguishing between *Cylindrocladium* black rot and tomato spotted wilt in previous years is critical when incorporating appropriate cultural and pest management practices for control of both diseases.

SUMMARY

Tomato spotted wilt is a major disease of peanut in the southeastern United States and has also become established in the Virginia-Carolina production region in recent years. Risk indices have been developed in both production regions to minimize the impact of tomato spotted wilt on peanut yield and quality. Planting date, plant population, row pattern, tillage system, cultivar selection, and in-furrow insecticide can influence the severity of tomato spotted wilt of peanut. However, these practices are incorporated into management systems early in the season before growers know the severity of infestation for that year. There are no curative or corrective practices for tomato spotted wilt that can be incorporated after peanut is planted. Defining interactions among these practices is important in order to determine which components are the most effective, especially when considering other pests. Research was conducted from 2002 through 2004 to evaluate interactions of tillage system, cultivar selection, in-furrow insecticide, and plant population/seeding rate on development of tomato spotted wilt and peanut pod yield.

Experiments were conducted in North Carolina at the Peanut Belt Research Station located near Lewiston-Woodville from 2002 through 2004 and at the Upper Coastal Plain Research Station located near Rocky Mount during 2003 and 2004. Peanut was seeded in conventional tillage systems or strip tilled into a killed wheat cover crop. Phorate at 5 lb ai/acre or aldicarb at 7 lb ai/acre were applied in the seed furrow with the cultivars Gregory or Perry. In 2002 each tillage system/cultivar/in-furrow insecticide combination was included in twin row and single row planting patterns at Lewiston-Woodville. In 2003 and 2004 peanut was seeded in single rows at in-row populations of 4 or 5 seed/row-foot. Twin row planting patterns consisted of rows spaced

9 inches apart on 36-inch centers. The percentage of plants in each plot exhibiting visual signs of tomato spotted wilt virus or *Cylindrocladium* black rot were recorded in mid September using a scale of 0 to 100% where 0 = no diseased plants and 100 = the entire peanut canopy exhibiting symptoms of disease. Pod yield was determined in late September or early October.

The interaction of experiment X tillage system X in-furrow insecticide X cultivar X plant population/planting pattern was not significant for disease incidence or pod yield. However, several two and three-way interactions were significant. At three locations incidence of tomato spotted wilt or *Cylindrocladium* black rot did not exceed 5%. When tomato spotted wilt was present, less disease was noted when peanut was seeded in conservation tillage systems, when the insecticide phorate was applied rather than aldicarb, when the cultivar Gregory was planted rather than Perry, and when peanut was planted in a twin row planting pattern rather than in single rows. When *Cylindrocladium* black rot was present, more disease was noted for Gregory compared to Perry. Suprisingly, less *Cylindrocladium* black rot was noted when Gregory was planted and aldicarb was applied compared to applying phorate. Incidence of *Cylinrocladium* black rot was also higher when the in-row plant population was increased.

Pod yield varied depending upon year, location, tillage system, and cultivar. Pod yield was higher in two experiments when peanut was seeded in conservation tillage systems. In two experiments there was no difference in yield when comparing tillage systems while at one location yield was higher in conventional tillage systems than in conservation tillage systems. Yield of the cultivars Gregory and Perry was similar in three experiments, lower for Gregory in one experiment, and lower for Perry in the other experiment. The interaction of experiment, in-furrow insecticide, and plant population was also significant. When comparing within experiments, there was no difference in yield between plant poulations when phorate was applied. However, when aldicarb was applied, pod yield was lower in one experiment when tomato spotted wilt was present and peanut was seeded at 4 seed/row-foot rather than at 5 seed/row-foot. The opposite response was noted when *Cylindrocladium* black rot was present and aldicarb was applied in-furrow.

INSECT PEST MANAGEMENT ISSUES IN STRIP-TILL PEANUT PRODUCTION

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ABSTRACT

A series of studies were conducted on the effects of tillage, soil insecticide treatment and cover crop on peanut arthropod pests. In an initial 2-year experiment, populations of corn earworn, granulate cutworm, and velevetbean caterpillar were lower in strip-tillage systems. Chlorpyrifos applications suppressed fire ants, thus triggering corn earworm and granulate cutworm outbreaks in all tillage systems, but these applications were more disruptive in strip-tillage.

Pod damage from lesser cornstalk borer and wireworms was lower in strip-tillage systems. Tomato spotted wilt virus incidence was also reduced by strip-tillage. However, threecornered alfalfa hopper damage to peanut was greater in the wheat residue strip-tillage system. Burrower bug injury to peanut kernels was also greater in strip-tillage systems. Under drought conditions, losses of $ 249/ha and $ 388/ha were attributed to burrower bug injury in untreated corn and wheat residue strip-tillage systems, respectively.

In a subsequent 2-year experiment, peanuts strip-tilled into corn or wheat residue had greater burrower bug injury than in rye residue or conventional tillage. However, when winter tillage was used to establish cover crops, burrower bug injury was reduced.

Another study evaluated the association of burrower bug kernel feeding in strip-tillage peanut with aflatoxin contamination. Across all grade categories, 98% of all aflatoxin contamination was associated with burrower bug feeding.

In summary, strip-tillage production systems were found to generally result in reduced injury levels for most insect pests. However, burrower bugs are capable of causing major economic injury to peanut, at least in some conservation tillage systems under drought stress.

SUMMARY

A series of studies were conducted on the effects of tillage, soil insecticide (chlorpyrifos) treatment and cover crop on peanut arthropod pests. In an initial 2-year experiment, main plot treatments consisted of three tillage systems: conventional moldboard plow, strip-tillage into a killed wheat cover crop, and strip-tillage into corn stubble residue. Subplot insecticide treatments were granular chlorpyrifos applied at early pegging (growth stage R2) and untreated. Populations of corn earworn, *Helicoverpa zea* (Boddie), granulate cutworm, *Agrotis subterranea* (F), and velevetbean caterpillar, *Anticarsia gemmatalis* Hübner, were lower in strip-tillage systems. Chlorpyrifos applications suppressed imported fire ant, *Solenopsis invicta* Buren, populations, thus triggering corn earworm and granulate cutworm outbreaks in all tillage systems, but these applications were more disruptive in strip-tillage. Chlorpyrifos treatment also increased populations of fall armyworm, *Spodoptera frugiperda* (J. E. Smith), but had no measurable effect on velvetbean caterpillar populations. Pod damage from lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller) and wireworms (Elateridae) was lower in strip-tillage systems, and chlorpyrifos suppressed pod damage in all systems. Threecornered alfalfa hopper, *Spissistilus festinus* (Say), damage to peanut was greater in the wheat residue strip-tillage system. Chlorpyrifos treatment reduced threecornered alfalfa hopper damage in all systems. Spider mite injury was not affected by tillage, but chlorpyrifos caused mite outbreaks in all tillage systems.

Incidence of tomato spotted wilt virus was reduced by strip-tillage. Burrower bug, *Pangaeus bilineatus* Say, injury to peanut kernels was greater in the strip-tillage systems and this injury was suppressed in the strip-tillage systems by chlorpyrifos treatment. There was a significant interaction effect for burrower bug injury between tillage and insecticide treatment.

Use of an effective fungicide program and a 3-yr crop rotation out of peanut production probably obscured any potential tillage effects on fungal diseases (southern stem rot, Rhizoctonia limb rot, and leaf spot). However, chlorpyrifos treatment increased Rhizoctonia limb rot incidence. Weed populations were generally greater in strip-tillage systems, but postemergence herbicides effectively eliminated any potential confounding effect on yield and grade.

Yield was not affected by tillage; however, chlorpyrifos increased yield and grade in both strip-tillage systems during a drought year due to suppression of burrower bug injury. Grade was also highest in conventional tillage where burrower bug injury was less prevalent. Under drought conditions, crop value losses of \$ 249/ha and \$ 388/ha were attributed to burrower bug injury in untreated corn and wheat residue strip-tillage systems, respectively. These observations prompted additional investigations of burrower bug in conservation tillage systems.

A subsequent 2-year experiment was conducted on the effects of cover crop, tillage timing and insecticide treatment on burrower bug injury. Peanuts strip-tilled into corn or wheat residue developed greater burrower bug populations and kernel-feeding injury levels than in rye residue or no-residue, conventional tillage systems. When the wheat cover crop was planted with conventional tillage rather than being drilled directly into corn residue, subsequent burrower bug populations and peanut kernel feeding were reduced, indicating that winter tillage disrupted diapaused adults. At-pegging granular chlorpyrifos treatments were most effective in suppressing kernel feeding. Kernels with burrower bug feeding sites were 10.3 ± 1.8 % lighter than kernels which were not fed-on. Burrower bug feeding reduced peanut grade primarily by reducing individual kernel weight and increasing the percentage of damaged kernels. Each 10 % increase in kernels fed on by *P. bilineatus* was associated with a 1.7 % decrease in total sound mature kernels, and kernel feeding levels above 30% increased the risk of damaged kernel grade penalties.

Another study evaluated the association of burrower bug kernel feeding in strip-tillage peanut with aflatoxin contamination. Across all grade categories, aflatoxin levels were 65x higher in kernels with observable burrower bug feeding, and 98% of all aflatoxin contamination was associated with burrower bug feeding. The DK grade category had the highest concentration of aflatoxin and accounted for 45% of total contamination. Burrower bug-induced aflatoxin contamination of the TSMK grade category is particularly interesting because this source would be most difficult to remove from the food supply.

In summary, strip-tillage production systems were found to generally result in reduced injury levels for most insect pests. However, burrower bugs are capable of causing major economic injury to peanut, at least in some conservation tillage systems. It appears that this injury is likely to be significant only under drought stress, although the efficacy of irrigation in suppressing burrower bug injury has not been experimentally demonstrated.

RESPONSE OF WHEAT TO WETLAND AND DRYLAND RICE TILLAGE, CROP RESIDUE INCORPORATION AND RATE OF FERTILIZER N APPLICATION IN RICE-WHEAT ROTATION ON COARSE ALFISOL OF EASTERN INDIA

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ABSTRACT

Tillage in combination with crop residue incorporation and application of fertilizer N at different rates are the main management options for the rice-wheat cropping system in Eastern India. A field experiment was conducted at IIT, Kharagpur to find out the impact of tillage, crop residue and rate of fertilizer N application on soil properties and yield of rice and wheat crops. The results of the experiment revealed application puddling increased the bulk density of soil measured after the harvest of rice or wheat crops. Puddling also decreased the saturated hydraulic conductivity, which in turn increased water retention of the soil and increased the yield of transplanted rainfed rice (TR). Yield of direct seeded rice (DR) grown in soil tilled with cultivator followed by disc harrow, was comparatively lesser than the grain yields of TR. The tillage treatment (cultivator followed by disc harrow) for wheat succeeding both TR and DR was same but yield of wheat crop succeeding DR was more than wheat succeeding TR. This phenomenon manifested that the practice of puddling though increased the yield of TR, the compaction caused by it reduced the yield of wheat crop. Incorporation of rice and wheat crop residues either singly or in combination increased the soil organic carbon content in both of the tillage treatments but the increase was more with dryland tillage under direct seeded rice-wheat-fallow system. The return of carbon to soil and yield of crops was maximum when both rice and wheat residues were added along with fertilizer N @ 120 kg N /ha.

INTRODUCTION

Rice and wheat are the important crops, which are grown in rice-wheat-fallow sequence in most parts of India. Both lowland irrigated/rainfed transplanted rice and upland irrigated/rainfed direct seeded rice is followed in northern and eastern parts of India with different tillage practice for transplanted and direct seeded rice. The tillage used for lowland transplanted rice is puddling or heavy wetland tillage, whereas, heavy or light dryland tillage is practiced for direct seeded rice.

Puddling or wet tillage in rice is used mainly to decrease the water loss through seepage as puddling or wet tillage reduces total water porosity and changes porosity distribution, which increases water storage. Puddling also leads to destruction of soil structure (Sawhney and Sehgal, 1989) as a result, it influences various soil hydraulic properties, reduces percolation of water and retains standing water in the field, which in turn reduces the irrigation requirement (Hobbs et al., 2000). It also changes the distribution of soil separates, leaving the clay particles in the surface soil layer. In this way, tillage may further improve the soil textural condition and increase water retention, if incorporation of crop residues also accompanies it (Bhagat, 1990). Crop residue has an innate property to condition the soil and prevent the loss of nutrients and soil-water, increases the water and nutrient holding capacity of soil, as well as preserves the soil structure (Lal, 1993). So, the incorporation of crop residue not only increases the soil and crop productivity, it is the best alternative to recycle the organic carbon to agricultural land and to conserve C and N in organic form. Nitrogen application is another management practice, which gets affected by tillage operation and its requirement varies with the different tillage practices. So it is very essential to detect the optimum level of N to be applied under specific tillage practice and crop residue application, for sustainable productivity with no detrimental effect on environmental consequences and also reduce the cost of production.

Thus tillage, crop residue incorporation and fertilizer N application are the three major management practices, which determine the successful and sustainable production of rice-wheat system in India. Therefore, a study was conducted to understand the combined effect of tillage practice, crop residue and N application rates on the productivity of Rice-wheat system and also to identify the best combination tillage and optimum rate of crop residue and N for this soil. Conservation of natural soil environment and enrichment of soil organic matter were the other objectives included in the scope of this study.

OBJECTIVES

The objectives of the present study were to

i) assess the effect of tillage practices on rice followed by wheat crops

ii) determine the influence of crop residue application on soil properties and crop productivity

iii) select the best combination of crop residue and N application rate under puddling and dryland tillage practices.

MATERIALS AND METHODS

Experimental Site

A field experiment was conducted at the experimental farm of Indian Institute of Technology, Kharagpur, which is situated in Red and laterite agroclimatic zone of the state West Bengal, India. Kharagpur is intersected by 22.19$^{|}$ N latitude and 87.19$^{|}$E longitude. The farm is situated at an altitude of 48m above the mean sea level.

Climate

The climate of Kharagpur is subhumid, subtropical characterized by hot and humid during summer months (April and May), rainy during June to September, autumn during October and November, cool and dry winter in December and January and moderate spring in February and March. The average maximum and minimum temperature and rainfall during rice growing season were 32.367$\pm$ 0.21^{0}C, 25.000$\pm$ 0.720^{0}C and 7.633$\pm$ 1.250mm/day. Whereas, 28.145$\pm$ 1.054^{0}C, 15.915$\pm$ 0.445^{0}C and 0.54$\pm$ 0.622mm/day were the average maximum, minimum temperature and rainfall noted during wheat growing season.

Soil

The soil of the experimental site is lateritic sandy loam, classified under great group of 'Haplustalf'. The soil is acidic in nature (pH 5.3) with electrical conductivity of 0.65 dsm^{-1}. The soil is low in organic carbon content (0.32%), CEC and nutrient and water holding capacity. The soil has high bulk density (1.62 Mg/m^3) and saturated hydraulic conductivity (12.80 cm/day).

Field Experiments

Rice-wheat cropping system was adopted for the study. Both transplanted rice (TR) and direct seeded rice (DR) followed by irrigated wheat were experimented following different management practices. Puddling with tractor drawn rotavator and dryland tillage with tractor drawn cultivator followed by disc harrow was practised as tillage treatments for wetland transplanted rice and direct seeded rice as well as wheat, respectively. At the time of land preparation for rice and wheat crops, wheat and rice crop residues were incorporated to soil @ 0 and 4 tonnes per ha. The rates of application of N fertilizer were at 0, 40, 60, 80, 100 and 120 kg/ha. N fertilizer (urea) in two splits 29 and 75 days after sowing for direct seeded rice, 14 and 46 days after transplanting in case of transplanted rice and 24 and 76 days after sowing in case of wheat crop. Whereas, recommended dose of P and K (50kg/ha of each P_2O_5 and K_2O) were applied in the form of single super phosphate (SSP) and mureate of potash (KCl) to both rice and wheat crops.

First crop, rice (cultivar IR36) was direct seeded at advent of monsoon in June 2001 and at the same day rice seeds were sown in the nursery plot separately which was later (nearly 21 days after sowing) transplanted in July in the puddled plot. The transplanted and direct seeded rice were harvested in October 2001. After the harvest of rice, wheat (Cultivar 'Sonalika') was sown in the month of November. Wheat was harvested in April, and after a short period of fallow, next rice was taken. Rice was grown as rainfed crop but wheat was irrigated with 6 cm water timed at IW/CPE ratios of 0.6. The grain yield of rice and wheat crops was recorded after harvest and biomass of wheat was recorded at boot leaf stage of the crop.

Soil Analysis

Soil samples were collected after harvest of each crops, processed and kept in dry place for further analysis. Organic carbon content of soil was estimated by the modified Walkley-Black method (Walkley and Black 1934). The experimental soil was analysed for basic chemical and physical properties following standard methods discussed as follows: pH in water was measured by glass electrode (Jackson, 1967), cation exchange capacity following the method described by Hesse (1994), bulk density by Blake (1965), saturated hydraulic conductivity by Laboratorium permeameter following the principle of Klute (1965).

RESULTS AND DISCUSSION

Impact of Tillage and Crop Residue Incorporation on Soil Properties

I) Impact of Tillage and Crop Residue Incorporation on Soil physical properties

The application of both wetland and dryland rice tillage increased the bulk density (BD) of soil but the increase in BD varied differently under wetland and dryland tillage (Table 1). Increase in BD was more under the treatment of puddling than dryland rice tillage. The increase in BD was less when crop residues were added and it was minimum when residues of both rice and wheat crops were applied. Intensive puddling by rotavator decreased the saturated hydraulic conductivity (Ks) from 12.80 to 7.81 cm/day (Table 1). The decrease in Ks was more under puddling treatment than dryland tillage with cultivator followed by disc harrow. The decrease in

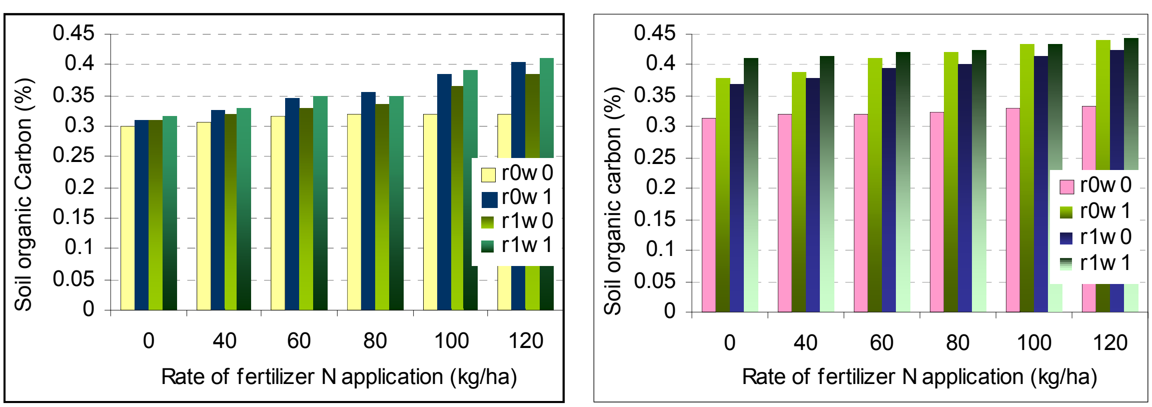
Ks was reduced when rice or/and wheat crop residues were incorporated and decrease was minimum when both rice and wheat crop residues were added.

BD decreased after the harvest of wheat following both transplanted (TR) and direct seeded (DR) rice but the decrease in BD was lesser in the soil where wheat was grown following transplanted rice. The difference in Ks, recorded after wheat following TR and DR, was very less. The impact of crop residue application on Ks after wheat harvest was same as it was found after rice harvest. The maximum Ks was recorded when residues of both rice and wheat crops were incorporated. Decrease in bulk density of surface soil with the application of crop residues might be due to increase in soil porosity (Joshi et al., 1994), which ultimately increased the Ks of soil (Boparai et al., 1992).

The difference in soil penetration values noted after harvest of wheat (2002-03) following TR and DR revealed that the soil under wheat following TR was more compact that the soil under wheat following DR (Table 2). This also manifested that the impact of puddling to the soil was such prominent that wheat tillage could not reduce it also.

II) Impact of Tillage, Crop Residue Incorporation and rate of fertilizer N application on Soil Organic Carbon (SOC)

Puddling with rotavator decreased SOC in transplanted rice-wheat-fallow (TR-W-F) system than dryland tillage followed for direct seeded rice-wheat-fallow (DR-W-F) system (Fig. 1). Similar was the findings of Doran (1980). Application of rice and wheat residues either individually or in combination increased SOC over that with no residue application (r_0w_0). The maximum SOC occurred with r_1w_1 under both TR-W-F and DR-W-F system. So, the return of organic carbon to soil is more in DR-W-F than in TR-W-F system. In other words, it can be said that the effect of puddling was negative for enrichment of SOC pool. Increase in rate of fertilizer N application increased the SOC content and SOC content was maximum at N_{120}.



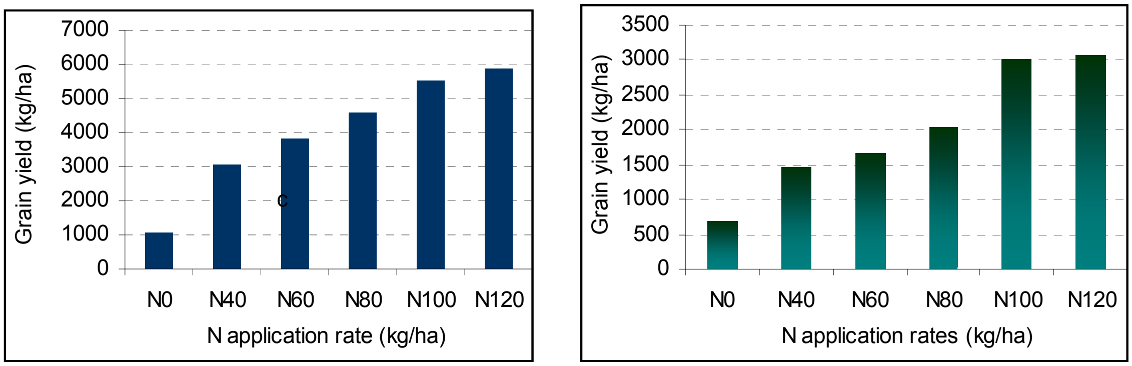
(a) (b)

Fig. 1 Effect of different combination of tillage and crop residue treatments on soil organic carbon under transplanted rice-wheat-fallow and direct seeded rice-wheat-fallow system.

Impact of Tillage in Combination with Crop Residue and N Incorporation on Yield of Rice and Wheat Crops

I) Yield of Rice

The yield of transplanted rice (2001) was higher than the yield of direct seeded rice (Fig. 2). This revealed that the intensive puddling with rotavator decreased Ks (Table 1) and increased water retention of the light sandy loam soil of Kharagpur. Increase in rate of fertilizer N application increased the yield positively but difference in yield at N_{100} and N_{120} was less (Fig. 2b).

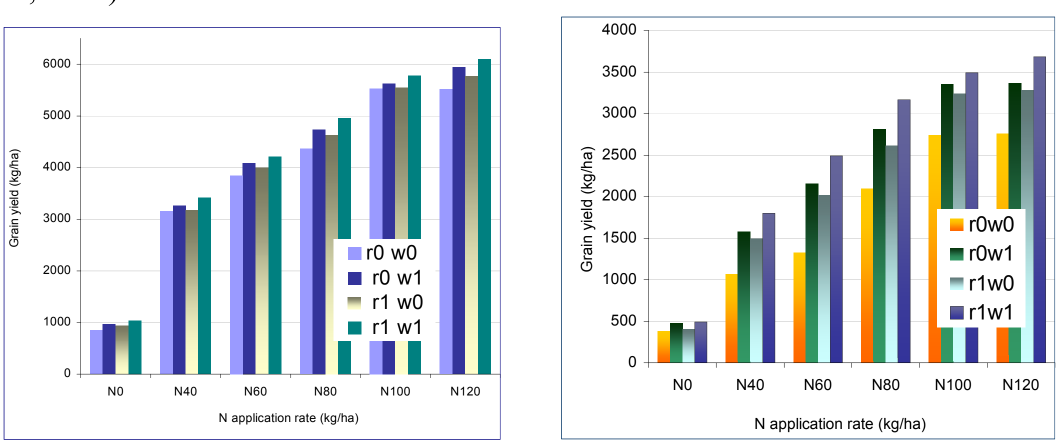


(a) (b)

Fig. 2 Grain yields of transplanted (a) and direct seeded (b) rice (2001) under different N application rates.

In 2002, the effect of tillage was same as in 2001. The yield of both transplanted and direct seeded rice was increased with application of rice and wheat crop residue singly or in combination. The yield was maximum with incorporation of both rice and wheat crop residues. Increase in direct seeded rice yield was noted as much as 34% at N_{120} level of N application. This manifests that a long term application of crop residues may increase the SOC level and help retain water in soil tilled with cultivator followed by disc harrow also.

The grain yields of transplanted and direct seeded rice also increased with increase in rate of fertilizer N application. Increases in N application rate increased SOC in surface layer, which helped retain the mineral N and its release in the later stages to be used by rice plants (Smith and Whitfield, 1990).



(a) (b)

Fig. 3 Grain yields of transplanted (a) and direct seeded (b) rice (2002) under different treatment combinations of crop residues and N application rates.

2) Yield of Wheat

Grain yield of wheat (2001-02) following direct seeded rice was a little higher without any residue and distinctly higher with application of rice residue than wheat following transplanted rice (Fig. 4). Less yield of wheat following TR manifests that the compaction of soil by puddling had malefic effect on wheat growth and yield. Increase in rate of fertilizer N application increased the yield of wheat succeeding both transplanted and direct seeded rice and was noted maximum with application of fertilizer N @120 kg N /ha.

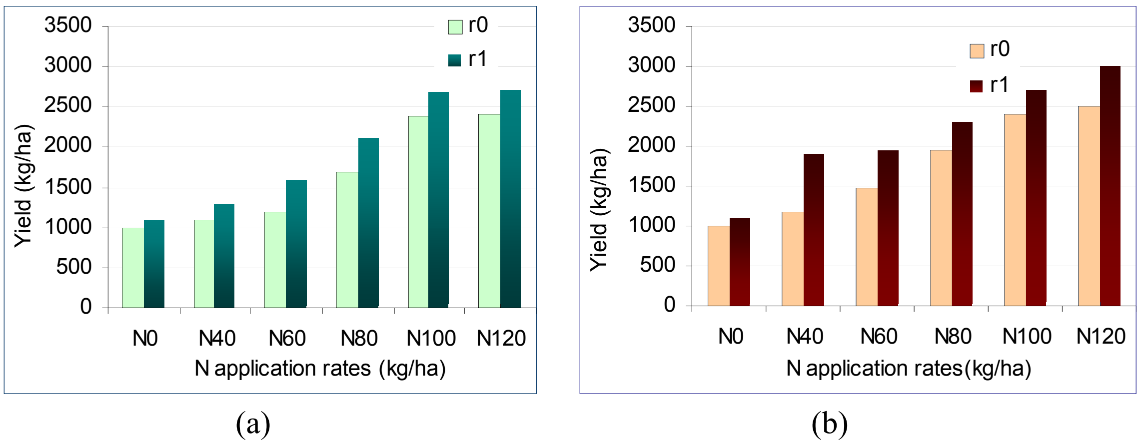


Fig. 4 Grain yields of wheat (2001-02) following transplanted (a) and direct seeded (b) rice under different treatment combinations of crop residues and N application rates.

The difference in yield of wheat (2002-03) succeeding transplanted and direct seeded rice was similar as it found in 2001-02 (Fig. 5). The incorporation of rice and wheat residues singly or in combination increased the wheat yields and it was maximum when both rice and wheat residues were applied.

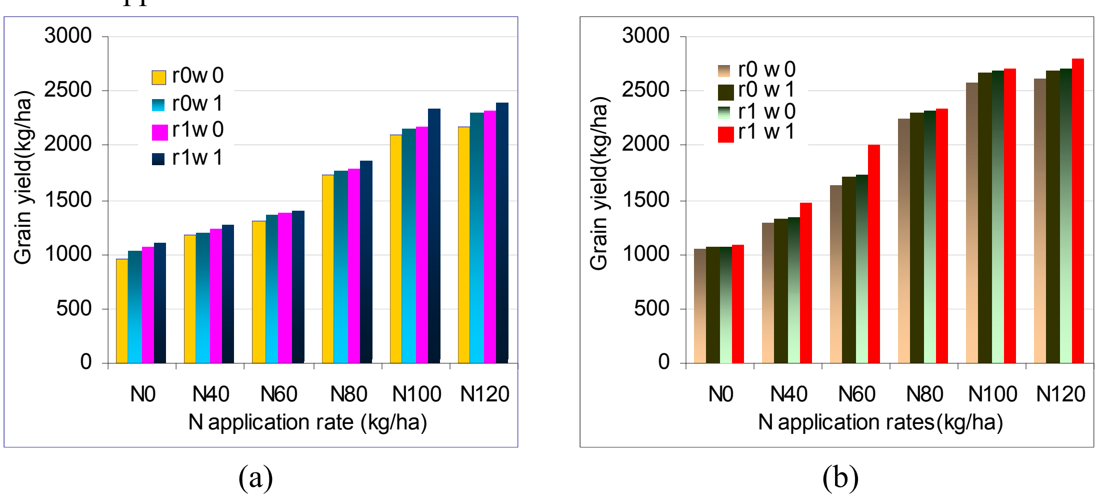


Fig. 5 Grain yields of wheat (2002-03) following transplanted (a) and direct seeded (b) rice under different treatment combinations of crop residues and N application rates.

SUMMARY AND CONCLUSION

Wetland tillage or puddling reduced the yield of wheat following transplanted rice crop. This study revealed that incorporation of crop residues has great potential to improve the status of soil organic matter and increase the yield of rice-wheat cropping system. Crop residue application is also effective in reducing the malefic effect of puddling to wheat succeeding transplanted rice crop. Though the yield of wheat following direct seeded rice crop is higher than the yields of wheat succeeding transplanted rice crop, yield of direct seeded rice is lesser than yield of transplanted rice crop. Application of both rice and wheat crop residues can mitigate the malefic effect of puddling on wheat succeeding transplanted rice crop. The treatment combination comprised of incorporation of rice and wheat crop residues along with application of fertilizer N @120 kg N/ha produced maximum grain yield of rice and wheat crops.

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Table 1 Influence of tillage and crop residue application on soil bulk density and saturated hydraulic conductivity of surface soil (0-15cm).

Tillage treatments	Crop residue treatments	Rice (2002)		Wheat (2002-03)	
		Bulk Density (Mg/m^3)	Saturated Hydraulic Conductivity (cm/day)	Bulk Density (Mg/m^3)	Saturated Hydraulic Conductivity (cm/day)
Puddling + wheat tillage with Cultivator & Disc Harrow	r_0w_0	1.75	7.81	1.67	12.51
	r_0w_1	1.74	7.95	1.66	12.70
	r_1w_0	1.73	8.24	1.65	12.82
	r_1w_1	1.68	8.48	1.65	12.96
Dryland rice tillage + wheat tillage (Cultivator & Disc Harrow)	r_0w_0	1.68	10.35	1.65	12.40
	r_0w_1	1.67	10.64	1.64	12.50
	r_1w_0	1.65	10.85	1.64	12.62
	r_1w_1	1.63	10.92	1.63	12.80

Table 2 Influence of rice and wheat tillage on soil penetration .

	Soil depth (cm)	Soil penetration (kg/sq. cm)
Puddling + wheat tillage with Cultivator & Disc Harrow	2.54	13.55
	7.62	14.46
	12.70	15.14
Dryland rice tillage + wheat tillage (Cultivator & Disc Harrow)	2.54	12.44
	7.62	13.02
	12.70	14.71

EVALUATING INVESTMENT IN PRECISION FARMING TECHNOLOGY

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ABSTRACT

CYMIDA (Cotton Yield Monitor Investment Decision Aid) is a decision aid designed to help cotton farmers analyze the cotton yield monitor information system investment choice. The decision aid utilizes a combination of partial budgeting, breakeven analysis, and sensitivity analysis techniques to evaluate the input cost savings and yield gains required to pay for a cotton yield monitoring information system. Users can evaluate the breakeven yield gains and input savings needed to cover the cost of a yield monitor for 11 potential crop input decisions that might be made using yield monitor information.

INTRODUCTION

Precision farming has the potential to improve profitability by increasing yields and lowering input costs for farmers. These benefits are potentially very important in input-intensive cotton production. A popular entry point for farmers interested in precision farming is the installation of electronic yield monitors on harvesting equipment. Electronic yield monitors provide farmers a way to collect spatial information about crop yields. Spatial yield data that have been referenced to specific locations in a farm field using a Global Positioning System (GPS) can then be converted from raw data into a yield map using Geographic Information System (GIS)-based computer applications. This database of spatial yield variability can be combined with other field information (e.g., grid soil sampling and remote sensing data) to make field maps for variable rate technology (VRT) input decisions and other crop management decisions such as field drainage, landlord rental negotiations, and documentation of environmental compliance.

One of the impediments to the adoption of precision technology by cotton farmers has been the lack of a reliable yield monitoring system. Cotton yield monitors, first introduced in 1997, had poor accuracy and were not reliable. Subsequent cotton yield monitor technology introduced in 2000 appears to be more reliable and may be more readily adopted by farmers. Because cotton yield monitors are a relatively new technology, information about the yield gains and input savings required to pay for a cotton yield monitoring information system would be useful for farmers considering an investment in the technology. The objective of this analysis is to show how the Cotton Yield Monitor Investment Decision Aid (CYMIDA) can be used by farmers to help them decide whether to purchase cotton yield monitors for their farming operations.

MATERIALS AND METHODS

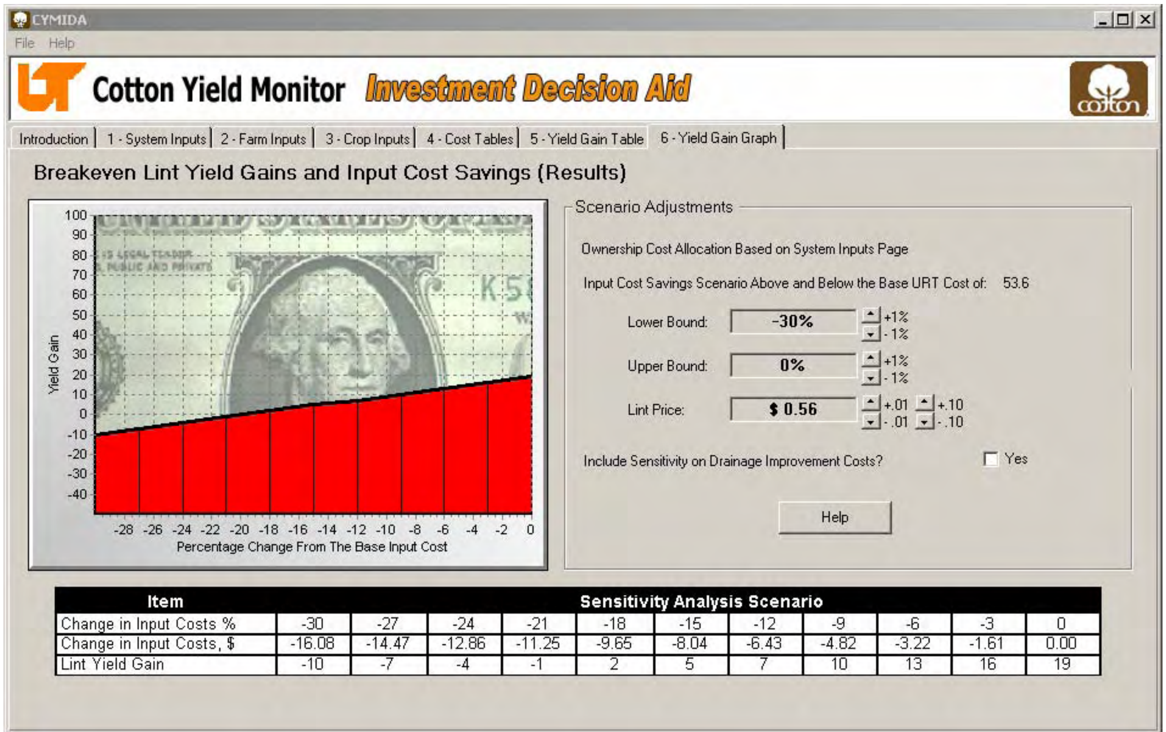
CYMIDA is a computer decision aid designed to guide the user through a systematic analysis of the cotton yield monitor investment decision. CYMIDA is available on-line to be downloaded from the Cotton Incorporated internet site at http://www.cottoninc.com/Agriculture/homepage.cfm?PAGE=3518. The decision aid utilizes a combination of partial budgeting, breakeven analysis, and sensitivity analysis techniques to evaluate the input cost savings and yield gains required to pay for a cotton yield monitoring information system. Users can evaluate the breakeven yield gains and input savings needed to cover the cost of a yield monitor for 11 potential crop input decisions that might be made using yield monitor information. The assumed equipment compliment for a yield monitoring information system includes a general-purpose monitor/controller console, cotton flow sensors on every other chute of a cotton harvester, a digital GPS receiver, a PCMCIA memory card, a desktop computer and color printer, and GIS-based mapping and application recommendation software. These components represent the necessary equipment needed to electronically collect and generate yield maps for management decision-making.

CYMIDA was used to evaluate the breakeven yield gains and inputs savings for a farmer wanting to use VRT to manage seed, nitrogen, and growth regulator inputs in the field. It was assumed that information from the yield monitor would be used to divide cotton fields into low, medium, and high productivity zones for the purpose of managing seed, nitrogen, and growth regulator inputs. Under this system, input usage may be reduced in the low and medium productivity zones because yield potential in these zones may be lower. Breakeven yield gains were calculated for input cost savings ranging from 0% to 30%. Annual ownership costs for the yield monitoring information system were calculated for a farm that has 2,000 acres of cotton and 1,500 acres of other crops. An expected lint price of $0.56/lb was used to calculate the breakeven yield gains

RESULTS AND CONCLUSIONS

For a farm with 2,000 acres of cotton and 1,500 acres of other crops, the annual total ownership cost for the yield monitoring information system is $6,044. This annual ownership cost assumes that cotton yield monitors are retrofitted onto each of the three cotton pickers owned by the farm and only one computer system is required for data management. On a cost per unit of cotton area basis the ownership cost is $3.02/acre if all of the information system costs are allocated to cotton area only. If computer, software, and annual workshop costs are spread over areas of all crops, the annual cost would fall to $2.60 acre^{-1} of cotton area.

Breakeven yield gains to pay for the information system for alternative input cost savings scenarios are presented in Figure 1. If no input cost savings are achieved using the information system to manage inputs, then the required yield gain to pay for the information system is 19 lb/ acre. On the other hand, lint yields can decline by 10 lb/acre and still breakeven with ownership costs if input savings of $16.08/acre (30%) are achieved using the information system. Total cotton production costs decline by $13.48/acre under the 30% input savings scenario. With care in specifying values in the model, users of CYMIDA should be able to evaluate a variety of precision farming "what if" scenarios.



Item	Sensitivity Analysis Scenario										
Change in Input Costs %	-30	-27	-24	-21	-18	-15	-12	-9	-6	-3	0
Change in Input Costs, $	-16.08	-14.47	-12.86	-11.25	-9.65	-8.04	-6.43	-4.82	-3.22	-1.61	0.00
Lint Yield Gain	-10	-7	-4	-1	2	5	7	10	13	16	19

Figure 1. Breakeven Lint Yield Gains and Input Costs Savings in CYMIDA

An Economic Decision Framework for Precision Application of Two Inputs

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Abstract

Substantial literature exists evaluating the profitability of variable rate technology (VRT) relative to uniform rate technology (URT) for the application of a single input. This paper presents a decision-making framework for determining the relative profitability of VRT for multiple inputs and applies that framework to the application of nitrogen and water in cotton fields with three management zones. This decision-making framework can help farmers make decisions about VRT application of inputs in fields with different spatial characteristics.

Introduction

Farmers who practice precision farming use a set of technologies to gather information about the heterogeneous makeup of a farm field and use that information to assess site-specific crop needs within the field. Farmers can then make decisions about using variable rate technology (VRT) for input application. The relative profitability of VRT compared to uniform rate technology (URT) for a particular field depends on the crop, the inputs, their prices, the cost of identifying management zones and yield response functions, and the added cost of using VRT versus URT for each input. In this paper, management zones (zones hereafter) are defined as areas of the field (not necessarily contiguous) that have different yield responses to production inputs. Thus, the relative profitability of VRT versus URT depends on yield response variability and spatial variability within the field. Yield response variability refers to variability in the magnitudes of crop yield responses among zones, while spatial variability refers to the spatial distribution of zones across a field. Substantial literature exists evaluating the profitability of VRT for a single input. Little attention has been given to VRT application of multiple inputs where inputs exhibit interactions in yield response. Our objective is to present a decision-making framework for evaluating the profitability of using VRT to apply multiple inputs in fields with multiple zones.

Materials and Methods

The general decision-making framework is presented first followed by an illustrative example of nitrogen and water applied to cotton fields with three zones. Assume optimal return above input cost per acre for VRT is $R^{*}_{VRT} = \sum \lambda_i [P_c Y_i^{*}(Z^{*}_{i1}, Z^{*}_{i2}, ..., Z^{*}_{in})]$, where λ_i is the proportion of the field in zone i ($\sum \lambda_i = 1$); P_c is the crop price; P_j is the price of input j; Z_{ij}^{*} is the optimal rate of input j in zone i, and $Y_i^{*}(Z_{i1}^{*}, Z_{i2}^{*}, ..., Z_{in}^{*})$ is optimal crop yield in zone i. Further assume that optimal return above input cost using URT is $R^{*}_{URT} = P_c Y_U^{*}(Z^{*}_{U1}, Z^{*}_{U2}, ..., Z^{*}_{Un}) - \sum P_j Z^{*}_{Uj}$, where $Y_U = \sum \lambda_i Y_i(Z_{i1}, Z_{i2}, ..., Z_{in})$ is the weighted-average, whole-field yield response function; Z_{Uj} (j=1,…,n) are uniform input application rates; and an asterisks indicates economic optimality using Y_U as the yield response function. Note that Z_{ij}^{*} is found by simultaneously solving the n first-order conditions for profit maximization using the yield response function for zone i (i=1,…,m), and Z_{Uj}^{*} is found by simultaneously solving the n first-order conditions using the whole-field yield response function. Optimal return to VRT is $RVRT^{*} = R^{*}_{VRT} - R^{*}_{URT}$. VRT is more profitable than URT if $RVRT^{*}–C_1–C_2>0$, where C_1 is the difference in application costs for VRT and URT and C_2 is the cost of gathering spatial information to identify zones and their yield response functions. If the zones and their response functions have already been identified, the profit-maximizing farmer will undertake VRT if $RVRT^{*}>C_1$, because C_2 is a sunk cost in making this decision.

Cotton fields with the following yield response functions in three zones are used as an example:

$$Y_1 = 233.72 + 0.44N_1 - 0.003N_1^2 + 23.65W_1 - 0.18W_1^2 + 0.02N_1W_1,$$
$$Y_2 = -1103.62 + 2.85N_2 - 0.004N_2^2 + 118.35W_2 - 1.63W_2^2 - 0.05N_2W_2,$$
$$Y_3 = -170.93 + 3.74N_3 - 0.01N_3^2 + 32.45W_3 - 0.02W_3^2 + 0.02N_3W_3,$$

where Y_i is cotton yield for zones 1, 2, and 3 (lb/acre); N_i is nitrogen rate for zones 1, 2, and 3 (lb/acre); W_i is irrigation water for zones 1, 2, and 3 (acre-inches); and N_iW_i is the interaction between N_i and W_i. In this example, C_2 is assumed to be known and C_1 is the difference between custom nitrogen application costs for VRT and URT plus the difference between the costs of VRT and URT irrigation. The prices of cotton lint, nitrogen, and water are assumed to be \$0.52/lb, \$0.26/lb, and \$4/acre-inch, respectively. Cost differences between VRT and URT are assumed to be \$3/acre and \$18/acre for nitrogen and water, respectively, giving C_1 = \$21/acre. $RVRT^{*}$ is evaluated for hypothetical cotton fields for all combinations of the $\lambda_i s$ varying between 0.0 and 0.9 in increments of 0.1.

RESULTS AND DISCUSSION

If a field has no area in zone 1, the proportion of the field in zone 2 must be between 2.2% and 86% and the proportion of the field in zone 3 must be between 97.8% (100% – 2.2%) and 14% (100% – 86%) for VRT to at least break even with URT application of the inputs. If a field has no area in zone 1 and 30% of its area in zone 2 (70% = 100% – 30% in zone 3), $RVRT^{*}$ is \$77/acre. Subtracting \$21/acre (C_1) from $RVRT^{*}$ gives a positive net return to VRT of \$56/acre, suggesting that the farmer would be \$56/acre better off using VRT than URT. As the percentage of a field in zone 1 becomes positive, the break-even proportions of the field in the other zones become narrower. For example, if the proportion of a field in zone 1 is 60%, the beak-even proportions in zone 2 are 3% and 37% and for zone 3 they are 37% (100% – 60% – 3%) and 3% (100% – 60% – 37%). Within these ranges of λ_2 and λ_3 (given λ_1 = 0.6), $RVRT^{*} – C_1$ is greater than or equal to zero and the farmer at least breaks even by using VRT instead of URT.

CONCLUSIONS

This paper suggests the potential for developing computerized decision aids to help farmers make choices about using precision farming technologies. One possible decision aid not mentioned above deals with the farmer's decision to gather spatial information about a field when the field's zones and yield response functions have not yet been estimated from spatial information, but educated guesses about them are available from the farmer's, or a consultant's, experience with the field. If C_2 is not known, the farmer can use conservative, educated guesses about the λ s, the corresponding yield response functions, and C_1 to estimate $RVRT^{*}–C_1$, which can be thought of as an education guess about the maximum amount the farmer can invest in gathering spatial information, identifying zones, and estimating yield response functions. If $RVRT^{*}–C_{1} > C_{2}$, the farmer might decide to invest in gathering the spatial information to more accurately delineate the zones and estimate yield response functions. For example, if educated guesses suggest that $RVRT^{*}–C_{1}$ = \$56/acre as in one of the example in the previous section, the farmer would not invest in gathering spatial information to more accurately estimate $RVRT^{*}$ if the cost of doing so (C_2) is greater than \$56/acre. A risk averse farmer might require $RVRT^{*}–C_{1}$ to be substantially greater than C_{2}, because the estimate of $RVRT^{*}$ is uncertain.

The other case, illustrated by the example in this paper, deals with the VRT versus URT decision when the farmer has already delineated the zones and estimated their yield response functions after gathering the required spatial information. The results are still uncertain because spatial information, although better than guessing, is subject to error. Thus, a risk averse farmer might still require $RVRT^{*}–C_{1}$ to be somewhat greater than zero for a particular field before switching from URT to VRT. Results emphasize that definitive, general statements about the profitability of precision farming technologies are not possible because net benefits depend on the spatial characteristics of each field, and spatial information gathering technologies, methods of zone delineation, and yield response function estimation do not provide perfect information.

Spatial Variability of Soil Cone Penetration Resistance as Influenced by Soil Moisture on Pacolet Sandy Loam Soil in the Southeastern United States

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Abstract

Soil hardpans found in many of the Southeastern USA soils reduce crop yields by restricting the root growth. Site-specific soil compaction management to alleviate this problem requires determination of the spatial variability and mapping of soil hardpans. The objective of this study was to determine the spatial variability of soil hardpan as influenced by soil moisture. Geo-referenced soil cone index measurements were taken in 200 grid cells (10 X 10 m^2 grid cell size) on Pacolet sandy loam soil (*Fine, kaolinitic, thermic Typic Kanhapludults*) in Auburn, AL (USA) on June 25, 2004 and August 29, 2004 representing wet and dry soil measurement dates. Core samples were also taken in 5.08 cm depth increments up to a depth of 66.04cm for soil moisture and bulk density determinations. Statistical and geostatistical methods were used for the data analysis. In the 0-30 cm depth, the soil moisture had dried significantly by August 29, 2004 (Dry) as compared to the soil moisture on June 25, 2004 (Wet; $P < 0.0001$). An isotropic spherical semivariogram model best fit the semivariances of the peak cone index for wet ($R^2 = 0.98$) and dry ($R^2 = 0.97$) soil conditions. Soil drying increased the peak cone index and the maximum semivariance value (sill). Small but statistically significant differences ($P < 0.0001$) were also observed on the predicted depth to the peak cone index as the soil dried in the 0-30 cm depth. In the dry soil condition, the semivariances of the predicted depth to the peak cone index were nearly constant over the separation distances suggesting that the depth to the hardpan did not exhibit spatial dependence.

Introduction

Soil compaction has been recognized as one of the major problems in crop production (Soane and Van Ouwerkerk, 1994). Soil hardpan layers found in many Southeastern US soils restrict root growth that in turn limits crop yield, especially during drought (Taylor and Gardner, 1963; and Camp and Lund, 1968). These excessively compacted layers may reduce soil aeration and soil water infiltration that could accelerate erosion and runoff. Farmers annually apply uniform depth tillage to disrupt this root restricting layer for optimum root growth environment (Busscher and Bauer, 2003 and Raper et al., 2004a). Many researchers have found that the soil hardpan layers exhibit spatial variability within a field (Fulton et al., 1996; Kenan et al., 2003; Raper et al., 2004b). Studies have also suggested that site-specific tillage has potential in reducing tillage energy and fuel consumptions as compared to the conventional uniform depth tillage (Fulton et al., 1996; Raper et al., 2000; Gorucu et al., 2002; Raper et al. 2004a). Raper et al. (2000) estimated about 50% reduction in energy requirements for shallow tillage (approximately 18cm) as compared to deep tillage (approximately 33cm). Gorucu et al. (2002) found that approximately 75 % of the test area required tillage operations shallower than the commonly used tillage depth for Coastal plain soils. Site-specific tillage is a component of precision agriculture management strategy that employs detailed site-specific soil and crop information to precisely manage the production inputs (Naiqian et al., 2000). Site-specific tillage in particular is geared towards achieving the goals of sustainable agriculture by determining within field variability and providing more accurate soil compaction records, and optimizing the tillage input within the field where root limiting soil compaction exists. The success of site-specific tillage depends on the availability of economical, rapid, easy and precise soil strength sensing technology, management of within field variability, accuracy of field positioning and controlling the application of real-time or prescribed site-specific tillage.

A soil cone penetrometer has been used widely to asses soil compaction, root penetration resistance; and to predict trafficability and bearing capacity for foundations (Perumpral, 1987 and Raper et al., 2004b). The soil cone penetrometer measures the soil penetration resistance, reported as cone index, as a function of depth (ASAE 1999a; 1999b). The influence of soil factors, mainly soil moisture, on the cone index reading and the difficulty in data interpretation in layered soils varying by soil moisture and soil strength, are the main challenges in using the soil cone penetrometer for site-specific tillage (Gill, 1968; Sanglerat, 1972 and Mulqueen et al., 1977). Gill (1968) and Mulqueen et al. (1977) showed that a soil wedge formed in front of the cone could erroneously increase the soil penetration resistance. In precision tillage, a precise detection of soil hardpan is important because errors of a few centimeters could cause large variations in accurately locating the soil hardpan and site-specific tillage depth recommendations.

Spatial variability analysis of soil compaction and application of site-specific tillage management has not progressed as the precision/site specific application of fertilizers and chemicals due to lack of appropriate technology or procedures to characterize soil physical properties. Hence, a research was needed to accurately characterize the soil hardpan and define its spatial pattern as influenced by soil moisture on landscape level for site specific tillage applications. Analysis of spatial variability and mapping of soil hardpans may further improve our understanding of soil compaction variability and the precision tillage decision making process for Southeastern US soils.

Therefore, our objectives were to:

- determine the effect of soil moisture on the peak cone index and its depth, and to
- determine the field spatial variability and spatial structure of the peak cone index and the depth to the peak cone index as influenced by soil moisture.

MATERIALS AND METHODS

The experiment was conducted during summer 2004 at the Auburn University experimental field plot located in Auburn, AL. Pacolet sandy loam (*Fine, kaolinitic, thermic Typic Kanhapludults*) is the dominant soil series in the experimental site. The field was divided into 200 grid cells each with a 10 X 10 m^2 covering an area of 2 ha. Because the objective of the experiment was to determine the spatial variability of soil hardpan, sampling patterns associated with crop management and trafficking were not considered. In the north and east directions of the field, a 10 meter transect distance was used for cone index sampling. A tractor mounted multiple-probe soil cone penetrometer (MPSCP) that has five probes was used to acquire cone index data at 25 Hz sampling rate (ASAE, 1999 a, b and Raper et al., 1999). Two sets of cone index measurements were obtained in each of the grid cells using the tractor mounted MPSCP equipped with GPS for field positioning. A Trimble ® 4600 L.S. Surveyor Total Station with DGPS was also used to obtain elevation data across the field. Soil core samples for soil moisture and bulk density determinations were also collected at every 5.08 cm depth increments to a depth of 66.04 cm in two replicates at 54 randomly selected grid cells near where the cone indices were sampled. The soil core samples were oven dried at 105 ^{0} C for 72 hrs to determine gravimetric soil moisture and bulk density. The cone index measurement and the soil core sampling were carried out simultaneously within an approximate 24- hrs period. With in this sampling period there were no rainfall events that minimized the risk of soil moisture differences. The measurements were obtained on June 25, 2004 and August 29, 2004 representing ‘wet’ and ‘dry’ soil moisture conditions, respectively. The sampling dates were chosen based on climatic data obtained for the Auburn University weather experimental station located near the field site.

Peak cone index and depth to the peak cone index were considered as soil hardpan characterizing attributes that were predicted by analyzing the change of cone index values with depth. The analyses were carried out on the cone index data averaged over the five probe data set interpolated at every 1 cm depth increments. Visual inspection on the 200 cone index-depth profile data revealed there were two peaks. The first peak cone index that occurred in depth range of 0 – 30 cm was considered as the root restricting layer in the soil profile. A maximum value of the cone index-depth profile within this depth range (0-30 cm) was determined for the peak cone index. In developing, the algorithm to define the peak cone index in the shallow depth (30 cm), instantaneous slope values (change in cone index per depth) were calculated and the values were tested in the following priorities, (1). If three consecutive negative slope values were obtained, the cone index and depth value at the first slope value were considered as peak cone index and its depth; (2). If the first test fails, two negative slopes were considered in deciding the peak cone index with the data values of the first negative value being used to define the hardpan; and (3) If the second test fails, three consecutive zero slope values were considered. These zero slope values indicated that the cone index increased till it reached the root restricting peak cone index value and the cone index depth profile curve flattened with depth. The data set at the first zero slope value characterized peak cone index and depth to peak cone index.

Geo-statistical procedures PROC VARIOGRAM and PROC NLIN (SAS. Release 8.02 SAS Institute Inc., Cary, NC, 2001) were used to quantify the isotropic spatial variability and to construct theoretical variogram models for the soil hardpan attributes, and maximum bulk density and its depth. Spherical, exponential and linear variogram models were considered in selecting the best fitting model based on the values of weighted residual sums of squares, regression coefficient (R^2) and relative spatial structure indicator (Scale/Sill). Scale is the amount of semivariance after the nugget is reduced (Sill-Nugget). A model with the largest R^2 value, the smallest weighted residual sums of squares at the end of iteration procedure and a value of the spatial structure indicator close to 1.0 was considered the best fitting semivariogram model. A scale to sill ratio close to 1 indicates the nugget effect is negligible implying a better spatial structure (Raper et al., 2004). After selecting the best theoretical semivariogram model, point kriging was used to interpolate values for un-sampled locations. Contour maps were created using Surfer (Surfer version 8.00 Golden Software Inc., 2002). All statistical comparisions were made using PROCGLM procedure (an alpha (α) level of 0.05) in SAS.

RESULTS AND DISCUSSION

Soil Moisture

The soil moisture distribution varied by depth (Fig.2; $P < 0.0001$). At the soil depth range of 0-30 cm depth, the soil moisture sampled on June 25, 2004 (11.97 %) was significantly higher than the soil moisture (10.09 %) sampled on August 29, 2004 ($P < 0.0001$). For convenience, the soil moisture conditions were assumed ‘wet’ and ‘dry’ for the measurement dates of June, 25

2004 and August 29, 2004, respectively. At the deeper profile (30 – 66 cm), the soil moisture trend was reversed (Fig. 2). The soil moisture (17.10 %) for the second measurement date (August 29, 2004) was significantly higher than the soil moisture (15.23%) for the first measurement date (June 25, 2004) (Table 1 and P < 0.0001). This may indicate a wetting front moving downward through the soil profile. The skewness value (Table 1) and frequency distribution (not shown) showed that the soil moisture variability for the shallow depth appeared to be skewed to the left and the skewness was higher in the dry soil than in the wet soil. At the deeper soil depth, the skewness and coefficient of variation values (Table 1) were relatively small indicating the subsoil soil moisture distribution tends to be symmetrically distributed around the mean.

Table 1. Descriptive statistics of soil moisture for the depths of 0-30 cm and 30 – 66 cm at the two measurement dates.

	Depth -cm-	Number of values	Mean	Median	Standard deviation	Coefficient of variation	Variance	Minimum	Maximum	95% Confidence interval	Kurtosis	Skewness
June 25,2004	0-30	378	11.97	10.94	3.82	0.34	16.56	5.05	5.86	11.60-12.38	2.34	1.49
	30-66	324	15.23	15.11	4.89	0.3	22	6.72	28	14.88-15.90	-1.06	0.19
August,29 2004	0-30	378	10.09	9.03	4.21	0.41	17.73	4.21	8.69	9.67-10.52	2.63	1.66
	30-66	324	17.1	16.96	4.89	0.29	23.88	7.45	28	16.57-17.63	-0.99	0.11

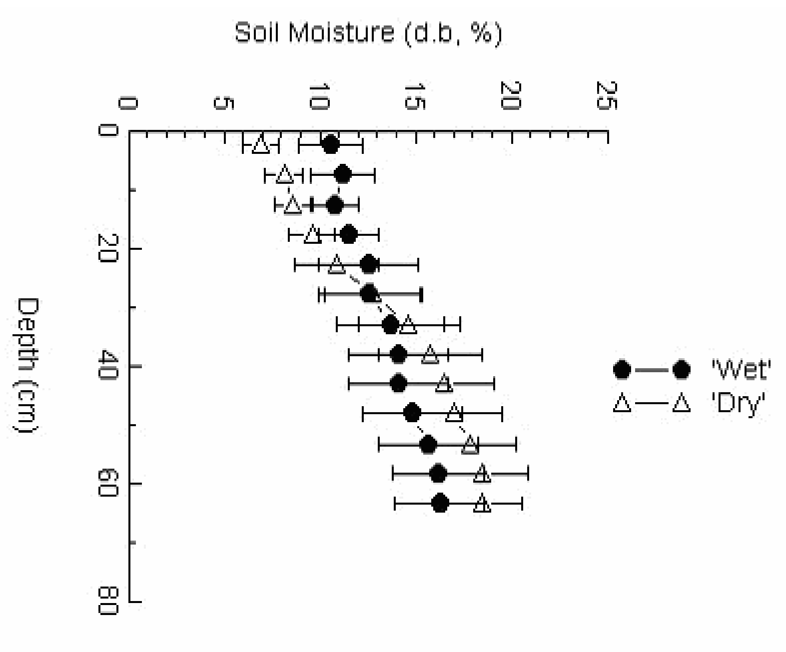


Fig. 2. Soil moisture profile for the two measurement dates of June 25, 2004 (‘Wet’) and August 29, 2004 (‘Dry’). The horizontal bars indicate standard deviations.

Bulk Density

The average bulk density profile for the field is shown in fig. 3. The bulk density varied by depth significantly (P < 0.0001). There were not statistically significant differences in the bulk density values by measurement dates ($P < 0.0001$). The skewness (-0.49) and coefficient of variation (0.1) showed that the distribution of bulk density was nearly symmetrical around the mean.

Table 2. Descriptive statistics for the maximum bulk density and the depth to the maximum bulk density.

	Number of values	Mean	Median	Standard deviation	Coefficient of variation	Variance	Minimum	Maximum	95% Confidence interval	Kurtosis	Skewness
Maximum bulk density (Mgm^{-3})	53	1.54	1.54	0.06	0.04	0.004	1.43	1.65	1.52-1.55	-1	0.05
Depth to the maximum bulk density (cm)	53	20.94	22.86	5.66	0.27	31.99	12.7	27.94	19.38-22.50	-1.36	-0.06

As shown in fig. 4 (A), the variability of the maximum bulk density showed spatial dependence that was best fit by the exponential semivariogram model ($R^2 = 0.96$ and a spatial structure indicator of 0.3). A linear semivariogram model best fit the semivariances of the predicted depth to the maximum bulk density with a sill value (14.3) nearly half of the sample variance (31.99) (Fig. 4, B). The semivariances appeared to be nearly constant over the entire separation distances indicating that the variability of the depth to the maximum bulk density was spatially independent. Contour map of the depth to the maximum bulk density showed that the predicted soil hardpan depth seems to vary across the field (Fig. 5).

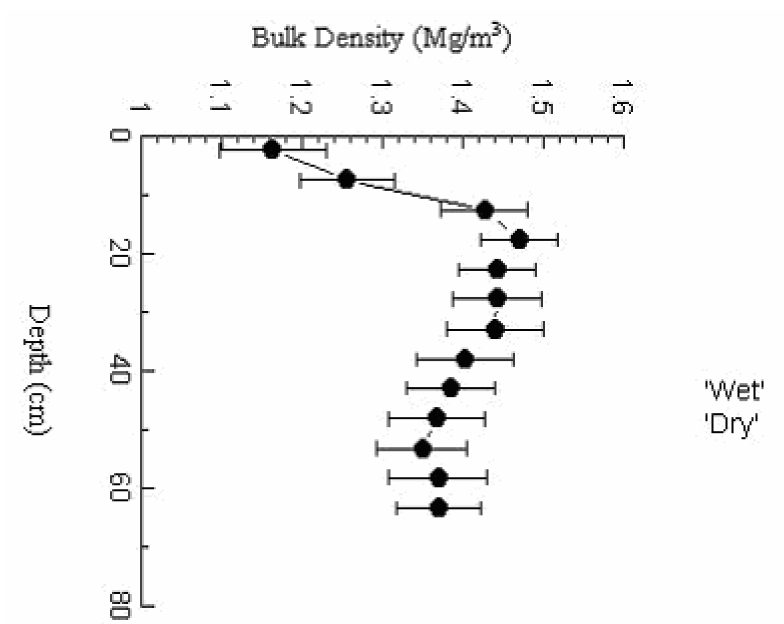


Fig. 3. Bulk density profile averaged over the two measurement dates of June, 25 2004 and August, 29 2004. The horizontal bars indicate standard deviations.

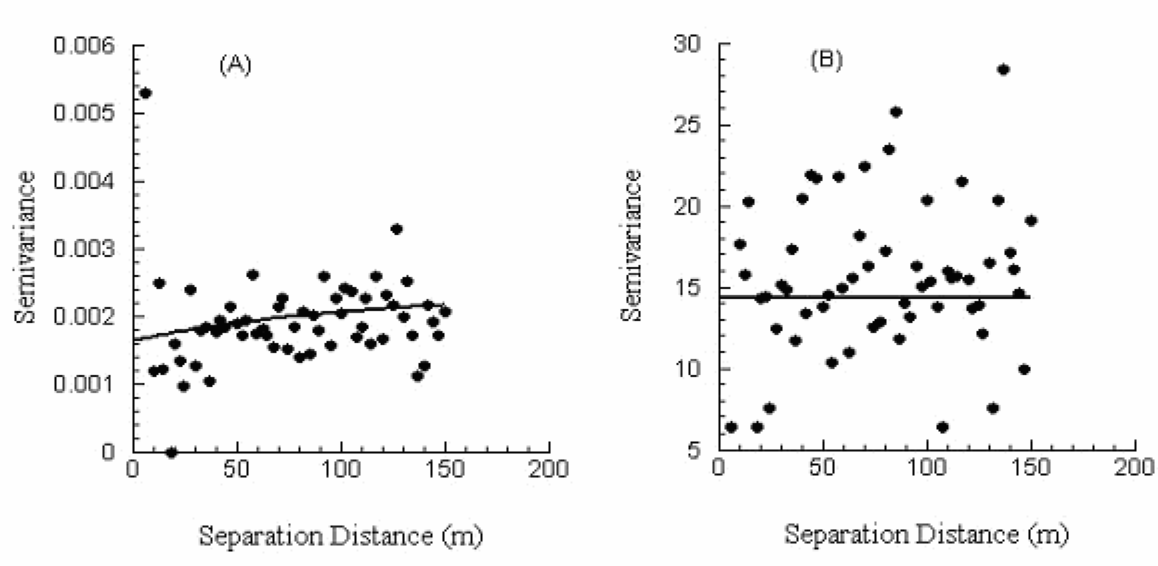


Fig.4. Semivariances (A) for the maximum bulk density with theoretical exponential semivariogram model fit and (B) depth to the maximum bulk density with theoretical linear semivariogram model fit.

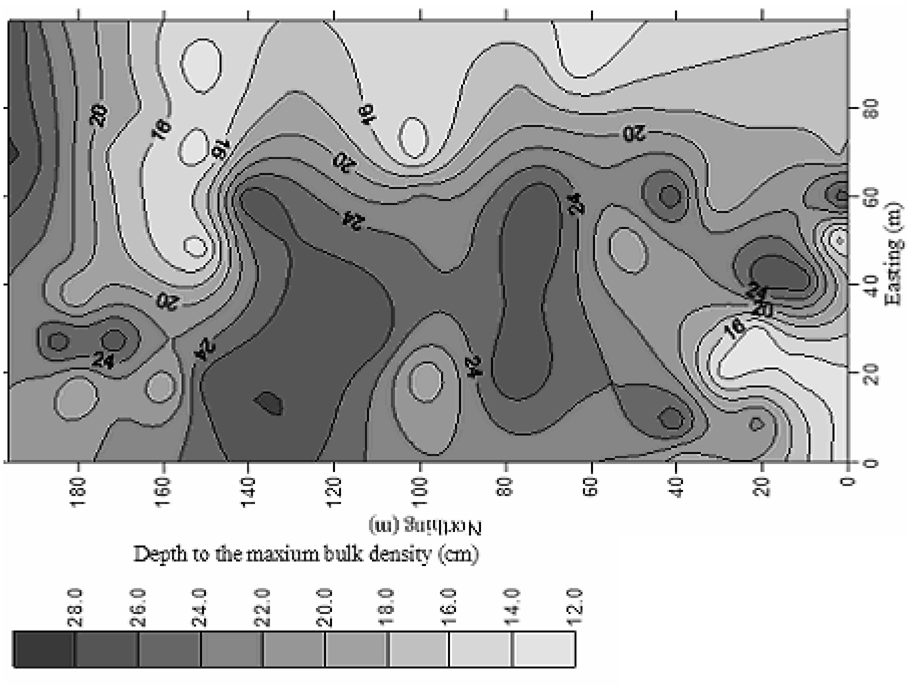


Fig. 5. Contour map of the depth to the maximum bulk density on Pacolet sandy loam soil.

Peak Cone Index and Depth to the Peak Cone Index

The average peak cone index was significantly higher for the dry soil condition than the value for the wet soil condition (Table 3 and $P < 0.0001$). By taking cone index measurements at the drier soil condition (August 29, 2004), the peak cone index increased by 28 %. As shown in fig. 6 (A), the relative frequency distribution of the peak cone index for the dry soil condition appeared to shift to the right as compared to the wet soil condition. For the dry soil condition, the relative frequency distribution of the depth to the peak cone index (Fig. 6 B) indicated a slight shift to the left (small depth values). Even though the difference in the depths appeared to be small, there was strong statistical evidence that the predicted depth to the peak cone index decreased by soil drying (Table 3 and P < 0.0001). The predicted depth occurred within the shallow depth range (0-30cm) where the soil moisture significantly decreased by sampling date.

Table 3. Descriptive statistics of the peak cone index and the depth to the peak cone index for the two measurement dates of June 25, 2004 and August 29, 2004.

		Number of values	Mean	Median	Standard deviation	Coefficient of variation	Variance	Minimum	Maximum	95% Confidence interval	Kurtosis	Skewness
June 25, 2004	Peak cone index (MPa)	198	3.29	3.2	0.88	0.27	0.78	1.23	5.86	3.23-3.36	0.11	0.42
	Depth to the peak cone index (cm)	198	21.08	21	3.36	0.16	11.29	13.5	28	20.84-21.31	-0.7	0.14
August 29, 2004	Peak cone index (MPa)	200	4.12	3.99	1.36	0.33	1.84	1.68	8.69	4.03-4.23	0.81	0.78
	Depth to the peak cone index (cm)	200	20.08	20	3.56	0.18	12.65	10	28	19.83-20.33	-0.04	-0.06

Tekeste et al. (2004) reported similar influences of soil drying on the peak cone index and the predicted depth of soil hardpan on Norfolk sandy loam soil. Comparing the soil hardpan depth prediction using the cone index and maximum bulk density method, the depths predicted at the wet and dry soil conditions from cone index data lies within the 95 % confidence interval of the depth to the maximum bulk density (Table 3).

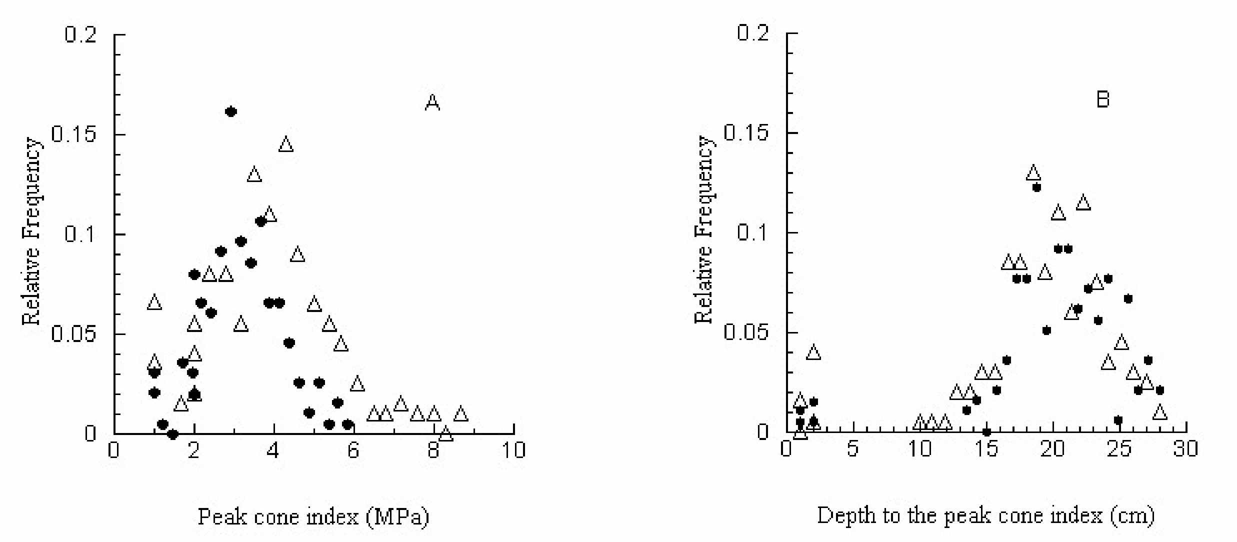


Fig. 6. Relative frequency distribution of (A) the peak cone index (MPa) and (B) the depth to the peak cone index for the two measurement dates of June 25, 2004 ('Triangle') and August 29, 2004 ('Circle').

Spatial Variability Analysis

Selection of sampling distance intervals is important in ensuring the quality of spatial variability analysis and interpolation of points for un-sampled locations using geostatistical techniques (Donald and Ole, 2003). A sampling interval distance less than a range, a distance over which pairs of observations exhibit spatial dependence, was considered appropriate in grid sampling. The ten-meter transect distance used in the cone index sampling was less than a range that Raper et al. (2004b) estimated for the depth of the soil hardpan on silty upland soils of Northern Mississippi.

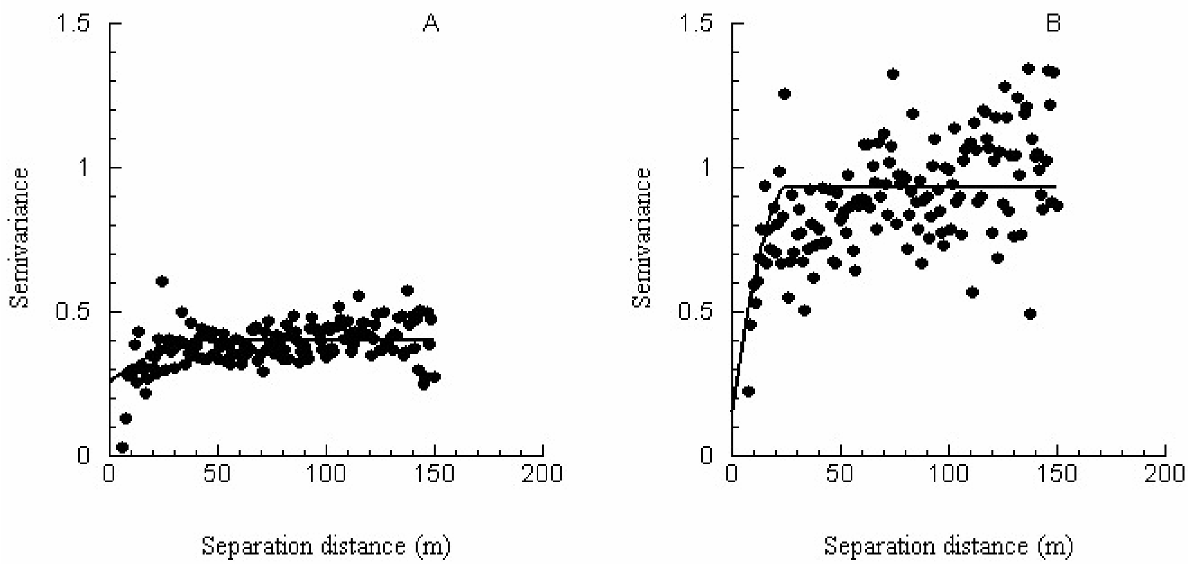
Table 4. Descriptive semivariogram statistics for the peak cone index and the depth to the peak cone index for the two measurement dates of June 25, 2004 and August 29, 2004.

		Model	Nugget u	Sill	Range	Regression coefficient	(Sill-Nugget)/Sill	WSS v
				--MPa^2--	--m--			
June	Peak cone index (Mpa)	Spherical	0.26	0.4	44	0.98	0.36	322
25, 2004	Depth to the peak cone index (cm)	Exponential	0.00	5.73	47	0.99	1.00	259
August	Peak cone index (Mpa)	Spherical	0.15	0.93	26	0.97	0.84	505
29, 2004	Depth to the peak cone index (cm)	Linear	5.80			0.98	0.15	151

u Nugget units are MPa^2 for the peak cone index and cm^2 for the depth to the peak cone index.
v WSS= Weighted Residual Sums of Squares

The spherical semivariogram was the best fitting model to the estimated semivariances of the peak cone index for both the wet and dry soil conditions (Table 4 and Fig.7). The sill for the dry soil condition was nearly twice the value for the wet soil condition. At a distance greater than the range, the square of the differences between pairs of peak cone index values would be approximately the same as the sample variance (twice the sill). Isaaks and Srivastava (1989) explained that increasing the sill has less effect on the value of kriging estimates for the sample site. The range for the dry soil condition (26 m) was smaller than for the wet soil (44 m). Smaller range value indicates that soil drying reduced the distance over which pairs of peak cone index values remain spatially dependant. At the dry soil condition, the spatial continuity of the magnitude of soil hardpan on Pacolet sandy loam could be captured by having sampling distances less than 26 m that may improve the efficiency of future cone index sampling procedure. The maps for the peak cone index of the field (not showen) indicate that the values exceeded the critical root limiting cone index value of 2 MPa (Taylor and Gardner, 1963) in most parts of the field with the values being higher for the dry soil condition.

Fig. 7. Semivariances for the peak cone index and spherical theoretical model fits for the two measurement dates of June 25, 2004 (A) and August 29, 2004 (B).



Similar to the peak cone index spatial variability, soil moisture variation also affected the estimated semivariances and the semivariogram models for the depth to the peak cone index (Table 4 and Fig. 8). Exponential semivariogram model explained the spatial variability of the depth to the peak cone index with a scale to sill ratio of 1 that indicates a well defined spatial structure. For the dry soil condition, the semivariances appeared to be spatially uncorrelated that the values were nearly similar over the separation distances (Fig. 8 B). The contour maps in fig. 9 (A and B) show that the predicted depths to the peak cone index appeared to be shallow for the dry condition in most parts of the field.

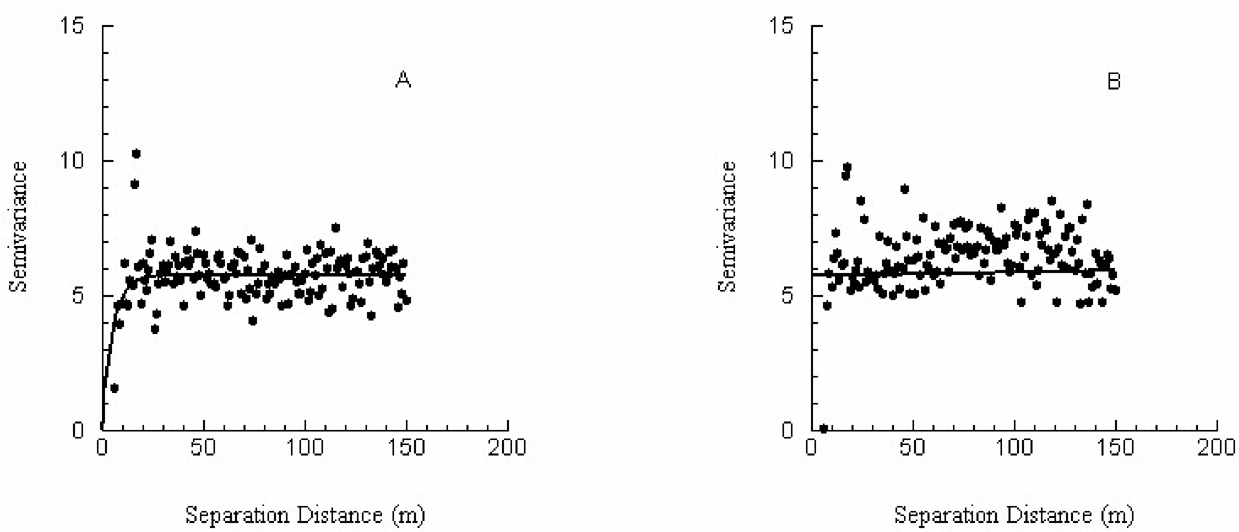


Fig. 8. Semivariances for the depth to the peak cone index and exponential theoretical model fit and linear theoretical model fit for the measurement dates of June 25, 2004 (A) and August 29, 2004 (B), respectively.

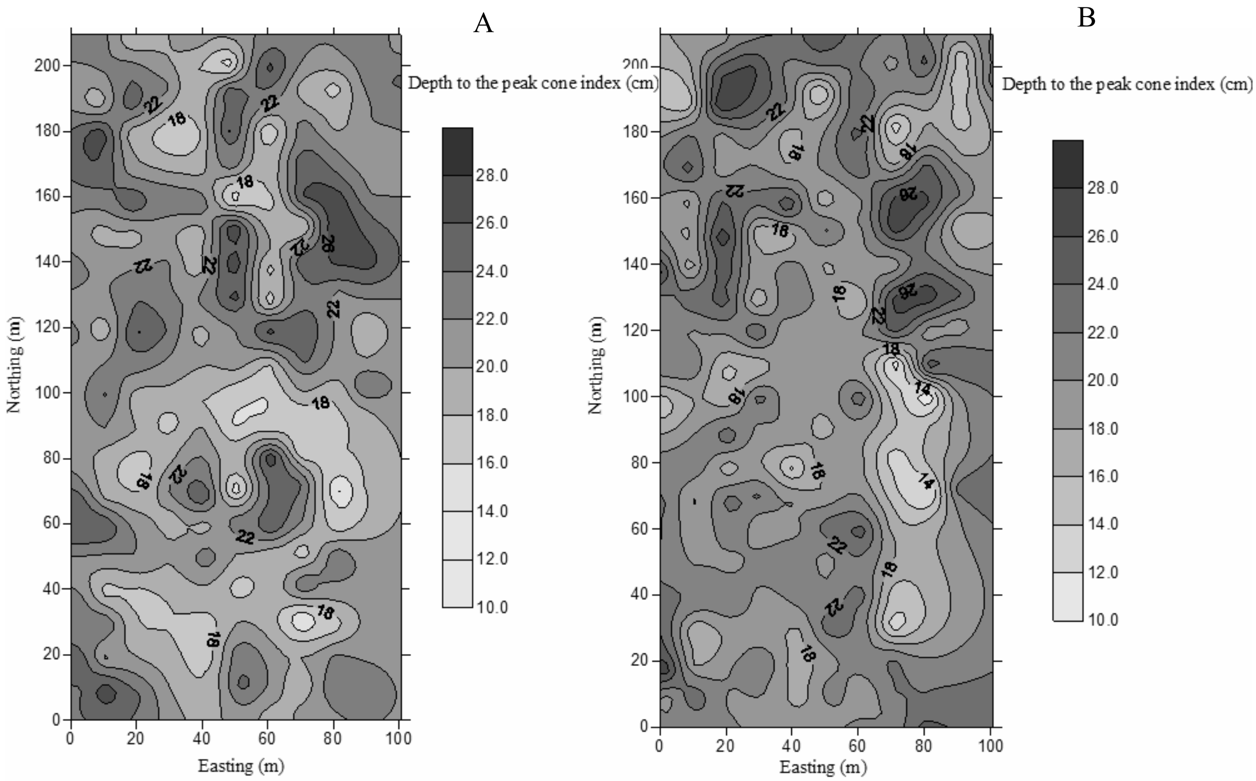


Fig. 9. Contour map of the depth to the peak cone index on Pacolet sandy loam soil for the two measurement dates of June 25, 2004 (A) and August 29, 2004 (B), respectively.

CONCLUSIONS

Soil drying increased the magnitude and spatial variability of the peak cone index on Pacolet sandy loam soil. The spatial pattern of the peak cone index was explained by spherical semivariogram model for wet and dry soil conditions. An exponential semivariogram model best fit the spatial variability of the depth to the peak cone index on the wet soil condition; however, in the dry soil condition the variability in the predicted depth to the peak cone index was nearly constant over the separation distances. The results suggested that soil moisture variations not only affected the values of the soil hardpan attributes (peak cone index and depth to the peak cone index) but also their estimated spatial structures which in turn may affect the prediction and soil sampling procedure.

Generally the distribution pattern of the soil hardpan depths across the field seems similar as predicted by the depth to the maximum bulk density or the depth to the peak cone index values. Maps of peak cone index values indicate that most part of the field requires deep tillage. The depths of tillage, however, need to vary according to the predicted soil hardpan depths. This indicates that applications of depth-specific tillage on Pacolet sandy loam soils may improve the sustainability of crop management.

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ENERGY SAVINGS WITH VARIABLE-DEPTH TILLAGE

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ABSTRACT

Soil compaction management in the southeastern Coastal Plain soils relies heavily on the use of costly annual deep tillage operations. Variable-depth or site-specific tillage which modifies the physical properties of soil only where the tillage is needed for crop growth, has potential to reduce costs, labor, fuel, and energy requirements. Although technology for site-specific tillage is available, there is very limited information on the fuel and energy requirements of site-specific tillage in southeastern coastal plain soils. Tests were carried out on three different coastal plain soils to compare energy requirement of site-specific tillage with uniform-depth tillage operations. Also, the effects of tractor speed, soil texture, moisture contents, and electrical conductivity on energy requirement and fuel consumption were determined. The energy saving of 50% and fuel saving of 30% were achieved by site-specific tillage as compared to uniform-depth tillage in a loamy sand soil type. Although draft force increased with an increase in travel speed in all soil types, the tillage depth had more effect on the draft and drawbar power than the tractor speed. The effect of soil moisture content on draft force and fuel consumption was not significant in loamy sand and sandy loam soil types. Soil EC was highly correlated to soil texture (R^2=0.916) and draft force across the field.

INTRODUCTION

Soil Compaction is an important problem in the Coastal Plain region. It restricts the root growth into deeper soil layers that are rich in terms of soil moisture and nutrients. Most soils of the southeastern Coastal Plain have a compacted zone or hardpan about 6 to 14 in deep and 2 to 6 in thick. Farmers in this region rely heavily on the use of annual uniform-depth deep tillage to manage soil compaction which improves yields (Garner *et al*., 1989; Khalilian *et al*., 2004). However, farmers usually do not know if annual subsoiling is required, where it is required in a field, nor the required depth of subsoiling. In addition, there is a great amount of variability in depth and thickness of hardpan layers from field to field and also within the field (Raper *et al*., 2000a & 2000b; Clark, 1999; and Gorucu *et al*. 2001). There is very little to gain from tilling deeper than the compacted layer and in some cases it may be detrimental to till into the deep clay layer (Garner *et al*., 1989). Applying uniform-depth tillage over the entire field may be either too shallow or too deep and can be costly.

A high-energy input is required to disrupt hardpan layer to promote improved root development and increased drought tolerance. Significant savings in tillage energy could be achieved by site-specific management of soil compaction. Site-specific variable-depth tillage system can be defined as any tillage system which modifies the physical properties of soil only where the tillage is needed for crop growth objectives. Raper (1999) estimated that the energy cost of subsoiling can be decreased by as much as 34% with site-specific tillage as compared to the uniform-depth tillage technique currently employed by farmers. Also, Fulton *et al.* (1996) reported a 50% reduction in fuel consumption by site-specific or precision deep tillage.

Tillage implement energy is directly related to working depth, tool geometry, travel speed, width of the implement, and soil properties (Gill and Vanden Berg, 1968; Palmer and Kruger, 1982).Soil properties that contribute to tillage energy are moisture content, bulk density, cone index, and soil texture (Upadhyaya *et al*., 1984). It has been reported that draft on tillage tools increases significantly with speed and the relationship varies from linear to quadratic. Similarly, effect of depth on draft, also varies linearly (Al- Janobi and Al-Suhaibani, 1998).

The technology for site-specific tillage (variable depth tillage) is available (Khalilian *et al.*, 2002) and the concept of site-specific tillage has been studied by some researchers (Raper, 1999 and Gorucu et al., 2001). However, this is an emerging technology and therefore minimal information is available on draft and energy requirements of variable-depth tillage, an important consideration in selecting tillage systems. Furthermore, there is a need to determine the effects of tractor speed and soil parameters such as texture, moisture, and electrical conductivity on energy requirements of site-specific and conventional uniform-depth tillage operations in coastal plain soils. The development of this information is the prime concern for an economical management of soil compaction and adoption of this technology by southeastern farmers.

The objectives of this study were:

1- To compare the energy requirement and fuel consumption between site-specific tillage and uniform-depth tillage on three different coastal plain soils.

2- To determine the effects of tractor speed and soil parameters such as texture, moisture, and electrical conductivity on tillage energy requirements and tractor fuel consumption.

MATERIALS AND METHODS

Equipment

A commercially available soil electrical conductivity meter, Veris Technologies 3100, was used to map the electrical conductivity (EC) of the test field (Lund et al., 1999). The system is equipped with six coulter-electrodes. One pair of electrodes applies a current into the soil, while others measure the voltage drop between the coulters. The system can measure the EC in either the top 12 or 36 in of soil.

A DGPS-based penetrometer system mounted on a John Deere Gator was used to quantify geo-referenced soil resistance to penetration (Khalilian *et al*., 2002). The driver of the Gator could operate the penetrometer (Figure 1). Soil cone index values were calculated from the measured force required pushing a 0.2-in.^{2} base area, 30-degree cone into the soil (ASAE Standards, 2004).

A front-wheel-assist, 105 HP instrumented tractor (John Deere 4050) was used to collect the energy consumption data during the tillage operations. The instrumentation system consisted of a three-point-hitch dynamometer, a fuel flow meter, engine speed (RPM) sensor, several ground speed sensors (fifth wheel, radar, and ultrasonic), Differential Geographical Positioning

System (DGPS) unit, a data logger, and an optical sensor determining the start and end of each plot (Gorucu *et al*., 2001).

Figure 1. Hydraulically operated penetrometer system with DGPS unit.

DGPS-based equipment for controlling the tillage depth to match soil physical parameters was used in this experiment (Figure 2). This equipment can control the tillage depth "on-the go" using either a soil compaction map, inputs from an instrumented shank, or entering the tillage depth data manually in the computer (Khalilian *et al*., 2002). The two out-side shanks of a 4-row subsoiler were removed for the tillage energy requirement study.

Figure 2. The control system for variable-depth tillage operations.

Field test

Field experiments were carried out, on coastal plain soils, in the fall of 2004 at the Edisto Research and Education Center of Clemson University near Blackville, South Carolina (Latitude

33˚ 21″N, Longitude 81˚ 18″W). The 6-acre test field had three different soil types: Faceville loamy sand, Fuquay sandy loam, and Lakeland sand.

Prior to initiation of tests, EC measurements were obtained with the Veris unit to determine variations in soil texture and soil physical properties across the field. A geo-referenced EC map was developed using SSToolbox GIS software. The results showed a great amount of variability in soil EC and the field was found to be an ideal site for variable-depth tillage study. The test field was then divided into 12.5 ft × 50 ft rectangular plots and soil samples were collected from each plot and analyzed for soil texture. Figure 3 shows soil electrical conductivity map, soil types, and plot arrangements over the entire field.

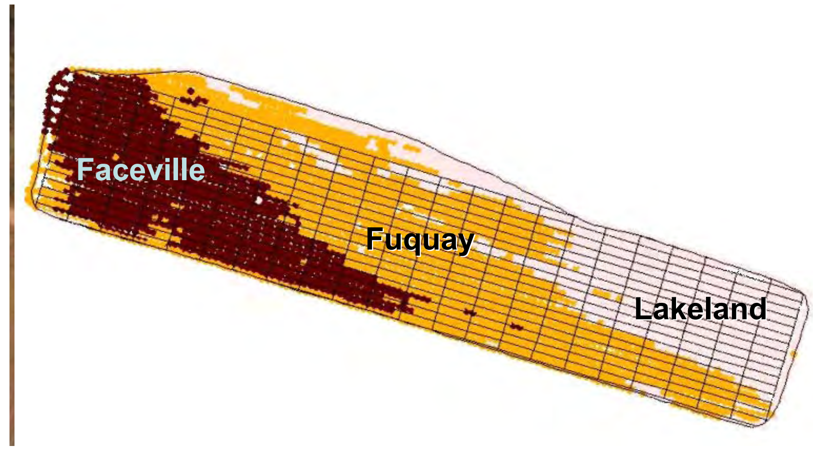

Figure3. Aerial photograph and soil electrical conductivity map of the experimental field.

A complete set of cone penetrometer measurements were obtained with the DGPS-based penetrometer system across the entire field. Nine geo-referenced penetrometer measurements, 5 ft apart, were taken from each plot. The depth and thickness of the hardpan were determined from the collected data using the criteria defined by Taylor and Gardener (1963). Within each plot, it was decided to set the tillage depth that would rupture compacted layers of the soil with cone index values above 300 psi.

Tillage experiments consisted of twelve treatments arranged in randomized complete blocks with three replications in each soil type. The treatments included two tillage systems (site-specific and uniform-depth), three levels of tractor speed (4, 5, and 6 mile/h), and two levels of soil moisture contents.

RESULTS AND DISCUSSION

The penetrometer data in each location was analyzed using an algorithm written in QBASIC program (Gorucu *et al*., 2001) for determining the tillage depth. A single depth-value was assigned to each plot by averaging the nine predicted-tillage-depth values within that particular plot. Using these data three tillage zones were identified in each soil type. In each zone, the two tillage treatments (uniform-depth and site-specific) were replicated 3 times.

The uniform-depth tillage was performed 18 in deep to completely disrupt the root-impeding layer. The site-specific tillage was applied according to the application maps generated from soil compaction data. The predicted tillage depth in Faceville soil type ranged from 8 to 14 in. In both Fuquay and Lakeland soil types, the tillage depth varied from 11 in to 18 in

Statistical analysis of energy requirement by using Proc ANOVA in SAS software (SAS Institute, 1999) clearly showed significant difference between tillage treatments in every soil types (P<0.01). Also fuel consumption was significantly different in Faceville soil (P<0.01) and also in the other two soil types (P<0.05) between site-specific and uniform-depth tillage.

Comparison of tillage energy and fuel consumption for both tillage systems in Faceville soil type showed that energy saving of 50% and fuel saving of 30% could be achieved by using site-specific tillage system. Also energy and fuel savings were 21% and 8% for Fuquay and 26.1% and 8.5% for Lakeland soil types, respectively. Figure 4 shows the energy requirements and fuel consumption for both tillage systems in each soil type.

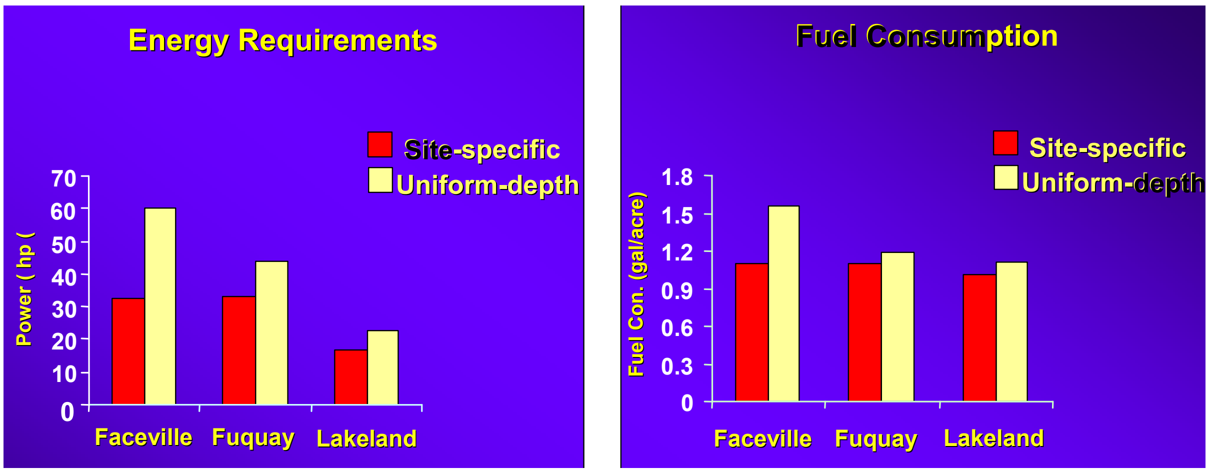

Figure 4. Energy requirements and fuel consumption for site-specific and uniform-depth tillage.

Although not statistically different, the draft force increased with an increase in tractor speed in all soil types. Also the results showed a strong correlation between the tractor speed and fuel consumption (gal/acre) in each soil types. This is due to increase in draft force and consequently increase in drawbar power. However, the tillage depth had more effect on the draft and drawbar power than the tractor speed.

The effect of moisture content on draft force and fuel consumption was not significant at loamy sand (Faceville) and sandy loam (Fuquay) soil types. However, an increase in soil moisture content resulted in a decrease in draft forces and fuel consumptions. In sandy soil type (Lakeland), draft forces and fuel consumptions decreased significantly when soil moisture content increased. This could be due to significant changes in cone index values, since only in this soil type cone index values were significantly affected by soil moisture contents compared to other soil types.

Results showed that use of soil electrical conductivity (soil EC) to predict soil texture and tillage draft requirement was very successful. There was strong linear correlation between soil EC and both soil texture, and tillage draft requirement at a given depth and speed. This indicates that draft requirement strongly vary with soil texture and depends on clay and sand contents of soil. Also for practical applications, EC data can be used to predict areas of the field with high or low tillage draft requirements. The Veris system provided reading from 0.1 to 7.0 mS/m, predicting percentage of clay across the field with a linear correlation coefficient of 0.912 and percentage of sand with a correlation coefficient of 0.916. Figure 5 shows the effects of soil texture (%clay) on soil electrical conductivity. A portion of the draft-requirement data with the same tillage depth (18 in) was selected to investigate the correlation between draft and soil EC.

There was a very strong correlation between EC data and tillage draft force at a given speed. Figure 6 shows the effects of EC data on draft force at three different speeds that have been obtained within three different soil types.

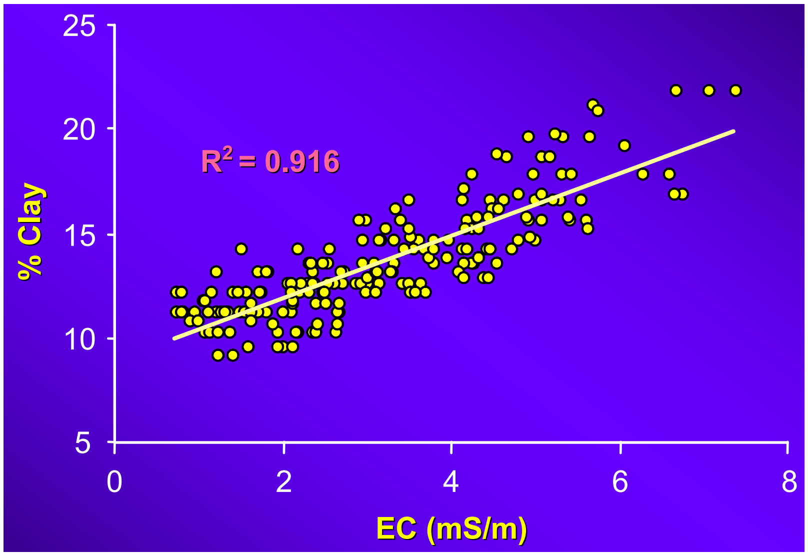

Figure 5. Effect of soil texture (percentage of clay) on soil electrical conductivity.

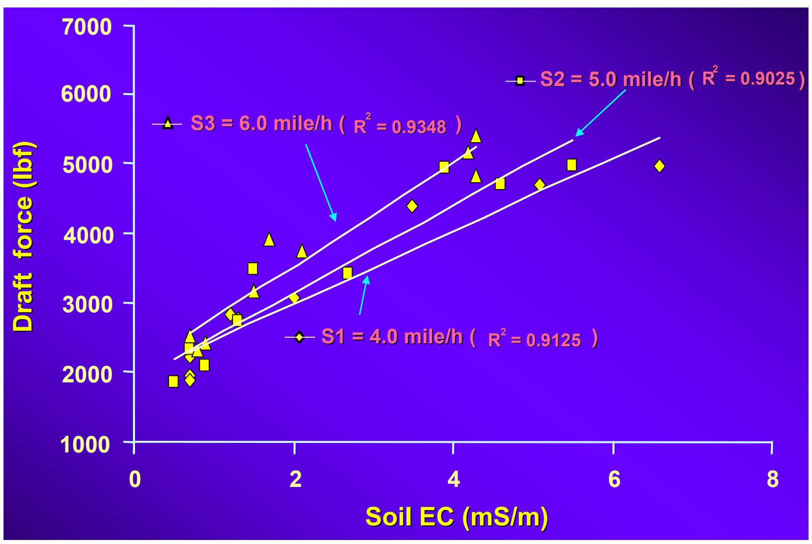

Figure 6. Effect of soil electrical conductivity on draft force.

CONCLUSIONS

1. The site-specific tillage resulted in a considerable energy saving of 50% and fuel saving of 30% in loamy sand soil type compared to conventional uniform-depth tillage. Also, energy and fuel savings were 21% and 8% for sandy loam and 26.1% and 8.5% for sandy soil type respectively.

2. The draft force increased as the travel speed increased in all soil types. However, the tillage depth had more effect on the draft and drawbar power than the tractor speed.

3. The effect of soil moisture content on draft force and fuel consumption was not significant in loamy sand and sandy loam soil types. However, draft force and fuel consumption had a negative correlation with the soil moisture contents.

4. Soil EC data were highly correlated to soil texture (%clay content) with a correlation coefficient of 0.916.

5. There was a strong linear correlation between soil electrical conductivity and draft force across the field.

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An Overview: Merging of Subsurface Drip Irrigation (SDI) and Auto-Guidance for Cotton Production in Alabama

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Abstract

This investigation was initiated to evaluate the integration of pressure compensated subsurface drip irrigation (SDI) installed on rolling terrain via tractor auto-guidance systems for cotton production in the Tennessee Valley of Alabama. One of many goals is to demonstrate the usefulness of these new technologies in conjunction with one another so farmers can determine how these technologies can be implemented into their management strategy. The objective of this paper is to provide an overview of this ongoing project which was employed in a 15-acre field located in northern Alabama. The experimental design is a randomized block design with two irrigation treatments (dry versus wet) and two cover crop treatments (cover versus no cover) with four replications. The cover crop treatment is being evaluated to determine its ability to increase water infiltration, provide soil protection during winter months, and reduce soil compaction at shallow depths. The pressure compensated SDI tape was installed using a real-time kinematic (RTK) autoguidance system to accurately place tape parallel on 80-in spacing at 1200-ft length. AB lines were established and archived for using the autoguidance system to properly locate cotton and cover crops in relation to SDI tape runs. Cotton is planted on 40-in row spacing placing SDI tape at the center of every other row of cotton. The 2005 cropping season represents the first year of operation for this new SDI system.

Summary

Cotton is a vital component of the row crop agricultural economy in Alabama. Production systems using conservation tillage have been widely adapted with resulting benefits for both soil and water conservation. However, drought continues to negatively affect yields with considerable yield variability within and between years depending on the timing and adequacy of rainfall. New precision agricultural technologies offer the opportunity to integrate precision farming techniques with precision irrigation technology to maximize yield each year while optimizing the use of production inputs such as fertilizer, agricultural chemicals, and seed.

Currently, SDI products are designed and recommended for fields that are flat or that have a minimum, uniform slope, but a new product (pressure compensated SDI) is now available, providing potential for many Alabama producers. A majority of the terrain supporting cotton production in Alabama is rolling, thus traditional SDI products are not a viable option. Pressure compensated SDI offers a method to apply water, subsurface, uniformly on rolling terrain by compensating water flow for varying ground pressure. This type of technology negates the effect of gravity, which causes more water to be distributed down slope with traditional SDI products. System design and management is a major factor in determining application uniformity. Therefore the objectives of this investigation are to 1) evaluate cotton production on rolling terrain irrigated with SDI in conjunction with cover crops, 2) evaluate spatial yield variability as related to SDI and topography, and 3) evaluate the performance of a new SDI product developed for use on rolling terrain.

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%. A detailed topographical map was developed using a total station with sub-centimeter accuracy. Additional data collection before installation included mapping soil electrical conductivity (EC) and grid soil samples. The soil EC measurements were collected using a Veris equipped with a Differential Global Positioning System (DGPS) to develop field EC variability based on 1-foot and 3-foot soil depths. Grid soil samples were collected at two depths; 0-10 in. and 11-16 in. The deeper soil cores were collected to look at subsoil acidity providing background data prior to SDI usage. Future plans include re-sampling the same soil core sites to assess fertility and acidity changes.

Implementation of this research required the establishment of an AB line (the initial guidance pass) prior to inserting the tape. This AB line was archived to use for all subsequent field operations using equipment with autoguidance capabilities; primarily planting of cotton and cover crops. SDI tape was installed on 80-in spacing between every other plant row average depth using precision guidance equipment. All treatments have rows 1200 ft. in length over rolling terrain. This placement of cotton rows in relation to the SDI tape allows each run of tape to feed two cotton rows. Cotton variety selection and soil fertility management will be conducted according to Alabama Cooperative Extension System guidelines and program used at TVREC.

Sand media and disc filters were installed to remove suspended particles from irrigation water in order to reduce drip emitter clogs. Routine flushing and chemical treatment will alleviate any evidence of clogging as a result of back siphonage. Totalizing water meters are used to monitor water flow volumes during irrigation events. Decreases in total water volume applied would suggest emitter clogging. Irrigation scheduling has been established at 60% evaporation of pan. This level was selected based on 6 years of prior irrigation research at the same research facility investigating the appropriate percent of pan evaporation for determining SDI timing.

The experimental design is a randomized block design with two irrigation treatments and two cover crop treatments with four replications. No irrigation versus SDI irrigation comprises the two irrigation treatments. Cover crops are being investigated to examine their ability to supply soil protection over the winter months while also increasing infiltration from frequent winter and spring rains. Organic matter is added to the soil, but may come at the price of increased moisture use by the cover crops. The presence of SDI would eliminate this problem by allowing irrigation to compensate for any moisture use by cover crops. Research has illustrated that Alabama soils can be improved by cover crops as they increase infiltration and eliminate compaction occurring at shallow depths.

Since the 2004 cropping season was the first season of operation, it was used to complete hardware installation and troubleshoot the system during irrigation events. A cotton crop was planted but minimal irrigation was scheduled due to the above average rainfall for the year. The irrigation events were used to diagnose and mend problems with the system, ensuring proper functioning for the 2005 growing season. The entire system was operated during any irrigation event meaning no analyses were performed. Moisture sensors were placed at five locations across the test plot at depths of 6, 13, and 30 inches to monitor soil moisture variability during the growing season within the various treatments. A wireless communication system was also installed to relay all flow and moisture data back to a central computer for automatic archiving.

A winter wheat cover crop was planted after the fall 2004 harvest and burned down prior to planting in spring of 2005. Cover crops were only established on those treatments requiring one. Future data collection includes site-specific cone index and soil moisture measurements on a yearly basis using a multiple-probe soil cone penetrometer system. Cone penetrometer measurements will be used to determine the development of compacted soil layers through the soil profile over the duration of the study. A cotton picker equipped with a yield monitoring system will be used to provide spatial crop performance. Yield data produced by the monitor system will be segregated by treatment to assess yield variability within and among each treatment. Total harvested yield will also be collected for each treatment using a weigh cart. Summed yield will be used for treatment comparisons and correction of yield monitor data so it reflects the actual magnitude of yield for each treatment.

In conclusion, 2005 represents the first year for comparisons between the different treatments. While it has taken over a year to ensure proper system operation, the implementation of this investigation has helped make pressure compensated SDI tape available to farmers in northern Alabama. It is currently estimated that approximately close to 1000 acres has been installed in northern Alabama with installation potentially occurring on another 3000 acres in the near future based on interests from farmers who already have experience with SDI or are looking at it as an irrigation alternative. These technologies along with current management practices, tillage, cover crops, etc., could provide a site-specific methodology of managing water resources and increasing profitability. Our goal is to demonstrate the usefulness of these new technologies in conjunction with one another and develop proper management strategies for them.

LONG-TERM BENEFITS OF DEEP TILLAGE ON SOIL PHYSICAL PROPERTIES AND CROP YIELD

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ABSTRACT

Plant available water limits dryland crop yields, but deep tillage used to disrupt dense subsoil layers may increase infiltration and root distribution for more soil water. Our objectives were to quantify long-term effects of deep tilling a Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll) on select soil properties and crop yield at the USDA-ARS, Conservation and Production Research Laboratory, Bushland, TX (35° 11' N, 102° 5' W). In 1971, paired 80 x 1500 ft. level conservation bench terrace plots were stubblemulch tilled or moldboard plowed to 27 in. and cropped with grain sorghum [*Sorghum bicolor* (L.) Moench] through 2004 for yield comparisons. Ponded infiltration, bulk density, and penetration resistance were measured during the summer of 2002. Deep tillage decreased initial soil profile bulk density and penetrometer resistance, but they were no longer different after 30 years. Ponded infiltration increased with deep tillage after 30 years. The mean annual grain yield increased approximately 10% in deep tilled plots compared with stubblemulch tillage because of increased infiltration and, possibly, rooting. Increased yields with deep tillage for two of 14 crops accounted for > 50% of the cumulative yield benefit, which was attributed to improved drainage of rain that flooded untilled plots. Deep tillage effects measured after > 30 years show that dense subsoil layers did not redevelop, which provides an extended period to recoup the 1971 installation costs of $65 per acre. For a Pullman soil, deep plowing may be an economical soil profile modification treatment to use with conservation systems.

INTRODUCTION

Precipitation on the semiarid North American southern Great Plains replaces, in an average year, approximately 25 % of the potential evapotranspiration for crop water use. To offset the resulting crop water deficit under dryland conditions, terrace structures have been adapted to reduce runoff of excess rain water. Hauser (1968) described a level bench terrace system constructed in 1958, which features a gently sloping (2%) watershed 1.5 times larger than the smaller conservation bench that receives the runoff (Fig. 1.). The increased soil water storage is evenly distributed in the crop root zone throughout the bench for crop use. Drainage of excess rain through the profile floods planted crops on the benches usually once in 5 years. Deep tillage may be used to fracture subsoil layers that limit infiltration and profile drainage and to enhance crop rooting for increased water availability.

The Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll) is found on 3.7 million acres of the southern Great Plains region and features a very slowly permeable montmorillonitic clay subsoil layer at 8 to 24 in. depth (Unger and Pringle, 1981). Deep tillage of this soil was proposed as a way to increase infiltration of rain and irrigation by eliminating flow limiting subsoil layers and, consequently, increase the plant available water by increasing the volume of soil explored by crop roots. Generally, this deep soil profile modification and tillage treatment to depths varying from 10 to 60 in. successfully disrupted the dense subsoil layers; thus, increasing infiltration and the depth that crops removed soil water (Schneider and Mathers, 1970). The caveat stated since 1970 was that soil consolidation might mask any long-term tillage benefits.

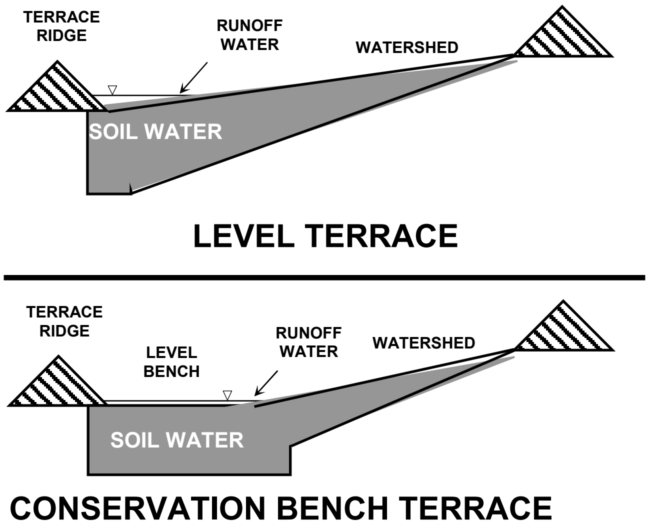

Figure 1. Cross section diagram of conventional and conservation - level bench terraces. Evenly distributing watershed runoff on benches permits annual crop production in most years.

Subsequent studies consistently show that infiltration and crop rooting are increased, which increased crop yields (Eck and Taylor, 1969; Eck, 1986; Eck and Winter, 1992; Unger, 1993). That is, deep tillage successfully reduced the effect of dense subsoil layers that restricted rain infiltration and root exploration for plant available water for some 26 years in irrigated experiments. These studies also reported consistently greater yields under limited irrigation, but dryland production systems were not evaluated. We hypothesized that tillage to a depth of 27 in. would have a sustained impact on select soil physical properties under dryland management. Our objectives were to quantify the long-term effects of deep tilling soil with a flow restricting subsoil layer on crop yield and select physical properties including infiltration, bulk density, and penetration resistance.

MATERIALS AND METHODS

The long-term (1972-2004) effects of deep tillage on crop yield and selected soil physical properties were evaluated at the USDA-Agricultural Research Service, Conservation and Production Research Laboratory, Bushland, Texas, USA (35° 11’ N, 102° 5’ W) on a pair of 80 ft. wide by 1500 ft. long contour-farmed conservation bench terraces. In September of 1971, the terraces were conventionally tilled (control) or plowed to a 27 in. depth using a 40 in. single blade “large” moldboard adjusted to retain the topsoil in the profile with an estimated installation cost of $65 per acre (Fig. 2). After this primary tillage, weed control tillage for stubblemulch residue management was performed as needed using 10 to 15-ft.-wide sweep-plow implements with overlapping V-shaped blades operated at a 4 in. depth (Baumhardt and Jones, 2002).

The terrace watersheds were uniformly cropped from 1971 to present with wheat (*Triticum aestivum* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench] using the wheat-fallow-sorghum (WSF) rotation described by Jones and Popham (1997) that produces two crops in 3 years with 11-month fallow (noncropped) periods between crops. The level benches received sufficient runoff from the watersheds to support annual crops that permitted paired comparisons during most years (i.e., 14 growing seasons), but only grain sorghum yields are reported. Grain sorghum, various cultivars, was seeded in single 30 in. rows during early to mid-June for a final population of 24,000 plants acre^{-1}, using unit planters. Growing season weed control relied on 1.5 lb a.i. acre^{-1} propazine [6-chloro-N,N'-bis (1-methylethyl)-1,3,5-triazine-2,4-diamine] applied pre-emergence after sorghum planting. We added 50 lb acre^{-1} N fertilizer to all benches, however no P or K fertilizers were required. Triplicate sorghum grain yield samples were hand harvested from paired rows 10-ft. long.

Figure 2. Moldboard plow used to till conservation benches to 0.70 -m depth without inverting the soil. Plow was pulled by a D-8 Caterpillar tractor.

Thirty years after deep tillage treatment, in the summer of 2002, we measured the time required for ponded infiltration of well water (pH of 7.7, electrolyte concentration of 819.0 ppm, and a SAR of 0.49) applied in 1.0 or 2.0 –in. depth increments. Our replicated (4 times) test areas were contained within a 40 in. wide by 60 in. long by 8-in. high metal frame that was pressed 2 in. into the soil. Four water applications were made with approximately 72 hours delay between each to permit drainage for a total infiltration depth of 4 and 8 in. Soil bulk density was determined in 8 in. intervals 4 in. beneath the surface to a depth of 36 in. using 4 in. long 2 in. diam. soil core samples taken from areas adjacent to the infiltration sites. Cone penetration resistance was determined approximately one week after the infiltration measurements to allow the sites to drain. We used a tractor-mounted penetrometer that recorded penetration resistance force and depth to 24 in. as described by Allen and Musick (1997). Cumulative infiltration, soil density, and penetration resistance were analyzed with an unpaired t-test while yield data were compared as paired data (SAS Inst., 1988).

RESULTS AND DISCUSSION

Soil Properties

Deep moldboard plowing disturbed the subsoil and increased pore space and size, which promoted greater infiltration. Measured infiltration after a rain in 1975 of 0.3 in. h^{-1} indicated a 6-fold increase with deep tillage compared to the control. Measured, in 2002, total time required for the observed incremental cumulative infiltration is shown in Fig. 3. Time for infiltration of 1.0 and 2.0 –in. of water did not vary with tillage because the estimated wetting front position was above most of the 8-24 in. deep flow-restricting subsoil layer. This subsoil layer impedes water movement and significantly increased differences in observed time of infiltration beginning with the 3 in. water application. This effect increased the difference in the time required for infiltration as the application depth increased. Overall, water infiltration into the deep tilled plots required 30% less time than in the untreated control plots (r^2=0.94). These data show that deep moldboard tillage eliminated a flow restricting subsoil layer and increased infiltration due to improved drainage for more than 30 years.

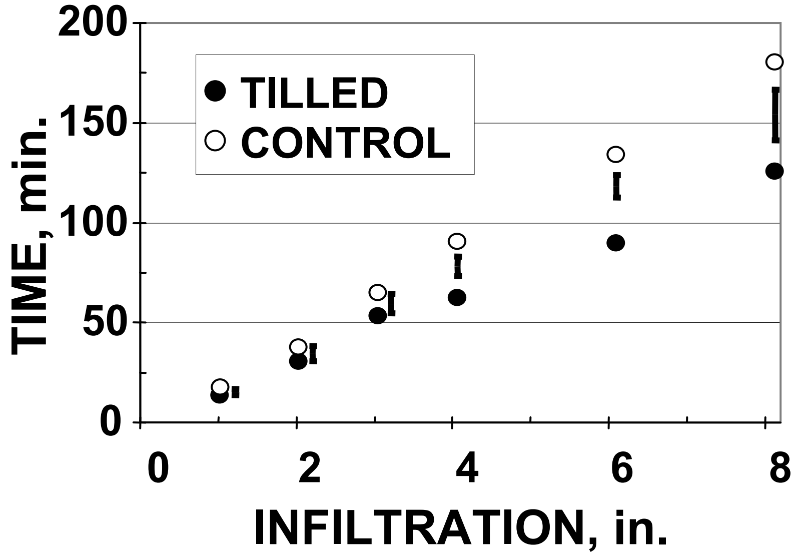

Figure 3. Total time required for the observed cumulative infiltration into deep tillage plots. Vertical bars are the least significant difference.

Soil bulk density after tillage in 1971 was expected to be lower than in control plots; however, density measured in 1975 averaged a similar 1.4 and 1.46 g cm^{-3} for the control and tilled profiles, respectively. The 2002 soil bulk density plotted with depth for tilled and control plots (Fig. 4) are similar to 1975 values except that the 12 in. tilled density was 1.35 g cm^{-3}. The resulting mean soil profile density was a constant 1.46 g cm^{-3} for control plots in 1975 and 2002. In contrast, the profile density in tilled plots was 1.40 g cm^{-3} in 1975 and 1.41 g cm^{-3} in 2002. Compared to the control, deep tillage tended to reduce soil density after 30 years, but those differences were not significant except for the 20 in. depth. Repeated tillage and traffic during the study may have contributed to soil consolidation.

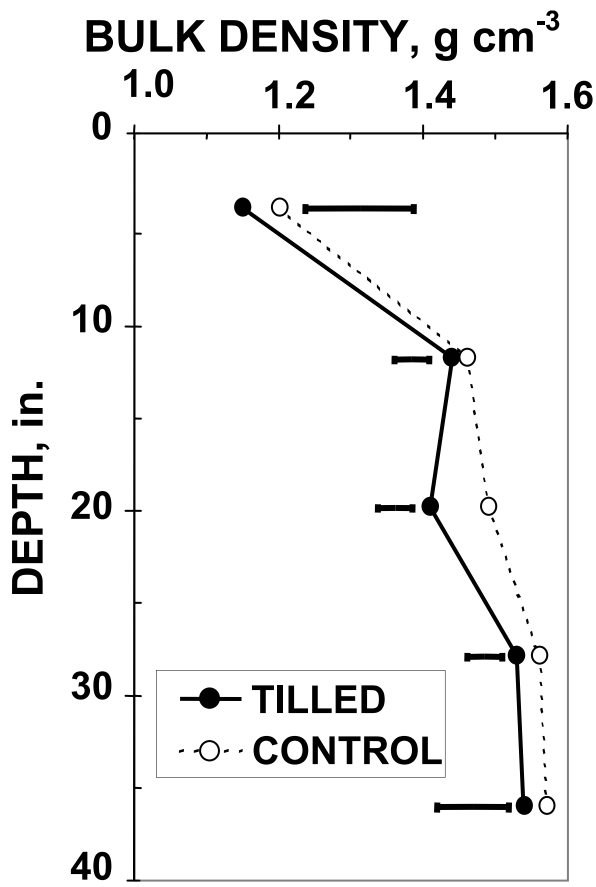

Figure 4. Soil bulk density determined with depth into tillage plots. Horizontal error bars are the least significant

We measured the indexed cone penetration resistance i.e., force per unit basal area to further assess long-term deep tillage effects to eliminate compacted subsoil layers in 2002. The cone index typically increases through dense layers. Our measured cone index was similar for both tillage treatments above the dense subsoil layers beginning at the 12 in. depth. Penetration resistance below 12 in., however, was significantly (P>0.90) less in the deep tilled compared to control plots except at the 18 in. and 24 in., near the plow bottom (Fig. 5). No corresponding 1975 penetrometer resistance data are available for comparison; however, deep tillage had a sustained impact to reduce the indexed penetration resistance through the dense subsoil. In the absence of this subsoil layer after tillage root proliferation could increase and expand the volume of soil explored by crop roots. Our study, however, did not assess the effect of deep tillage on rooting and the potential amount of soil water available to the crop.

Crop Yield

We hypothesized that deep tillage used to fracture a dense 8-24 in. subsoil layer in the Pullman clay loam will increase the volume of soil explored by crop roots and, consequently, increase the available soil water and yield of dryland crops. Annual sorghum grain yield, shown in Fig. 6., revealed no large yield response to deep tillage during the years immediately after plowing (1972-1974) when crop rooting would benefit the most. Also, we observed no gradual decline in yield differences between tilled and control plots due to soil consolidation as a result of sustained tillage and traffic on the plots. Sorghum grain yield calculated from 14 crops grown during the 1972-2004 study average 2300 lbs. acre^{-1} with deep tillage compared with 2060 lbs. acre^{-1} for the control plots. The small 14 crop mean increase of approximately 240 lbs. acre^{-1} in the deep tillage plots was significant (P>0.95) in pairwise t-tests and resulted in a cumulative increase of 3350 lbs. acre^{-1}. We speculate that these yield increases could be attributed to more prolific root growth and greater distribution in the soil profile and increased rain infiltration and storage in the soil. Conspicuously large yield increases with deep tillage compared with the control treatments were observed in 1984 (820 lbs. acre^{-1}), 1999 (990 lbs. acre^{-1}), and 2003 (750 lbs. acre^{-1}). The cumulative yield increase with deep tillage for those three years of 2560 lbs. acre^{-1} accounted for approximately 75% of the yield difference during the study.

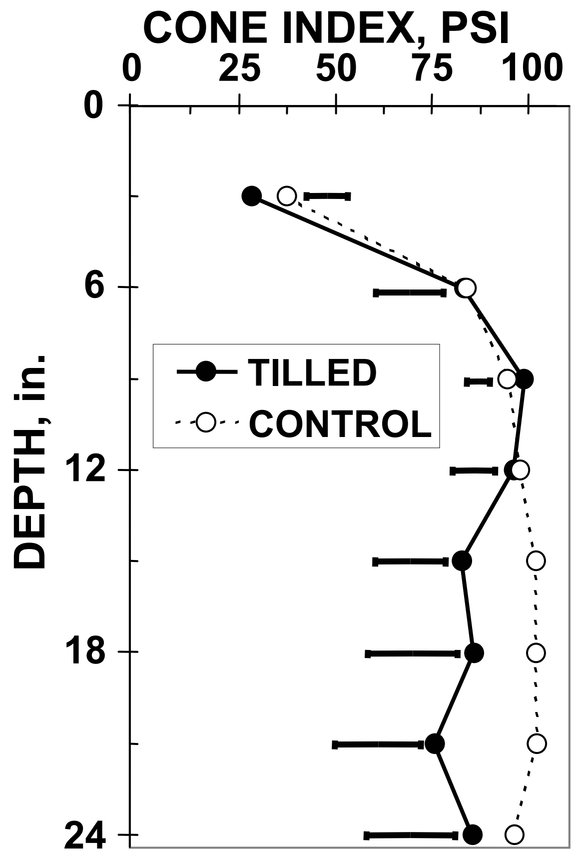

Figure 5. Indexed cone penetration resistance determined with depth into tillage plots. Horizontal error bars are the least significant difference.

To explain the large sorghum grain yield increase with deep tillage during 1984, 1999, and 2003 compared with the remaining 11 years, we reviewed growing season precipitation. During our test, annual grain sorghum yield normally increased with increasing growing season precipitation or if fallow precipitation increased the amount of stored soil water at planting (data not shown) as reported by Unger and Baumhardt (1999). The 2003 yield increase from 670 to 1420 lbs acre^{-1}

was probably due to improved storage of pre-plant precipitation in plots where deep tillage had been used. However, in 1984 and 1999 early, post planting, growing season precipitation exceeded 3 in. during brief, < three days, periods and was sufficient to flood the unplowed terrace benches (Fig. 7.). As previously shown by ponded infiltration measurements, deep tillage has a sustained effect to increase infiltration by improving profile drainage. Consequently, flooding injury to growing crops in 1984 and 1999 was prevented in deep tilled plots because of greater profile drainage that removed ponded water compared with the untilled control. Eck et al. (1977) noted a similar benefit for irrigated Alafalfa (*Medicago sativa* L.) grown on soil profiles modified to 36 in. in 1964.

Figure 7. Bench terrace flooding of seedling crops.

CONCLUSIONS

Crops grown on the southern Great Plains

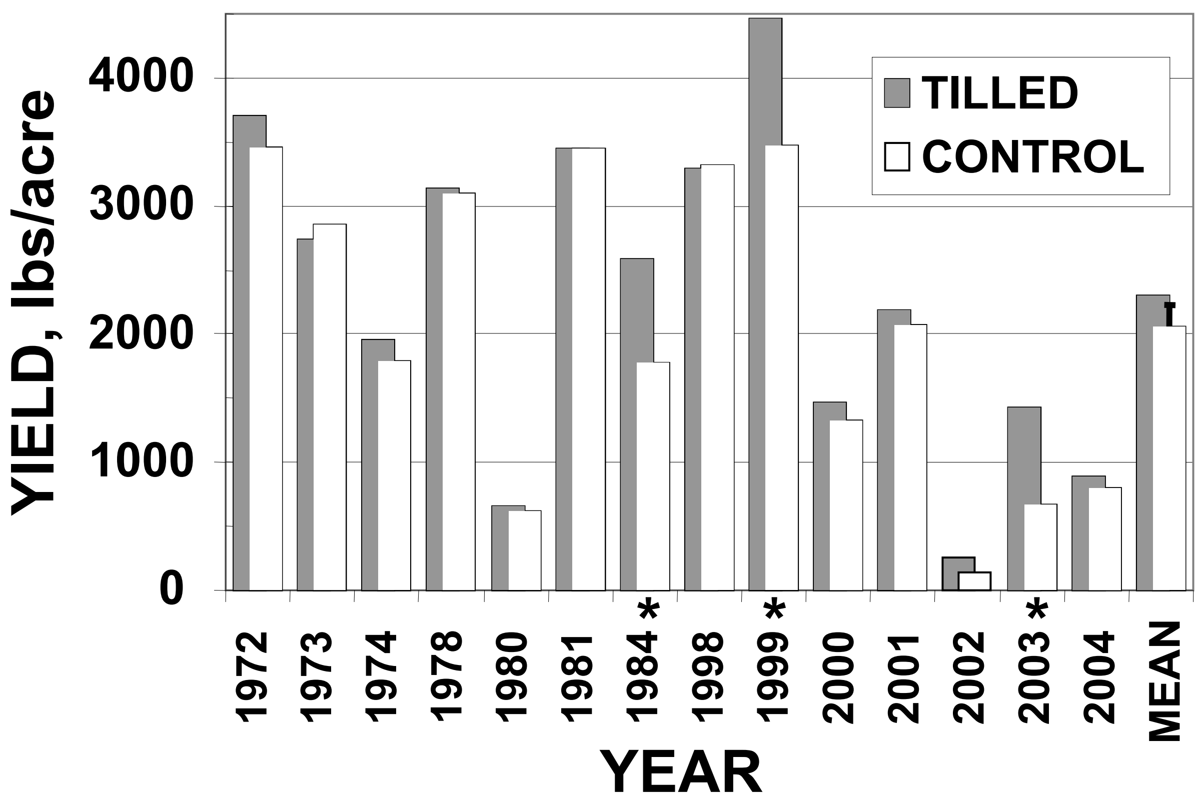

Figure 6. Sorghum grain yield for paired tillage treatments by year. Asterisks denote those years with early post planting precipitation > 3 in.

under dryland conditions rely on stored soil water to augment growing season precipitation.

Conservation tillage retains surface residue that reduce evaporation and increase rain infiltration; however, we measured increased infiltration where deep tillage had been used to eliminate dense subsoil layers. Profile modifying deep tillage reduced soil penetration resistance and, to a lesser extent, soil bulk-density during a long-term, 30-year, evaluation. Ponded infiltration increased significantly with deep tillage because of improved drainage through the subsoil. The sustained benefits of deep tillage suggest that the dense subsoil layers did not completely redevelop after 30 years, which extends the period to recoup the 1971 installation costs of $65 per acre. Although it is difficult to characterize all the factors governing crop yield response to deep tillage treatments, increased root growth expands the soil volume a crop explores for the water needed to increase dryland yield. However, the 10% increase in mean grain sorghum yield on deep tillage plots was largely (> 50%) attributed to overcoming an infrequent problem of poor soil drainage. For a Pullman soil, deep plowing may be an economical soil modification treatment to use with conservation systems because of sustained yield increases that extend the period to recoup installation costs.

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SHORT AND LONG TERM EFFECTS OF CONSERVATION TILLAGE ON SOIL RESISTANCE AND AGGREGATE STABILITY IN RICE PRODUCTION SYSTEMS.

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ABSTRACT

Rice production is traditionally tillage intensive and has seen little adoption of conservation tillage practices. This situation has occurred during a time when soil organic matter and structure were declining in quantity and quality. Water management, tradition, land tenure, crop subsidies, and soils that are not responsive to conservation tillage are some of the reasons given for low adoption of conservation tillage in rice production areas. In order to determine if soil aggregate stability and resistance were affected by conservation tillage a series of measurements were taken from on-station tillage studies and a on-farm site where conservation tillage has been practiced on specific fields from 2 to 41 years. Data indicate that the percentage of water stable aggregates increases with the adoption of conservation tillage and values continued to increase up to the 41 year measurement. Changes in soil resistance were dependent on soil type, crops grown, and length of time conservation tillage was practiced. Soybeans were effective in reducing soil resistance in no-till plots while corn was the opposite. Continuous rice reduced soil resistance in fields no-tilled up to 41 years (when measurements stopped). Aggregate stability and soil resistance were sensitive to tillage and were found to be good indicators of soil health.

INTRODUCTION

Rice production, as practiced in eastern Arkansas, is tillage intensive. Rice producers generally level fields to a slope between 0 and 0.15% so that, during flooding, water can flow evenly across the field. Leveling involves disking and harrowing fields several times as well as smoothing it with a land plane before planting. Rice is harvested at 18 to 20% moisture, which is shortly after the field is drained. Depending on the weather conditions after drainage, moist soil can lead to rutting during harvest and the need for additional tillage (Anders et al., 2002).

The percentage of conservation tillage used in the United States increased from 5.1% in 1989 to 16.3% in 1998 (Conservation Technology Information Center, 1999). In rice production, conservation tillage is not readily accepted. In the Delta, which covers most of eastern Arkansas, conservation tillage adoption increased from 2.4% in 1989 to 10.7% in 1998 (Parsch et al., 2001). Much of this increase is attributed to soybean production and not rice production. This low percentage could be partially due to the fact that the clay soils in this area are difficult to manage and rice production has specific water management needs.

Benefits of conservation tillage have been well documented for many crops. Some benefits include: reductions in soil erosion, increased soil aggregate stability, increased soil carbon, reduced soil resistance, increased diversity and activity of soil microbes, and increased water infiltration. Unlike many of the row crops where extensive studies have documented these benefits, data available from rice production systems are limited. In a long-term study located at the University of Arkansas Rice Research and Extension Center, data comparing conventional- and no-till rotations containing rice have shown a 10-fold reduction in runoff from no-till rotations compared to conventional-till rotations (Harper et al., 2003; Anders, 2004). These results suggest that many of the soil processes documented in non-flooded row crop production systems are present in rice (flooded) production systems.

Increased soil aggregation is one beneficial aspect of conservation tillage. Soil aggregation is the process whereby smaller soil particles bind together to form larger, more stable particles. Amezketa, (1999) reported that newly formed soil aggregates are bound by organic and inorganic compounds. Without intensive tillage, soil particles become more stable. Formation of more stable soil units creates space between them allowing movement of air and water in to the soil (Soil Quality Indicators, 1996). Stable soil aggregates, resulting from conservation tillage, improve the ability of air and water to mix, allowing beneficial plant growth in a shallow root zone. Shallow root development also enables the plant to utilize nutrients and elements such as nitrogen and carbon that are near the surface (Fawcett and Caruana, 2001). The impact of conservation tillage on soil aggregation and aggregate stability in rice production systems has not been documented.

Soil strength or resistance is the ability of the soil to resist penetration or displacement by outside forces such as erosion. Soil strength increases as soils become drier and is strongly dependent on moisture (Kay, 1990). This increase could result in poor infiltration and depending on moisture content; soil strength can influence plant root development. In intensively tilled rice soils there is little attention given to soil strength because rice has a fibrous root system that is concentrated at the soil surface. However, much of the rice production in Arkansas is found in rice-soybean rotations where soybeans are a crop that is characterized by deep rooting. In these systems soybeans may require frequent irrigation because of restricted rooting. Soil strength is often measured with a penetrometer, a device that measures the force required to force a rod with a pointed tip straight down through the soil (Schuler and Wood, 1992). Soil resistance data indicate that soils under no-till management have decreased resistance (Anders 2004). Soil strength relationships between tillage, rotation, and aggregate stability have not been documented in rice production systems.

The objectives of the data presented in this paper are to: 1) Determine the effect of conservation tillage, rotation and soil type on soil aggregation, 2) Determine the effect of conservation tillage, rotation, and soil type on soil resistance, and 3) Determine possible relationships between soil aggregate stability and resistance.

MATERIALS AND METHODS

On-station data were collected from a long-term rotation initiated in 1999 at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas. Soil at the study site is a silty clay loam (fine, montmorillonitic, thermal, Typic Albaqualf of the Dewitt soil series). Four replications planted into 10 main plots; each representing 7 rotations. Main plots were divided into tillage sub-plots (no-till vs. conventional-till). Sub-plots were further divided into fertility (standard vs. enhanced) and variety (2) sub-plots. Rotations reported on in this paper are: 1) continuous rice, 2) rice-soybean, and 3) rice-corn. The field was graded to a 0.10% slope in 1999 with rotation and no-till comparisons beginning in 2000. All crops are similarly managed with the exception of treatment differences. Levees are constructed around all main plots during the winter to collect winter rainfall and aid in residue decomposition. Data presented for tillage and rotation comparisons are made from contrasting 3m x 9m plots where variety and fertility were the same.

On-farm data were collected from the Isbell Farms located near Humnoke, Arkansas. Soil at all field locations is described as heavy (buckshot) clay. All fields have been planted into continuous rice for between 2 and 41 years. All fields are flooded during the winter and shallow tilled when weeds become a problem (5-10 years). Additional samples were collected from a prairie reserve area with the same soil as the station and where no tillage has taken place.

Aggregate stability samples were collected using a 7.62 cm diameter core to a depth of 20 cm in March of 2003. All samples were forced through a 8 mm screen and allowed to air-dry. Sub-samples of 200 g dried soil were processed using a "wet sieve" method (Yoder, 1936). Five screen sizes were used (0.25, 0.50, 1.00, 2.00, and 4.00 mm) with samples cycled for 5 minutes at 130 cycles per minute. Separated sizes were oven dried and weighed.

Soil resistance measurements were collected in March of 2003 using a Spectrum® Field Scout SC-900 penetrometer. Four samples to a depth of 40 cm were collected from each plot at the same time a moisture samples was collected to the same depth. Moisture samples were divided into 5 cm segments and dried to determine moisture percent.

Data analysis was completed using standard error bars calculated using Systat (SPSS Inc.) at a 0.68 difference level.

RESULTS AND DISCUSSION

Aggregate stability: Total weight of water stable aggregates increased in the no-till when compared to the conventional-till for the continuous rice and rice-soybean rotations after 4 years of no-till (Table 1). Percentage of increase was 4% higher for the continuous rice rotation when compared to the rice-soybean rotation. For the rice-soybean rotation there were increases in four of the five size classes with a decrease in the largest (4.00mm) class from 0.67% to 0.52%. The largest increase was with the smallest aggregate size where weights increased from 5.18% to 7.10%. There were increases in the three smallest class sizes in the continuous rice rotation. However these increases were of a larger magnitude than were observed in the rice-soybean rotation data. Total values were significantly lower than the 55% reported from samples collected in an undisturbed prairie (data not presented).

Aggregate stability values from continuous rice fields that were managed as no-till for 2 to 41 years showed a trend of increasing total water stable aggregate percents with increased time in conservation tillage (Fig. 1). Total percent water stable aggregates increased from 65% at 2 years to over 73% at 41 years. Biggest changes came in the percentage of large water stable aggregates. Overall values for these measurements were much higher than those presented in the station study and this reflects differences in soil type. These values suggest that if the approach of using water stable aggregates as a means of measuring soil health is used; these soils have improved in quality. They would also support the type of management used in these fields as a valid approach for improving soil quality in rice production areas.

Soil resistance: Soil resistance values in the continuous rice rotation ranged from 200 Kpa near the surface in the conventional-till to nearly 4000 Kpa in the same treatment (Fig. 2). Values greater than 2000 Kpa are restrictive to root growth. Resistance in the continuous rice rotation decreased significantly in the 10 to 25 cm depth range in the no-till treatment when compared to conventional-till in the same rotation (Fig. 2). Lower resistance values in the 0-5 cm depth in the conventional-till plots is attributed to tillage. Higher values in the no-till treatment are the result of a plow layer. Soil moisture values were greater in the no-till plots through the top 35 cm of the soil profile. Reductions in the plow layer resistance did not result in increased irrigation requirements in the no-till plots (data not shown).

Reductions in soil resistance were dependent on tillage and rotation phase in the rice-soybean rotation (Figures 3 & 4). Values recorded following soybeans showed significant reductions in soil resistance in the no-till plots compared to the conventional-till plots for all depths between 10 and 35 cm (Fig. 3). The same comparison following the rice phase of the same rotation showed reductions in soil resistance through a smaller profile range. Increasing reductions in soil resistance in plots previously planted into soybeans when compared to those previously planted into rice suggests soybeans have a more extensive and vigorous root system. Soil moisture values were higher at all depths in the no-till plots when compared to the conventional-till plots at all depths (Figures 3 & 4). These differences were significant in only a few cases and there were no distinct patterns.

Of the rotations compared in this paper the only comparison where there was not a significant reduction in soil resistance was following corn in the corn-rice rotation (Figures 5 & 6). Soil resistance values were higher for the no-till treatment in the 16 to 35 cm depth range when compared to the conventional-till treatment. These results suggest that corn is not effective in reducing soil resistance. These results are bore out by the fact that corn yields have been consistently low (data not shown) and corn oftentimes requires irrigation on a more regular basis than soybeans. These observations suggest corn roots are often restricted to the surface soil layers and may not penetrate the soil. There were some reductions in soil resistance following the rice phase of the rice-corn rotation (Fig. 5). There was a small increase in soil moisture when comparing no-till to conventional-till in both rotation phases. These results indicate corn is possibly not well suited for no-till in rice rotations if farmers are hoping to reduce plow layer resistance and improve plant root densities.

Soil resistance values in no-till fields where continuous rice has been grown from 2 to 41 years show a general decrease in soil resistance with increasing years of production (Fig. 7). None of the values shown in these comparisons are sufficient to reduce root growth. In total these results indicate that there is no detrimental effect on soil resistance when continuous no-till rice is grown on a heavy clay (buckshot) soil.

CONCLUSIONS

Aggregate stability measurements were sufficiently sensitive to measure trends of increasing percentages of water stable aggregates in plots that were no-till for four years compared to those who were conventional till for the same time period. No-till resulted in a greater percent of larger aggregates in all rotations. There was an increase in total water stable aggregates and a shift to larger aggregates in a heavy clay soil that had been no-till farmed from 2 to 41 years.

Changes in soil resistance were dependent on tillage and crop species. Soil resistance was reduced in no-till plots where rice and soybeans were rotation components. When corn was included in the rotation there was an increase in soil resistance through much of the profile. There was an increase in soil water content in no-till plots compared to conventional-till plots regardless of crop species and rotation sequence. No-till rice production in a heavy clay soil resulted in a steady decrease in soil resistance from 2 to 41 years of continuous rice. Changes in soil resistance that can be attributed to tillage were evident earlier than detected changes in soil aggregate stability. Trends of increased percent water stable aggregates and decreased soil resistance were noted and need to be further investigated.

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Table 1: Percent water stable aggregates collected in 0.25, 0.50, 1.00, 2.00, and 4.00 mm sieve sizes for conventional-and no-till continuous rice and rice-soybean rotations in March 2003 at the University of Arkansas Rice Research and Extension Center.

Rotation	Tillage	Sieve diameter					
		0.25mm	0.50mm	1.00mm	2.00mm	4.00mm	Total
Rice-soybean	Conventional	5.18	1.68	1.06	0.68	0.67	9.27
Rice-soybean	No-till	**7.10***	**1.95**	**1.15**	**0.75**	0.52	**11.46**
Rice-rice	Conventional	4.44	1.64	0.96	0.79	0.60	8.44
Rice-rice	No-till	**6.19**	**2.26**	**1.16**	0.65	0.58	**10.84**

- Bold designates an increase in percent water stable aggregates.

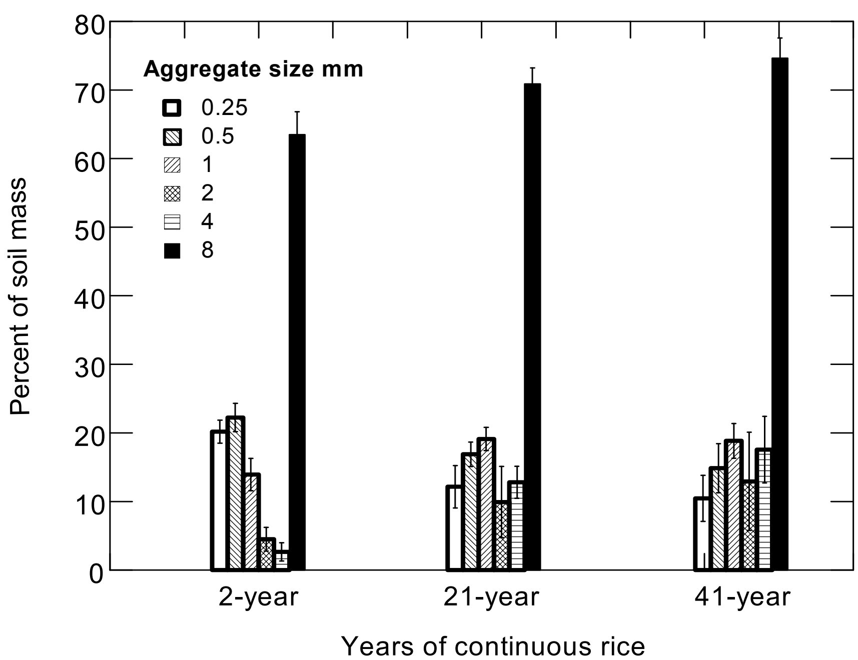


Figure 1: Percent of soil mass for five aggregate sizes from samples collected at the Chris Isbell farm on fields that were no-till continuous rice for 2, 21, and 41 years.

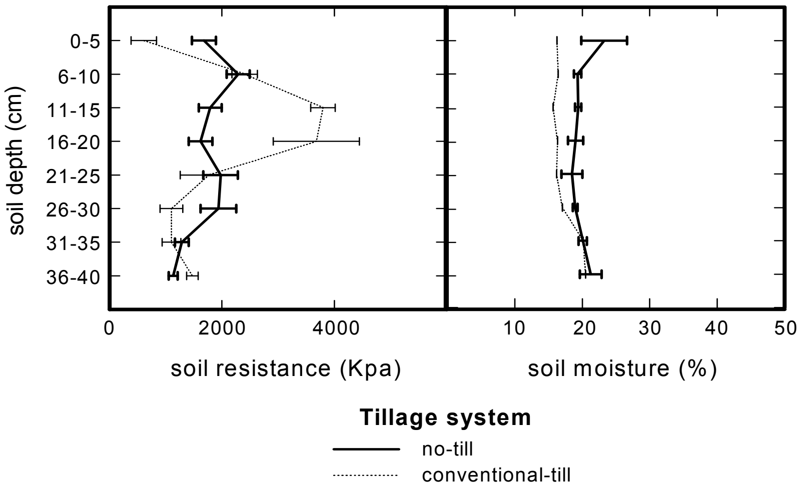
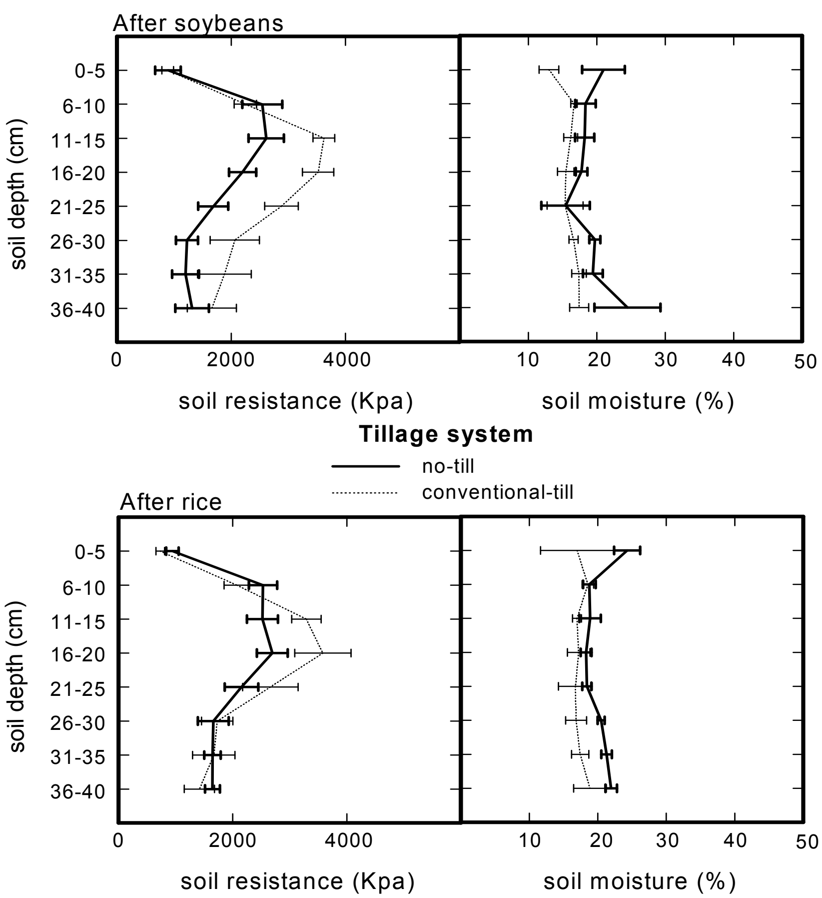
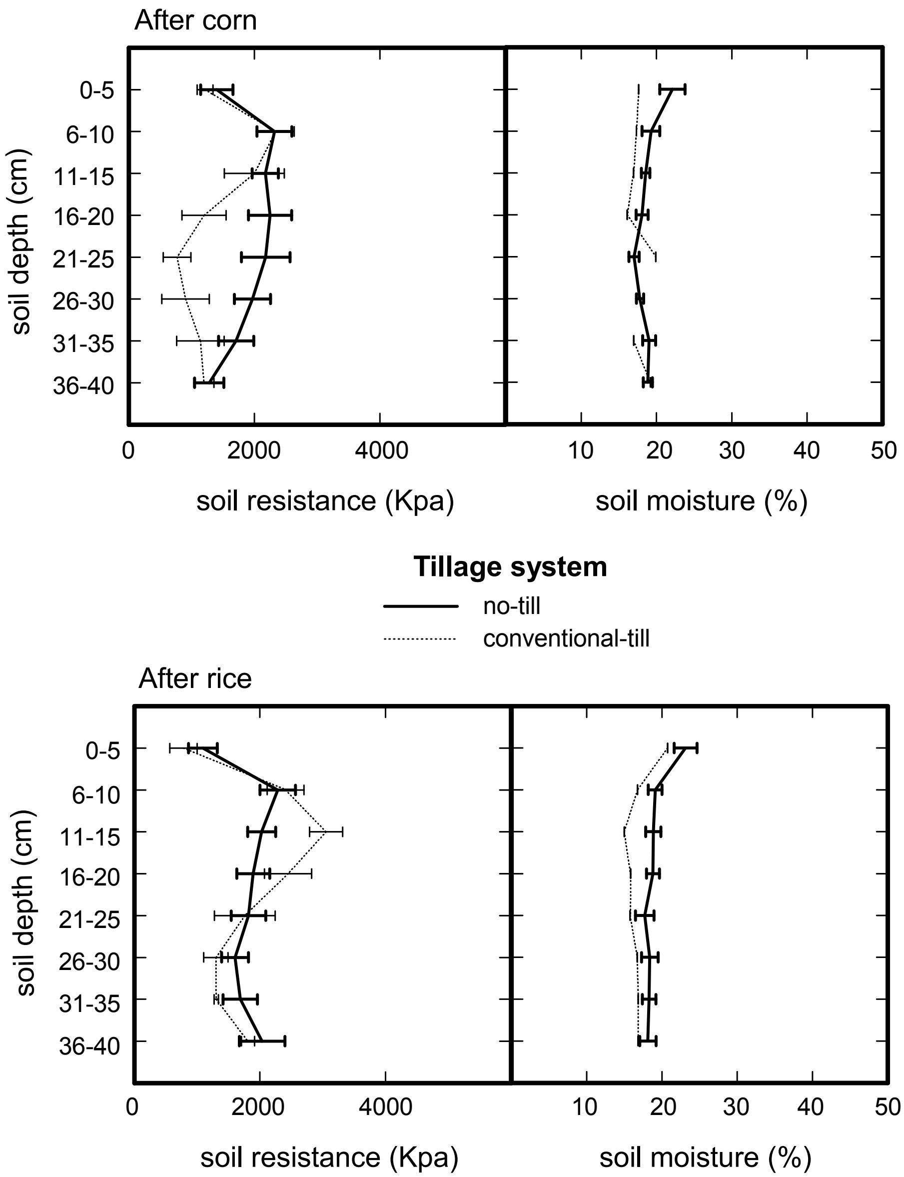


Figure 2: Soil resistance (Kpa) measured in no-till and conventional-till continuous rice plots at the University of Arkansas Rice Research and Extension Center in 2003.



Figures 3 & 4: Soil resistance (Kpa) and water content (%) measured in no-till and conventional-till plots in 2003 that were planted into a rice-soybean rotation at the University of Arkansas Rice Research and Extension Center.



Figures 5 & 6: Soil resistance (Kpa) and water content (%) measured in no-till and conventional-till plots in 2003 that were planted into a corn-soybean rotation at the University of Arkansas Rice Research and Extension Center.

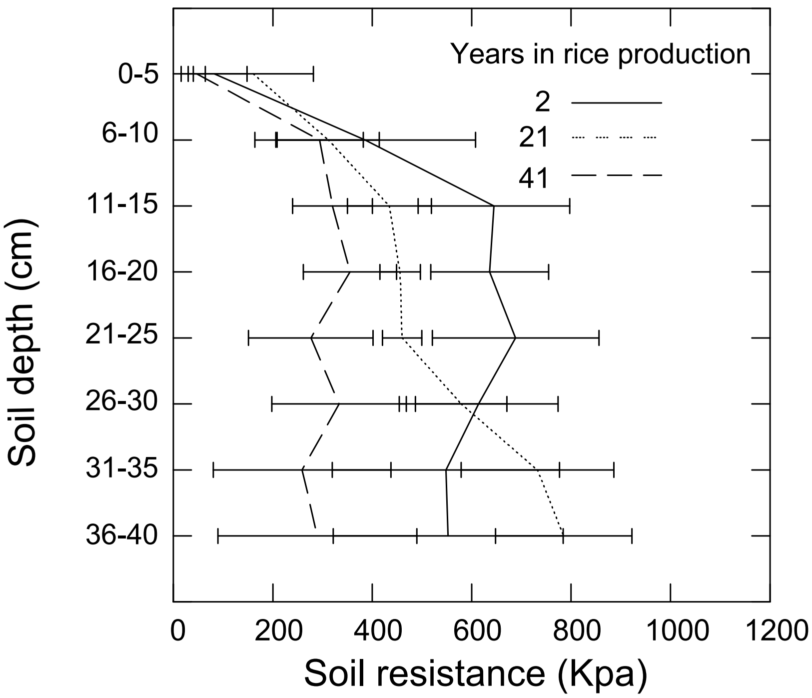


Figure 7: Soil resistance (Kpa) values for continuous rice fields that were no-till managed for 2, 21 and 41 years.

SOIL MOISTURE AND COTTON LEAF TEMPERATURE IN CONSERVATION SYSTEMS

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ABSTRACT

Cotton (*Gossypium hirsutum* L.) yields are typically reduced by soil compaction due to reduced root development. Soil compaction is usually a concern in soils with low soil organic matter content. A survey conducted in 2002 revealed that many soils in central Alabama have hard pans within the top 12 inches of soil, and these soils also had low organic matter contents. In the fall 2003 a field experiment was started to determine the potential of conservation tillage systems (no tillage, fall paratill, spring paratill, and spring strip tillage) and winter cover crops (no cover, rye, and wheat) to reduce soil compaction, increase soil organic matter content and moisture availability. Soil moisture was monitored continuously during the growing season to a depth of 12 inches. An infrared thermometer was used to determine cotton leaf temperature of the uppermost fully extended leaf during the fruiting period. Cover crops increased soil moisture contents, reduced leaf temperature, and increased lint yields when compared to the no cover treatment.

SUMMARY

Cotton yields can be depressed by soil compaction. Compaction restricts root development, reducing the ability of plants to obtain nutrients and uptake water. Soil organic matter can help reduce compaction. Many fields in central Alabama have soil compaction problems, with hard pans present in the top 12 inches. In all likelihood, these are trafficpans created by tillage operations since they are typically located at the bottom of the plow layer. Nevertheless, these layers usually affect water movement and limit root growth. Soils in this region of Alabama with compaction problems frequently have low organic matter contents.

Soil organic matter content can be increased with the use of winter cover crops, such as rye (*Secale cereale* L.) and wheat (*Triticum aestivum* L.). The cover crop is usually rolled in the spring to form a mat and left on the soil surface. This plant residue protects the soil from erosion and increases soil organic matter content as it decomposes. Increases in organic matter will improve soil physical properties over time. Water infiltration can also increase since cover crops reduce soil surface crusting. Also, decomposing roots create channels into which water can infiltrate. Further, non-inversion tillage systems can reduce soil surface disturbances while promoting organic matter accumulation and eliminate below-ground hard pans. Therefore, the objective of this study is to evaluate a combination of conservation tillage systems and winter cover crops to increase organic matter content, soil moisture availability and reduce soil compaction, while improving cotton production.

The study was initiated in fall 2003 at the Prattville Agricultural Research Unit of the Alabama Agricultural Experiment Station (AAES) in Prattville, AL. The soil at the site is a Lucedale fine sandy loam soil (fine-loamy, siliceous, thermic Arenic Paleudult). A factorial treatment arrangement with four conservation tillage systems (no-till, fall paratill, spring paratill, and spring strip-till) and three winter cover crops (no cover, rye, and wheat) was established. All cover crops were planted on 23 Nov. 2003 at a seeding rate of 1.5 bu/ac. Three weeks prior to planting, the cover crops were chemically terminated and rolled to facilitate planting operations. Cotton was planted on 11 May 2004. Soil moisture was monitored in-row during the growing season between 12- and 16-in of depth. An infrared thermometer was used to determine cotton leaf temperature of the uppermost fully extended leaf five times during the fruiting period. Temperature of the uppermost fully extended leaf can serve as an indicator of plant water stress, with higher temperatures indicating more stress than lower temperatures

Biomass production was greater with rye (4,607 lb/ac) than wheat (3,287 lb/ac). However, both cover crops increased soil moisture about 5% during most of the growing season when compared to the no cover treatment. Additionally, leaf temperatures were reduced with cover crops, with the lowest temperatures recorded in the rye, followed by wheat. Lint yields were significantly affected by the winter cover crops, with rye (709 lb/ac) producing the greatest yields followed by wheat (665 lb/ac). However, greater differences in yield due to cover crop use could be expected in drier years.

Soil water content in the no-till treatment was lower for most of the season when compared to fall paratill and spring strip-till. Below-ground soil disruptions usually aids infiltration and soil water redistribution compared to no-till, especially in soils with hard pans. However, soil moisture was lowest for the spring paratill treatment, but this was most likely caused by the location of the moisture sensor and time of tillage. After paratilling, a slot is created which can remain intact for a considerable period of time. This slot can create preferential water movement. The location of the soil moisture sensor in relation to the paratill slot allowed rainfall water to move into the soil bypassing the sensor. This was not observed with the fall paratill because some reconsolidation of the soil profile probably occurred during the winter. This is supported by yield data, since there were no significant differences in lint yield between tillage treatments (655, 662, 676, and 683 lb/ac, for no-till, strip till, spring paratill, and fall paratill, respectively). Additionally, there were no major differences in cotton leaf temperature among the four tillage treatments.

First-year data showed no effect of tillage on leaf temperature and lint yield. However, rye and wheat increased soil moisture content and decreased leaf temperature. These translated to increased lint yields, with the increase being significant with rye. As work continues on this study, future data should help determine which tillage and cover crop practices are beneficial for these degraded soils.

PROFITABILITY AND RISK ASSOCIATED WITH ALTERNATIVE MIXTURES OF HIGH-RESIDUE COVER CROPS

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ABSTRACT

Conservation tillage systems with cover crops may increase crop yields and net returns when compared to conventional tillage systems. This benefit may be further enhanced with mixtures of high-residue cover crops. The purpose of this paper is to examine the economic profitability and risk associated with alternative high-residue cover crops as part of a conservation tillage system. An experiment was conducted near Shorter, AL using a factorial arrangement of two management systems with six replications on a two-year corn (*Zea mays* L.) - cotton (*Gossypium hirsutum* L.) rotation with both phases of the rotation present each year from 2001 to 2003. The first management system was a conservation system with two groups of cover crops planted prior to corn and cotton. The first group of cover crops was a mixture of white lupin (*Lupinus albus* L.), crimson clover (*Trifolium Incarnatum* L.), and fodder radish (*Raphanus sativus* L.) planted prior to corn. The second group of cover crops was a mixture of black oat (*Avena strigosa* Shreb.) and rye (*Secale cereale* L.) planted prior to cotton. The second management system is a conventional tillage system with no cover crop. Results indicate that the use of alternative mixtures of high-residue cover crops, while being more costly to plant than more traditional cover crops, can increase crop yields and decrease the risk of obtaining lower crop yields and net returns in drought years. Given the conservation system with cover crop used was relatively immature; we would expect that these benefits would become more evident over time.

INTRODUCTION

Traditionally, cotton (*Gossypium hirsutum* L.) and corn (*Zea mays* L.) were grown in the Southeast under conventional tillage systems, resulting in degraded agricultural soils due to extensive soil erosion. In an attempt to curb this degradation, conservation tillage methods, such as no-till, reduced tillage and minimum tillage were developed; and have been readily adopted by a significant group of farmers in the Southeast. In Alabama, about 58 and 64 percent of farmers use conservation tillage systems for cotton and corn production, respectively (CTIC, 2004).

On Coastal Plain soils of Alabama, frequent occurrence of short-term droughts threatens crop growth due to the low water holding capacity of soils in this region. The use of cover crops as part of a conservation tillage system can help alleviate drought stress by increasing infiltration rates and increasing soil moisture content. In addition, cover crops can further improve soil quality by helping to relieve compaction, improve soil organic matter and reduce soil erosion (Reeves, 1994; Sustainable Agricultural Network, 1998). All of these characteristics have the potential to increase crop yields and in turn on-farm profits.

The purpose of this paper is to examine the economic profitability and risk associated with two alternative mixtures of high-residue cover crops used in a two-year corn-cotton rotation as part of a conservation tillage system. This information should provide insight concerning the economic viability of using different mixtures of cover crops in a relatively immature conservation tillage system.

MATERIALS AND METHODS

Two crop management systems, a conventional and conservation tillage systems were established on a 24-acre Coastal Plain field at the E.V. Smith Research and Extension Center near Shorter, AL. Prior to the experiment, the site had a long history of continuous cotton production under conventional tillage. The conventional tillage system resembled one commonly used on the southern Coastal Plain. Tillage included disking, chisel plowing, disking and cultivation to level the seedbed, and non-inversion tillage prior to planting. In addition, no cover crop was used, but winter weeds were not controlled. The conservation tillage system included the use of winter cover crops and non-inversion in-row subsoiling prior to planting to minimize surface soil disturbance and disrupt the inherent hardpan found in these soils. Two different groups of cover crops were planted. The first group (Group 1) was a mixture of white lupin (*Lupinus albus* L.), crimson clover (*Trifolium Incarnatum* L.), and fodder raddish (*Raphanus sativus* L.). The second group (Group 2) was a mixture of black oat (*Avena strigosa* Shreb.) and rye (*Secale cereale* L.). Group 1 was planted prior to corn, while Group 2 was planted prior to cotton. All cover crops were planted with a no-till drill. A mechanical roller was used in conjunction with herbicide to terminate each cover crop mixture prior to spring planting. The experimental design was a factorial arrangement of two management systems (with and without manure) using 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. Treatments with manure were excluded from this analysis, but all agronomic experimental results were reported in Terra et al. (2004). The remainder of production practices, such as pesticide applications, followed Alabama Cooperative Extension System (AAES) recommendations. Using information on crop and input prices provided by the AAES (2004), net returns and risk associated with using each group of cover crops in a conservation tillage system was compared to a conventional tillage system with no cover crop.

RESULTS AND DISCUSSION

Net returns were estimated for the conservation tillage system with each cover crop group and for the conventional tillage system with no cover crop for both corn and cotton. Estimates of net returns and yields are provided for 2001, 2002 and 2003 (Tables 1 and 2). Negative returns to cotton in 2002 can be attributed to low prices and limited rainfall. The yearly average spot price in Alabama was \$0.28/lb in 2001 and \$0.44/lb in 2002. Rainfall was lower than average in 2001 and a short-term drought occurred during the summer of 2002. Of interest is that corn and cotton lint yields from 2001 to 2003 from the conservation tillage systems exceeded yields from the conventional tillage system by as much as 20 percent. These results are not surprising given the advantage conservation systems with cover crops have on increasing soil water use efficiency and soil organic matter (Snapp et al., 2005). In 2003, a high rainfall year, both yields and net returns (without cost share) of cotton for the conservation tillage system were 15 and 10 percent higher respectively, when compared to the conventional tillage system with no cover crop. For corn, net returns were lower in 2003 due to the high cost of establishing the cover crop.

Table 2 provides detailed estimates of the production costs for both corn and cotton in rotation for both tillage systems with and without cover crops in 2003. Production costs followed similar trends in 2001 and 2002. Machinery (both variable and fixed) and labor costs are lower for the conservation tillage system, but pesticide costs are higher due to the use of additional herbicide to terminate the cover crop. The lower machinery costs are due to less passes across the field, which translates into lower labor and fuel costs and saved time. In 2003, for cotton, this reduced labor costs by $3.64 per acre. On a 500 acre farm this would amount to a savings of $1820. Assuming other production costs do not change, the farmer could use this saved labor to farm an additional 57 acres of land this year, retaining the same labor costs as under the conventional tillage system on a 500 acre farm and increasing profits by almost $8000 (not adding in farm payments and cost share for cover crops). This provides some indication of the value of the "saved labor and time" that a conservation system and cover crop can provide.

The cover crop mixtures used in the conservation tillage system were relatively expensive, when compared to a small grain cover crop such as rye or wheat (*Triticum aestivum* L.), which could have been planted for about $20-$35 per acre using the same production costs (Table 2). The primary cost to plant each cover crop was the seed. Seeding rates for Group 1 were 90, 25 and 15 lbs per acre for white lupin, crimson clover, and fodder radish, respectively. Seeding rates for group 2 were 40 and 60 lbs per acre for rye and black oats respectively. The cost of seed was $0.80/lb for white lupin, $0.84/lb for crimson clover, $2.36/lb for fodder radish, $0.19/lb for rye and $0.63/lb for black oat. High seeding rates were used to test practicality of experimental germplasm to generate a high residue cover, and the high costs of certain cover crops were due to their limited commercial availability. Costs of establishing a cover crop may be reduced if nitrogen fertilization rates are decreased to take account of the nitrogen provided by legume cover crops and nitrogen mineralization from cover crop residues (Snapp et al., 2005). Furthermore, the Natural Resource Conservation Service (NRCS) of the USDA offers financial incentives for planting cover crops in Alabama through the Environmental Quality Incentives Program (EQIP) and the Conservation Security Program (CSP). Under EQIP, NRCS offers a cost share of $5/acre if there is greater than 30 percent residue cover on the field and $40/acre if there is greater than 50 percent for up to three years (NRCS, 2005). It is assumed that cost share was obtained from NRCS through EQIP when calculating estimates of net returns.

To examine the economic potential for these cover crop regimes, net revenues in 2002 were re-estimated using different prices of cover crop seed and spot prices for corn and cotton. This year was chosen due to the short-term drought and the fact that a cover crop can help alleviate some of the losses in income that could occur due to a drought. It is assumed that the price of seed for white lupin, rye and black oat change and the price of seed for crimson clover and fodder radish are equal to $0.80/lb. Results are reported in Table 3. The figures reported are the difference from what the farmer would have obtained had they used the conventional tillage system with no cover crop instead of the conservation tillage system with cover crop. Even with no change in the spot price of corn or cotton the results indicate that in 2002 use of these alternative mixtures of cover crops in a conservation tillage system could be more profitable than a conventional tillage system (Table 2). As spot prices increase, the difference in net returns between tillage systems grows, highlighting the economic advantage of the conservation tillage system with a cover crop. Similar trends are found for 2001 and 2003.

The ability to enhance profits is a significant concern for farmers when they are considering the use of cover crops, but not the only concern. Given that farmers are faced with uncertainties due to unpredictable factors when using a cover crop such as nutrient availability, weather, pests, etc., farmers may be concerned about the economic risks associated with using a cover crop, as well (Jaenicke et al., 2003). For example, a farmer may want to choose a cropping system that maximizes expected profit, while at the same time minimizes the variability in profits from year to year and across the field. Lu et al. (1999) found that a cropping system consisting of a corn-soybean [*Glycine Max (*L.) Merr.] rotation with hairy vetch (*Vicia villosa* L.) planted prior to corn and wheat prior to soybean had the lowest yield variability, highest gross margin and second lowest variability in gross margins over time when compared to conservation tillage systems with no cover, no tillage with manure and no tillage with a crown-vetch (*Coronill varia* L.) living mulch. Jaenicke et al. (2001) found that cotton grown after a wheat cover crop was the least risky cover crop alternative in terms of lowering net returns when compared to using no cover crop, crimson clover and hairy vetch. Larson et al. (2001) found that when considering the risk associated with obtaining lower net returns, risk-averse farmers are more likely to adopt a conventional tillage system over a no-tillage system for cotton, when taking into account the cost of planting a cover crop prior to cotton.

Give that soil conditions and topography can differ significantly within a given field, spatial variability may be of interest to a farmer. If conservation tillage systems with cover crops can reduce spatial variability of crop yields, then it may help to reduce variability in net returns. This would have the added benefit of lowering the risk of reduced revenues when converting to conservation tillage systems with cover crops. Given the experiment was conducted on 24-acre field, spatial variability was examined each year by calculating the coefficient of variation for crop yields and net returns for each tillage system, using the data from the cells in the corresponding strips in the field for each treatment examined (Table 4). The coefficient of variation provides a mechanism for comparing variability between different treatments. The results for 2002 provide evidence that conservation tillage systems with cover crops have the potential to reduce spatial variability of crop yields for corn and cotton; and net returns for cotton in years with low rainfall. In years of higher than average rainfall, the use of these mixtures of cover crops may actually increase the spatial variability of yields and net returns, especially for cotton. Thus, a farmer may expect that the conservation tillage system with alternative high residue cover crop examined may reduce the risk of lower net returns in drought years, but may increase the risk of lower net returns in years with more than average rainfall when the system is relatively immature.

CONCLUSION

A review of the literature by Snapp et al. (2005) in the northern Midwest found that the most direct benefit of using cover crops in different cropping systems was an increase in crop yields. A secondary benefit was greater long-term yield stability, especially in drought years. Both of these benefits are evidenced in this study. The use of mixtures of high-residue cover crops, while being more costly to plant than a single species, did increase yields for both corn and cotton; decreased the risk of obtaining lower crop yields for corn and cotton; and decreased the risk of lower net returns in drought years for cotton, when compared to a conventional tillage system with no cover crop. Given that the conservation system with cover crop used in the experiment was relatively immature, we would expect that these benefits would become more evident over time.

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Table 1: Yield for different tillage systems: 2001 – 2003.[a]

	Corn		Cotton	
	Tillage System			
	Conventional Tillage	Conservation Tillage	Conventional Tillage	Conservation Tillage
	bu/ac		lint lb/ac	
2001	154	161	959	1078
2002	111	141	438	559
2003	195	206	1032	1188

[a] Terra *et al*. (2004) found that differences between yields was statistically significant when comparing across tillage systems ($p < 0.001$) using a mixed model.

Table 2: Estimated revenues and costs for different tillage systems for 2003 and estimated net returns for 2001 to 2003.

	Corn		Cotton	
	Tillage System			
	Conventional Tillage	Conservation Tillage	Conventional Tillage	Conservation Tillage
	$/acre		$/acre	
Gross Receipts – Spot Price[a] (Corn: $2.61/bu, Lint: $0.56/lb)	$509.60	$538.06	$652.04	$750.27
Farm Payments[b]	25.20	25.20	103.63	103.63
Variable Costs of Crop Production				
Seed and Technology Fees	30.80	30.80	50.03	50.03
Fertilizer and Lime	71.43	71.43	53.43	53.43
Pesticides	31.16	38.10	65.60	72.54
Growth Regulators and Harvest Aids	0.00	0.00	21.31	21.31
Scouting and Soil Testing	8.00	8.00	16.00	16.00
Drying/Hauling/Storage	29.29	30.92	103.24	118.79
Crop Insurance	0.00	0.00	18.00	18.00
Tractor/Machinery	23.94	19.49	56.07	50.68
Interest on Operating Capital	6.32	6.68	12.47	13.02
Labor	22.12	16.25	35.43	31.79
Total Variable Costs	223.06	221.67	431.58	445.59
Fixed Costs of Crop Production				
Tractor and Machinery	64.87	55.01	75.21	70.87
General Overhead	14.07	13.85	27.73	28.97
Total Fixed Costs	78.94	68.86	102.94	99.84
Cost of Cover Crop				
Seed		115.40		45.20
Fertilizer/Machinery/Labor		10.03		19.73
NRCS Cost Share[c]		-40.00		-40.00
Total Cost of Cover Crop		85.43		24.93
Total Costs	302.00	375.96	534.52	570.36
Net Return[d]				
2001	$96.43	$58.96	$80.40	$149.85
2002	$64.67	$82.73	-$113.83	-$68.71
2003	$232.80	$187.30	$221.15	$283.54

Sources: AAES, 2004; NRCS, 2005; Terra *et al*., 2004.

[a] Estimates of gross receipts for cotton include sales of cottonseed at $0.04 per lb.

[b] Farm Payments include direct, countercyclical and loan deficiency payments. The loan deficiency payments varied by year due to fluctuations in crop prices. State average yields and prices were used to calculate all payment levels. Payment levels are the same for both tillage systems for each crop, because the basis was determined assuming conservation tillage was used prior to 2001 on the entire field.

[c] NRCS cost share is based on EQIP payment levels as of 01/12/05 for residue management at a fixed rate of $40/acre for 50%+ residue at planting (NRCS, 2005). This amount is subtracted from the total cost of planting the cover crop.

[d] Net return is equal to gross receipts plus farm payments minus total cost.

Table 3: Increase in net returns per acre for a conservation tillage system with high residue cover crop mixtures above a conventional tillage system using different prices of cover crop seed and spot prices for corn and cotton in 2002.

Spot Price[a]	Price of Cover Crop Seed[b]			
	$0.20/lb	$0.16/lb	$0.12/lb	$0.08/lb
Corn				
$2.72/bu	$45.49	$49.49	$53.49	$57.49
$2.75/bu	$46.37	$50.37	$54.37	$58.37
$2.80/bu	$47.87	$51.87	$55.87	$59.87
$2.85/bu	$49.37	$53.37	$57.37	$61.37
$2.90/bu	$50.87	$54.87	$58.87	$62.87
$3.00/bu	$53.87	$57.87	$61.87	$65.87
Cotton[c]				
$0.44/lb	$34.04	$38.04	$42.04	$46.04
$0.47/lb	$37.67	$41.67	$45.67	$49.67
$0.50/lb	$43.73	$47.73	$51.73	$55.73
$0.55/lb	$49.78	$53.78	$57.78	$61.78
$0.60/lb	$61.89	$65.89	$69.89	$73.89
$0.70/lb	$80.05	$84.05	$88.05	$92.05

[a] Spot price for cotton is for cotton lint. Spot price for cottonseed is assumed to be $0.04/lb
[b] It is assumed that the price of seed for white lupin, rye and black oat change and the price of seed for crimson clover and fodder radish are equal to $0.80/lb.
[c] Loan deficiency payments were calculated using average spot and loan market price in Alabama, resulting in a difference of $9.68 due to difference in cotton yields between the conventional and conservation tillage systems.

Table 4: Spatial variability in the field for different tillage systems with cover crops for corn and cotton.

Crop[a]	**Year**	**Tillage System**	**Coefficient of Variation**[b]	
			Yield	**Net Returns**
Corn	**2001**	**Conventional**	12.43	62.32
		Conservation	14.96	584.23
Cover Crops: Group 1	**2002**	**Conventional**	24.29	264.82
		Conservation	16.16	1706.10
	2003	**Conventional**	7.03	14.15
		Conservation	6.46	26.34
Cotton	**2001**	**Conventional**	9.49	8.87
		Conservation	9.48	9.21
Cover Crops: Group 2	**2002**	**Conventional**	21.68	12.19
		Conservation	12.53	11.43
	2003	**Conventional**	7.12	29.01
		Conservation	7.59	35.05

[a] Group 1 is white lupin, crimson clover and fodder radish. Group 2 is black oat and rye.

[b] The coefficient of variation is equal to $\left(\frac{\text{standard deviation}}{\text{mean}}\right)\times 100$ and is a measure of how much a variable will vary around its own mean.

ECONOMICS OF LIME IN ALTERNATIVE COTTON COVER CROP AND TILLAGE SYSTEMS

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ABSTRACT

Soil acidity and cotton yields are influenced by cover crop, nitrogen, and tillage method. Applying half the University of TN Extension recommended lime rate resulted in cotton lint yields and net revenues that were either comparable or greater than the full lime rate for both conventional and no tillage systems. Hairy vetch was associated with the largest net revenue and lint yield among the cover crop options, while crimson clover had the lowest lint yield and net revenue.

INTRODUCTION

Conservation tillage practices such as no tillage and winter cover crops have been shown to improve soil quality by increasing organic matter, reducing erosion, and improving water-holding capacity. Grass covers immobilize excess nitrogen in the soil during winter thus preventing nitrogen leaching into groundwater. Legumes provide nitrogen to the next crop while reducing the need for commercial nitrogen fertilizer. Winter cover crops increase production costs due to establishment costs combined with changes in nitrogen requirements.

The build up of plant materials and surface placement of fertilizer can influence soil properties such as soil pH. No tillage in combination with surface applied nitrogen can result in the top few inches of the soil becoming more acidic due to nitrification. As a result, the productivity of nitrogen fertilizers in a no tillage system may be affected by lower soil pH levels, requiring additional liming and increasing production costs.

Lime has long been viewed as a crop production input providing certain benefits, but those benefits come with a cost. If crop yields are increased with lime application and the cost of the lime and its application is less than the increase in total revenue from the additional yield, lime can be viewed as profitable. The objective of this research was to determine cotton profitability and lint yields for lime applied at the full University of Tennessee Extension recommended rate and half the recommended rate for various cover crop, nitrogen rate, an tillage alternatives.

MATERIALS AND METHODS

Cotton yield data for 1995 through 2001 were obtained from a long-term winter cover crop experiment at the West TN Experiment Station, Jackson, TN. Cotton was planted on conventional and no tillage plots after four cover crop alternatives and four nitrogen fertilizer rates. After letting pH deteriorate by delaying the regular application of lime for several years, plots were split into blocks that were randomly assigned two lime rates in 1995 - 100% of the recommended University of TN Extension lime rate and one-half the recommended lime rate.

A quadratic yield response function was estimated using the data for each winter cover alternative. Estimated yield response functions were used to predict profit-maximizing nitrogen fertilizer rates, yields, costs, and net revenues above variable and fixed production costs.

RESULTS AND DISCUSSION

Nitrogen significantly increased yields for all cover crop alternatives except crimson clover. No tillage was significantly different from zero for hairy vetch and crimson clover and positively influenced yields. The time variable included to represent the long-term effects of lime was significant for the no cover and wheat alternatives. However, the interaction term for time and tillage was significant for all four cover crop alternatives.

No tillage consistently produced higher lint yields and net revenues compared to conventional tillage for all four cover crop options; however, profit-maximizing nitrogen rates were about the same among the two tillage methods. Overall, the legume covers required the least amount of nitrogen fertilizer with crimson clover requiring no application of nitrogen in a no tillage system. The profitability of the half and full rates of lime were about the same.

CONCLUSION

When using hairy vetch and crimson clover covers, no tillage was significant in increasing lint yields compared to conventional tillage. Among the cover crop options, hairy vetch resulted in the largest net revenue and lint yield when using the half rate of lime and no tillage. Using a winter cover of crimson clover did not require nitrogen fertilizer, but resulted in the lowest net revenues and lint yields among the tillage methods and lime rates. Cotton lint yields and net revenues achieved with one-half the University of TN Extension recommended rate of lime were either comparable or greater than the full rate of lime for both tillage methods.

WINTER WEED SUPPRESSION BY WINTER COVER CROPS IN A CONSERVATION-TILLAGE CORN AND COTTON ROTATION

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ABSTRACT

An integral component of a conservation-tillage system in corn (Zea mays L.) and cotton (*Gossypium hirsutum* L.) is the use of a winter cover crop. A field experiment was initiated in 2002 to evaluate winter weed dynamics following various winter cover crops in both continuous cotton and a corn and cotton rotation. Winter cover crops included black oats (*Avena strigosa* Schreb.); two crimson clover entries (*Trifolium incarnatum* L.); two cultivars of forage rape (*Brassica napus* L. var. *napus*), spring and winter; oil radish (*Raphanus sativus* var. *oleiformis Pers.*); three cultivars of turnip (*Brassica rapa* L. *subsp. rapa*); white lupin (*Lupinus albus* L.); and a mixture of black oat and lupin. Two-year conservation-tillage rotational sequences included conventionally tilled continuous corn and cotton winter fallow systems as controls. The 10 conservation-tillage, winter cover-crop systems investigated were three continuous cotton systems that alternated a winter legume (lupin or clover), six cotton-corn systems, where lupin preceded cotton and radish, rape, or turnip preceded corn, and a cotton-corn system that had a lupin-black oat mixture as a winter cover crop every year. Use of lupin or 'AU Robin' clover resulted in weed biomass reduction of up to 80% and 54%, respectively, in weed biomass compared to the fallow system. The highest yielding corn-cotton conservation tillage rotation with a winter cover yielded 200 lbs/acre more that the continuous cotton winter fallow system. Continuous conventional corn with winter fallow yielded 30 bu/acre less than the highest yielding 2-yr, conservation tillage winter crop system.

INTRODUCTION

Winter cover crops utilized in a conservation tillage system increases soil carbon, water infiltration, and availability while reducing soil erosion. Cereal rye (*Secale cereale* L.) and soft red winter wheat (*Triticum aestivum* L.) are the two most common winter cover crops recommended for corn and cotton production in the southeastern U.S. with the addition of vetch and annual clover for corn (Jost et al. 2004; Mask et al. 1994; McCarty et al. 2003; Monks and Patterson 1996). However, alternative cover crops are increasingly being used and developed for use in corn and cotton for reasons including nutrient cycling, pathogen control, and weed suppression. Black oat has recently been introduced in the southeastern U.S. through a joint release between USDA-ARS, Auburn University, and The Institute of Agronomy of Paraná, Brazil, and is currently marketed as "SoilSaver black oat" (Bauer and Reeves 1999). AU Homer is a bitter (high alkaloid) white lupin (*Lupinus albus* L.) developed at Auburn University as a winter cover crop for cotton production systems.

The use of cover crops in conservation tillage offers many advantages, one of which is weed suppression through physical as well as chemical allelopathic effects (Nagabhushana et al. 2001; Phatak 1998). Cover crops contain allelopathic compounds that inhibit weed growth (Akemo et al. 2000; Chase et al. 1991; Perez and Ormeno-Nunez 1991; Yenish et al. 1996). Residues from

Brassica crops have been shown to have biotoxic activity against many soilborne pathogens and pests, including weeds (Chew, 1988; Peterson et al. 2001). However, little research has been conducted evaluating winter weed suppression provided by winter cover crops. Two of the most troublesome southeastern weeds in glyphosate tolerant cotton are cutleaf eveningprimrose [*Oenothera laciniata* (Hill) Cronq.] and glyphosate resistant horseweed (*Conyza canadensis* L.). Winter cover crops that displace troublesome winter weeds may offer growers an alternative control strategy.

Crop rotation is also an important component of cotton production in the Southeast. Because cotton is the main cash row-crop for many growers, much of the acreage is in continuous cotton. Continuous cotton production causes many problems including increased soilborne pathogen populations and an increase in hard to control weeds due to the lack of herbicide chemistry rotation. Rotations with corn are typical, due to the lower production costs, ease of production, and because corn is a non-host to many cotton pathogens.

While some reported research has evaluated weed-suppressive qualities of winter cover crops, few experiments have evaluated winter weed suppression prior to cash crop planting following the use of alternative winter covers in rotation. Therefore, our objective was to evaluate weed dynamics and cash crop yields following various winter cover crops within 10 different conservation-tillage corn-cotton rotations. Weed dynamics following continuous corn and cotton grown in a conventional-tillage winter fallow system were also included.

MATERIALS AND METHODS

An experiment evaluating winter cover crop sequence preceding a 2-yr corn-cotton rotation was established in autumn 2001 at the Field Crops Unit, E.V. Smith Research and Extension Center of the Alabama Agricultural Experiment Station, Shorter, AL. The experimental design was a standard RCB with two replicates. In autumn 2002, the identical experiment was established again, thus ensuring that both phases of the 2-yr rotation could be evaluated each year. Soil at the experimental site is a Compass loamy sand. Winter cover crops included black oats (*Avena strigosa* Schreb.) cv. SoilSaver; crimson clover (*Trifolium incarnatum* L.) cvs. AU Robin and Dixie; two cultivars of forage rape (*Brassica napus* L. var. *napus*), spring (cv. Liforum) and winter (cv. Licapo); oil radish cv. Rufus (*Raphanus sativus* var. *oleiformis Pers.*); cultivars Civastro, Rondo, and Common of turnip (*Brassica rapa* L. *subsp. rapa*); bitter (high alkaloid) white lupin (*Lupinus albus* L.) cv. AU Homer; and a mixture of 80% lupin and 20% black oat by weight. Two-year conservation-tillage rotational sequences included conventionally tilled continuous corn and cotton winter fallow systems as controls (Table 1). The 10 conservation tillage winter cover crop systems investigated were three continuous cotton systems that alternated a winter legume (lupin or clover) with black oats, six cotton-corn systems, where lupin preceded cotton and radish, rape, or turnip preceded corn and black oats preceded cotton, and a cotton-corn system that had a lupin-black oat mixture as a winter cover crop every year.

The seeding rate was 4 lb/ac for all *Brassica* species. Oil radish was seeded at 8 lb/ac, clovers at 20 lb/ac, black oat, lupin, and the mixture at 90 lb/ac. Fifty lb/ac of nitrogen (N) as ammonium nitrate was applied to all non-leguminous cover crops in autumn of 2002 and 2003 after establishment. Cover crops were seeded with a no-till drill in early November of each year and terminated 2 to 3 wk prior to planting corn and cotton in early April and May, respectively.

Covers were terminated each year with an application of glufosinate at 0.46 lb ai/ac utilizing a compressed CO_2 backpack sprayer delivering 15 gal/ac. Additionally, biomass from winter weeds and winter cover crops were measured in all plots immediately before glufosinate application in all years. The aboveground portion of each winter cover crop was clipped from two randomly selected 10.7-ft^2 sections in each plot, dried at 140 F for 72 h, and weighed. Winter weeds were measured similarly in three 10.7-ft^2 sections in each plot, including winter fallow.

Corn hybrids Pioneer 3455LL and Dekalb 6972RR were planted in spring 2003 and 2004, respectively. The cotton cultivars Surgrow 501BGRR and Stoneville 5242BGRR were planted in spring 2003 and 2004, respectively. Corn seed was planted with a six-row planter at a seeding population of 28,000 seed/ac. Cottonseed was planted with a 4-row planter at a seeding population of 80,000 seed/ac. Both planters were a John Deere MaxEmerge®[1] equipped with row cleaners and double-disk openers. Plots were 60 ft long and 30 ft wide, accommodating either 12 rows of corn (30 in row width) or eight rows of cotton (40 in row width). Because the site had a well-developed hardpan each year, the experimental area was in-row sub-soiled prior to planting with a narrow-shanked parabolic subsoiler, equipped with pneumatic tires to close the subsoil channel. Conventional-tillage plots were prepared utilizing a disk harrow and a 14 ft tractor-mounted rototiller. Alabama Cooperative Extension System recommendations were used for insect control and nutrient management. Crops were harvested from the eight center rows for corn and the four center rows for cotton.

Data were analyzed by analysis of variance using mixed model methodology as implemented in SAS Proc Mixed (Littell et al., 1997). Rotation (tillage plus cover crop + cropping sequence) was considered a fixed effect, whereas replicates, years, and their interactions with rotation were considered random effects.

RESULTS AND DISCUSSION

As expected from experience and previous conservation tillage systems research in the southeastern USA, continuous cropping utilizing winter fallow had the lowest cotton and corn yields (Table 1). Using an average 2:1 ratio of seed to fiber, the difference between cotton lint yield between the highest yielding corn-cotton conservation tillage rotation (No. 10) and continuous conventional cotton with winter fallow was over 200 lbs/acre. Continuous conventional corn with winter fallow yielded 30 bu/acre less then the highest yielding 2-yr, conservation tillage winter crop system (No. 12). Research conducted by Raper et al. (2003) and Terra et al. (2005) on Coastal Plain sites in southeastern USA established that it is absolutely essential to include cover crops as an integral part of conservation tillage systems.

The average total combined biomass for winter covers was 928 lbs/acre preceding cotton compared to 447 lbs/acre for the corn phase. The difference is the combined effect of cover crops and delayed termination for cotton (approximately 3 wk) compared to corn.

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[1] Mention of trade names or commercial products in this manuscript is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U. S. Department of Agriculture.

Cover crop biomass yields ranged from 261 lbs/acre for the oil radish cv. Civastro preceding corn to 1259 lbs/acre for the lupin plus black oat mixture preceding cotton (Table 2). The difference in yield between AU Robin and Dixie is due to the fact that the termination date for cover crops preceding cotton was in late April, which favors the later-maturing cultivar Dixie. AU Robin was specifically developed for early maturity in corn production systems (van Santen et al., 1992). Pure legume cover crops (lupin and crimson clovers) produced significantly more biomass (500 lbs/acre; $P < 0.01$) than rape, turnip, and radish. However, crop yields in general were not related to the amount of biomass produced by the preceding cover crop.

Most cover crop systems had numerically less weed biomass than the fallow system (Table 2), except for the turnip cultivar Rondo preceding corn and two systems that contained lupin preceding cotton. However, two systems that contained lupin resulted in up to 80% reduction in weed biomass compared to the fallow system. The system that contained AU Robin preceding cotton reduced weed biomass 54% compared to winter fallow. The lupin and black oat mixture provided a 40% reduction in weed biomass preceding corn but was less effective preceding cotton. Winter weeds in both years consisted of chicory (*Cichorium intybus* L.), corn spurry (*Spergula arvensis* L.), cudweed (*Gnaphalium* spp.), cutleaf eveningprimrose, knawel (*Scleranthus annuus* L.), and wild radish (*Raphanus raphanistrum* L.).

CONCLUSIONS

It should be emphasized that this experiment is in its early stages. The current consensus is that crop rotation studies don't reach their "equilibrium" before the fifth cropping season. Based on experience in other studies, we can expect that the differences between fallow and rotation treatments most likely will increase.

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Table 1. Tillage, cover crop treatments, and crop yields for the crop rotation study conducted at the Field Crops Unit, E.V. Smith Research and Extension Center of the Alabama Agricultural Experiment Station, Shorter, AL for crop years 2002/3 and 2003/4.

		Rotation				Crop yield					
		Phase 1		Phase 2		Seed cotton			Corn		
No.	Tillage	Autumn	Spring	Autumn	Spring	Yield	Rank	StdErr	Yield	Rank	StdErr
						lbs acre^{-1}			bu acre^{-1}		
1	Conventional	Fallow	Cotton	Fallow	Cotton	2170	10	485			
2	Conventional	Fallow	Corn	Fallow	Corn				83	8	10
3	Subsurface only	Lupin	Cotton	Black oats	Cotton	2389	5	485			
4	Subsurface only	AU Robin	Cotton	Black oats	Cotton	2344	8	485			
5	Subsurface only	Dixie	Cotton	Black oats	Cotton	2261	9	485			
6	Subsurface only	Raddish	Corn	Lupin	Cotton	2722	4	505	97	2	12
7	Subsurface only	Civastro	Corn	Lupin	Cotton	2108	11	505	95	5	12
8	Subsurface only	Licapo	Corn	Lupin	Cotton	2811	2	505	97	3	12
9	Subsurface only	Liforum	Corn	Lupin	Cotton	2378	6	505	92	6	12
10	Subsurface only	L + BO†	Corn	L + BO†	Cotton	2825	1	505	90	7	12
11	Subsurface only	Rondo	Corn	Lupin	Cotton	2369	7	505	96	4	12
12	Subsurface only	Common	Corn	Lupin	Cotton	2745	3	505	113	1	12

† Mixture of 80 % lupin and 20 % black oats by weight.

Table 2. Cover crop and weed biomass yields for the crop rotation study conducted at the Field Crops Unit, E.V. Smith Research and Extension Center of the Alabama Agricultural Experiment Station, Shorter, AL for crop years 2002/3 and 2003/4.

Rotation	Preceding cotton					Preceding corn				
	Cover			Weeds		Cover			Weeds	
No.	Name	Yield	StdErr	Yield	StdErr	Name	Yield	StdErr	Yield	StdErr
1	Fallow	0	291	939	253					
2						Fallow	0	273	995	279
3	Lupin	884	299	721	253					
4	AU Robin	742	291	432	253					
5	Dixie	1085	291	607	292					
6	Lupin	814	335	306	358	Raddish	535	329	680	348
7	Lupin	851	335	1043	358	Civastro	261	329	563	348
8	Lupin	826	335	190	358	Licapo	793	329	449	348
9	Lupin	1027	335	338	417	Liforum	356	329	648	348
10	L + BO†	1259	335	875	358	L + BO†	297	329	387	348
11	Lupin	860	335	531	358	Rondo	430	329	1374	348
12	Lupin	929	335	1029	358	Common	458	368	903	348

† Mixture of 80 % lupin and 20 % black oats by weight.

TILLAGE EFFECTS ON COTTON AND FLAX

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ABSTRACT

The purpose of this study was to determine if various tillage and sub-soiling techniques were detrimental or beneficial to winter flax (*Linum usitatissimum L.*) yields under South Carolina conditions. Flax was double-cropped with cotton. Subsoiling increased the cotton and flax yield which is similar to findings for other crops on southeastern USA Coastal Plain soils. Cotton yields were not influenced by tillage treatment while flax dry plant matter yields were significantly greater for chisel and disk treatments than for no tillage. For the fiber properties studied, micronaire, fiber length, and fiber length uniformity of cotton along with flax fiber strength were impacted by the tillage management studied. Cotton fiber properties are such that conservation systems appear to be a viable option for growers due to fiber property improvements. Fiber flax yield and fiber properties indicate additional field preparation may be required to produce increased yields with improved fiber properties. Our results indicate that conservation tillage practices can be beneficial for cotton production under Florence, SC growing conditions but additional research on improved techniques is needed for the production of fiber flax with this management practice.

INTRODUCTION

Flax (*Linum usitatissimum L.*) is a dual purpose crop from which seed and fiber can be removed at varying degrees depending upon its agricultural production (Parks et al., 1993). Compared to flax grown for seed, fiber flax plants are taller, have fewer branches, produce more fiber, have lower oilseed content and produce less seed (Anonymous, 1992). Long growing seasons and production of flax as a winter crop allows the land to be utilized for cotton and flax fiber, thereby providing growers two fiber crops. There are limited studies, however, related to flax double-cropped with cotton (Bauer and Frederick, 1997) and physical properties of flax fiber related to soil conditions (Elhaak et al., 1999).

Soil nutrients are known to affect fiber quality (Mikhailova, 1975, Tarent'ev et al., 1976, and Hocking et al., 1987). Southeastern Coastal Plain soils typically have a shallow soil layer with coarse texture that limits root depth and lowers water storage so that deep tillage is recommended to boost available water and avoid yield reductions in drought (Camp et al., 1999).

Seed flax grows well in reduced tillage with flax yields equal or much higher than in conventional tilled plots (Gubbels and Kenaschuk, 1989, Brandt, 1992, Lafond, 1993). Tillage affects cotton fiber quality and yield inconsistently as an indirect response due to a shift in the growing season relative to conventional tillage (Pettigrew and Jones, 2001, Bauer and Frederick, 2005). No-till produces cotton fibers with higher fiber length uniformity and may help reduce cotton bale variability (Bauer and Frederick, 2005). Bauer and Frederick (2005) indicate that tillage management may control canopy position specific property distribution. Little is known about the impact of tillage or sub-soiling on the quality or variability of flax fiber quality.

The purpose of this study was to evaluate the production of cotton and flax in consecutive harvests under various tillage and subsoiling techniques. Further, yields and properties of cotton and winter flax fibers under South Carolina conditions were determined for the various tillage techniques.

MATERIALS AND METHODS

'Laura' flax was grown in northeastern South Carolina as a winter crop. Flax was planted at seeding rates of 100 lb ac^{-1}. This variety was selected for this study because of its potential as a dual crop for both seed and fiber. Plots were planted in the fall of 2001-2002 and 2002-2003 in Darlington County at the Pee Dee Research and Education Center located near Florence, SC (latitude 34^{o} 17' North and longitude 79^{o} 41' West). Soil was Eunola loamy sand (fine-loamy, siliceous, thermic Aquic Hapludult), and the previous summer crop was cotton. The sixteen plots were irrigated with subsurface alternate furrow drip irrigation (Geoflow Rootguard, Corte Madera, CA). Laterals had in-line labyrinth emitters 2 ft apart that delivered 0.45 gal hr^{-1} of water. Flax was planted using a John Deere 750 No-Till Drill (Deere & Company, Moline, IL). Treatments were arranged as a randomized complete block of sixteen plots with four replications. Plots were 50 ft long and 25 ft wide. Rows were spaced at 8 in.

The studies were carried out in plots located adjacent to each other, and each plot received different land preparation. Soil surface tillage treatments included: 1.) no tillage, 2.) disking the soil twice to a depth of 6 in then smoothed with a harrow equipped with s-shaped tines and rolling baskets, and 3.) chisel plowing with a 7 ft wide seven shank KMC chisel (Kelly Manufacturing Co., Tifton, GA) to a depth of 8 in, disked twice to a depth of 6 in and then smoothed with a harrow equipped with s-shaped tines and rolling basket. For each of these three techniques, sub-soiling was either not done or performed to a depth of 16 in with a KMC (Kelly Manufacturing Co., Tifton, GA) straight 45 degree forward angled subsoiler shanks spaced 3 ft apart.

Surface tillage and subsoiling treatments before planting cotton were performed on May 31 in 2001 and May 14 in 2002. Cotton (variety DP 458BRR) was planted in 38 in wide rows at 4 plants per ft on June 4, 2001 and May 15, 2002 using a 4 row Case-IH 900 series planter (Case IH, Racine, WI) equipped with Yetter wavy coulters (Yetter Manufacturing, Colchester, IL). A pre-plant fertilizer application (58 lb ac^{-1} P_2O_5, 100 lb ac^{-1} K_2O, 10 lb ac^{-1} S, and 0.5 lb ac^{-1} B was made on March 19, 2001. Nitrogen as ammonium nitrate (120 lb ac^{-1} in 2001 and 80 lb ac^{-1} in 2002) was applied in a split application each year with 40 lb ac^{-1} applied at planting and the rest about a month later when plant had their first flower buds. Each year weeds were controlled with hand weeding and a combination of herbicides (Pendimethalin [0.8 lb ac^{-1}], Fluometuron [1.0 lb ac^{-1}], Glyphosate [1.0 lb ac^{-1}], Prometryn [0.5 lb ac^{-1}], Sethoxydim [1.2 lb ac^{-1}], and Monosodium methyarsonate [2.0 lb ac^{-1}]). In mid to late October, cotton was chemically defoliated with thidiazuron (N-phenyl-N-1,2,3-thiadazol-5-urea) and S,S,S-tributyl phosphorotithioate, and bolls were opened with ethephon [(2-chloroethyl) phosphonic acid] at the recommended rates each year. Plots were harvested on November 7, 2001 and October 28, 2002. Two interior rows were harvested using a two-row spindle picker for seed cotton yield.

After harvest, plants located within interior rows were counted. Each harvest bag was sub-sampled and saw-ginned to determine lint yield. Fiber qualities were graded according to HVI techniques (ASTM International, 1993)

After cotton harvest, cotton stalks were shredded in the field. In 2001-2002, fertilizer (7-21-32) was applied on November 13 at a rate based upon soil test results and Clemson University Cooperative Extension Service recommendations for small-grain production, applying 20 lb nitrogen, 60 lb P_2O_5, and 90 lb K_2O per ac. Tillage treatments were performed before planting flax on November 19 with sub-soiling performed on November 20. Planting date was November 27. On February 15, all plots received 60 lb N ac^{-1} applied as ammonia nitrate. Bromxynil herbicide was applied at a rate of 0.5 lb a.i. ac^{-1} on March 8. Flax stands were drip irrigated with 0.25 in of water on April 19 and April 22. Flax stand was cut with a drum mower on May 1 at the onset of flowering for straw yield. Dried flax stalks were harvested on May 8 using a rectangle baler. Samples were bagged, dried at 160 ^{o}F for 48 hours, and weighed.

In 2002-2003, 1000 lb ac^{-1} of dolomitic limestone to reduce soil acidity along with fertilizer (7-21-32) was applied on October 30 at a rate based upon soil test results and Clemson University Cooperative Extension Service recommendations for small-grain production, applying 20 lb nitrogen, 60 lb potassium, and 90 lb phosphorous per ac. Tillage and sub-soiling treatments were performed on selected plots on October 31. Planting date was Nov 4. On February 15, all plots received 66 lb N ac^{-1} applied as ammonia nitrate. Bromxynil herbicide was applied at a rate of 0.5 lb a.i. ac^{-1} on March 5. Flax was harvested on May 7 at the onset of flowering for straw yield. Samples were bagged, dried at 160 ^{o}F for 48 hours, and weighed.

Flax stalks were collected and transported to the Cotton Quality Research Station, ARS-USDA, Clemson, SC, where the bast fibers were released from the stem by a process termed dew-retting in which indigenous fungi and bacteria colonize and partially decompose the plant stems of flax. Following dew-retting the plant stalks were processed through the typical set-up for the USDA Flax Fiber Pilot Plant (Flax-PP) according to Foulk et al. (2004). These modules are 32 in rather than 48 in (commercial line) and built under specifications of the commercial ‘Unified Line’, which was delivered by Czech Flax Machinery, Měřín, Czech Republic (Akin et al., 2004). The components comprising the USDA Flax Fiber Pilot Plant are the following: a 9-roller crushing calender, top shaker, scutching wheel, and 5-roller calender. Flax-PP fiber yield is the percent of fiber separated from the dew-retted flax stalks.

Flax-PP cleaned fibers maintain their length through processing and require cottonizing (fiber length and fineness comparable to cotton) for textile applications. The Shirley Analyzer (SDL America, Charlotte, NC) shortens flax fibers and separates foreign matter and coarse fibers from the finer fibers (Pfeiffenberger, 1944). Fine fiber yield is the percent of fine fiber separated from the Flax-PP cleaned fiber. Shirley-cleaned fibers were analyzed for strength and elongation using the Stelometer, based on the methods developed for cotton (ASTM International, 1999a), and for fineness using air flow, based on the micronaire (ASTM International, 1999b) that was modified to use 5.0 g fiber samples based on calibration with flax fineness standards from the Institut Textile de France, Lille, France (Akin et al., 1999).

RESULTS AND DISCUSSION

In the southeastern USA, conservation tillage systems are being widely used for cotton production and other crops. Subsoiling allows plants to more easily penetrate the soil and locate water as well as nutrients. Soil strength appears to limit rooting depth, development, and irrigation effects (Camp et al., 1999). In this study, differences for the fiber properties and yield existed between years. The yield and fiber quality responses to tillage were similar for both years as no year X tillage interactions were significant in any year of the study. Therefore, data presented are averaged over years. The effect of subsoiling, determined by combining the three tillage techniques for subsoiling or not, was to increase lint yields for cotton and plant yields for flax (Tables 1 and 3). Combining all tillage techniques, the only significant difference (at the 0.05 level) observed in subsoil treatments for cotton production was the cotton yield which was larger (967 vs. 850 lb lint/ac) with subsoiling. Combining all tillage techniques, at the 0.1 level, flax dry plant matter yields (Table 3) were significantly higher with subsoil treatment (1933 vs. 1534 lb plant matter/ac) as were the fiber yields from the Flax-PP (24 vs. 22%). Flax-PP yield is a percent of straw processed through Flax-PP and not based on straw per acre. These results indicate that we can extract the same amount of fiber from straw, regardless of tillage. Yearly subsoiling is typically recommended for Coastal Plain soils (Threadgill, 1982) and provides increased yields of corn, soybean, and wheat (Frederick et al., 1998 and Busscher et al., 2000). Busscher and Bauer (2003) note that omitting deep tillage from management for 2 years may be a viable wide row cotton production practice for fields with controlled traffic. Nevertheless, subsoiling continues to be an option that could increase cotton lint and dry fiber flax plant matter yields.

Cumulative water applied to cotton and fiber flax plants through irrigation plus rainfalls in both years were nearly the same. Equivalent water was applied to each crop but soil treatments varied the soil and surface residue on the soil which may have impacted the plant's rate of water and nutrient uptake and resultant fibers. However, cotton plant population, lint turnout, and lb of cotton per ac were not influenced by tillage treatment (Table 2). Flax dry plant matter yield was significantly larger for disk treatment than for no till treatment (Table 4). This difference in dry plant matter yield did not correlate to increased Flax-PP fiber yields nor increased fine fiber yields from passage through a Shirley Analyzer. Fine fiber yield is a percent of fine fiber separated from the Flax-PP cleaned fiber and not based on straw per acre. The no-tillage system produces a lower fiber flax stalk yield which may have been due to reduced plant populations because fiber flax prefers a good seedbed, weed control, and a flat, uniform, and firm seedbed for germination (Foulk et al., 2003). Reduced plant populations with no-tillage could also have been related to planting date, delayed emergence, and reduced fall growth under wet and cool conditions.

Many phenological models are based on the concept of degree day, which is the difference between daily mean temperature (maximum daily temperature + minimum daily temperature)/2 and a base temperature. Cotton heat units were calculated using a base temperature of 15 ^{o}C. Cotton fiber quality properties are affected by cumulative heat units (Bradow and Davidonis, 2000). Cotton growth and development are dependent upon many factors including early, medium, and full season varieties with cumulative heat unit approximations normally ranging from 1550 to 1850 (Norfleet et al., 1997). In this study, cotton cumulative heat units ranged from 1350 to 1641. Flax heat units were calculated using a base temperature of 5 ^{o}C. Flax yields and stem lengths are affected by cumulative heat units (Sultana, 1992). Sultana (1992) further states that with flax work performed in Europe, cumulative heat units typically fall around 900 for harvesting with 1400 cumulative heat units the optimal for seed, scutched flax, and tow. In this study, flax cumulative heat units ranged from 1161 to 1322. The two different years produced substantially different yields and physical properties for both crops. Cotton lint yield averaged 992 lb ac^{-1} in 2001 and 825 lb ac^{-1} in 2002 while flax stalk yield averaged 1321 lb ac^{-1} in 2001 and 2145 lb ac^{-1} in 2002. Straw yields were low compared to other data (Foulk et al., 2003 and Parks et al., 1993). Overall, cotton fiber in 2001 was significantly longer (1.14 in vs. 1.08 in), more uniform (84% vs. 82%), weaker (29.3 g/tex vs. 30.1 g/tex), and finer (3.9 vs. 5.0) than the cotton fiber in 2002 while flax fiber in 2001 was significantly finer (4.2 vs. 5.0) and weaker (30.9 g/tex vs. 38.5 g/tex) than the flax fiber in 2002. Dew-retting is inconsistent and any flax fiber quality variations could be due to differential retting.

The degree of soil loosening and soil surface characteristics differed among the three tillage systems. Cotton fiber physical properties of length, length uniformity, and micronaire significantly varied at the 0.05 level between the three surface tillage techniques (Table 2). Micronaire values were significantly lower for cotton produced with chisel (4.3) than with disk (4.5) or no-tillage (4.4) treatments. However, no differences were detected for reflectance, yellowness, elongation, or strength of cotton fibers. For cotton production, fiber length from no-till cotton was comparable to chisel plowing but was significantly longer than disk plowing. Disk plowing produced shorter cotton fibers with a significantly lower uniformity. For cotton, micronaire was significantly lower for chisel treatment. A higher fiber length uniformity result from no tillage systems agrees with work performed by Bauer and Frederick (2005). Longer fibers with no-till may be related to more surface residue and the reflected light from the soil surface environment. Kasperbauer (2000) demonstrated that cotton grown over far-red red light reflectors (green and red) were significantly longer and finer than cotton grown over high photosynthetic photon flux reflectors (aluminum and white). In this study, there was generally no effect of tillage treatment on strength suggesting that strength is likely not influenced by tillage practices under the soil and growing conditions tested.

The tillage systems affect on the flax fiber crop production and the physical properties of fibers are shown in Table 3. As indicated by Elhaak et al. (1999) increases in the percentages of α- and hemi-cellulose in flax fibers lead to improved spinnability and fiber strength, which is a function of soil texture and nutrient availability. Elhaak et al. (1999) further state that drought stress can lead to increased deposition of lignin and pectins in plant stems and reduced fiber strength. In this study, flax fiber strength was the only measured physical property that significantly varied at the 0.05 level between 3 tillage systems (Table 4). Flax fiber strength was significantly larger for chisel than no-till crop production systems. This increase in fiber strength may have been related to nutrient availability, moisture retention, and soil surface physical properties created by chisel plowing vs. no-till. Dew-retting is inconsistent and flax fiber quality variations could be due to differential retting. Additional field preparation better incorporates plant residue into the soil thus creating a less compacted surface for early growth.

Double-cropping winter small grains with summer crops and conservation tillage is common throughout the southeast USA. A possible problem for cotton in a flax double crop system is the late planting for cotton (especially if the crop is also harvested for seed). In some years with cool fall temperatures, late harvest of cotton may not allow for timely flax planting. Harvesting flax just for fiber before seeds mature will make this system more reliable for cotton production. Flax production problems may include low soil temperatures in the fall during crop establishment (especially for no tillage flax production) and damage from frost. The amount of foreign matter in flax straw was not evaluated in this study, but may be a concern with commercial flax straw harvesting equipment. More research is needed on many aspects of this system. Nevertheless, conservation tillage management has shown to increase soil organic matter and thereby may improve soil productivity while reducing erosion. Improved conservation tillage management techniques should be developed for successful establishment of a sustainable flax industry in the southeast.

The intention of this study was to determine if various tillage and sub-soiling techniques were detrimental or beneficial to cotton and winter flax yields under South Carolina conditions. As expected, subsoiling increased the cotton and flax yield response which is similar to findings for other crops. In this study, cotton yields were not influenced by tillage treatment while flax dry plant matter yields for disk treatment were significantly greater than no till treatments. For the fiber properties studied, micronaire, fiber length, and fiber length uniformity of cotton along with flax fiber strength were impacted by the tillage management studied. Dew-retting is inconsistent and any flax fiber quality variations could be due to differential retting. Cotton fiber properties are such that conservation systems appear to be a viable option for growers due to fiber property improvements. Fiber flax yield and fiber properties indicate additional field preparation may be required to produce increased yields with improved fiber properties. Increases in straw yield will clearly affect the total fiber yield per acre. Our results indicate that conservation tillage practices can be beneficial for cotton production under Florence, SC growing conditions but additional research is vital for reliable fiber flax production.

Disclaimer

Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture, information is for information purposes only, and does not imply approval of a product to the exclusion of others that may be suitable.

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Table 1.
Cotton yield and fiber quality on 64 cotton grid plot.*

Tillage	Subsoil	Lint turnout (%)	lb lint ac (lb/ac)	Plants per plant row (Plants/1 ft row)	Length [a] (in)	Uniformity [a] (%)	Strength [a] (grams/tex)	Micronaire [a]
Chisel	Yes	39.5a	955 a,b	3.2 a	1.12 a	83.5 a	29.4 a	4.2 b
Chisel	No	39.5 a	883 a,b	2.9 a	1.11 a,b	83.2 a,b	30.0 a	4.4 a
Disk	Yes	39.8 a	980 a	3.0 a	1.10 b	82.6 b	29.3 a	4.5 a
Disk	No	39.6 a	804 b	3.2 a	1.11 a,b	83.1 a,b	30.2 a	4.5 a
No-till	Yes	39.5 a	968 a	3.1 a	1.12 a	83.5 a	29.9 a	4.4 a
No-till	No	39.8 a	865 a,b	3.3 a	1.11 a,b	83.3 a	29.4 a	4.4 a

* Values followed by different letters within columns are significantly different, P<0.05, according to Duncan's New Multiple Range Test.
[a] Fiber properties determined using standard test methods (ASTM International, 1993)

Table 2.
Cotton yield and fiber quality on 64 cotton grid plot. Data are averaged over subsoiling*

Tillage	Lint turnout (%)	lb lint ac (lb/ac)	Plants per plant row (Plants/1 ft row)	Length [a] (in)	Uniformity [a] (%)	Strength [a] (grams/tex)	Micronaire [a]
Chisel	39.5 a	919 a	3.0 a	1.12 a,b	83.3 a	29.7 a	4.3 b
Disk	39.7 a	891 a	3.1 a	1.10 b	82.8 b	29.7 a	4.5 a
No-till	39.6 a	916 a	3.2 a	1.12 a	83.4 a	29.6 a	4.4 a

* Values followed by different letters within columns are significantly different, P<0.05, according to Duncan's New Multiple Range Test.
[a] Fiber properties determined using standard test methods (ASTM International, 1993).

Table 3.
Flax yield and fiber quality on 64 cotton grid plot.*

Tillage	Subsoil	Dry yield (lb/ac)	Flax Pilot Plant yield [a] (%)	Shirley Analyzer yield [b] (%)	Strength [c] (grams/tex)	Elongation [c] (%)	Micronaire [d]
Chisel	Yes	2127 a	23.5 a,b	21.0 a	36.8 a	1.4 a	4.7 a
Chisel	No	1374 a,b	22.5 a,b	23.0 a	35.7 a,b	1.5 a	4.7 a
Disk	Yes	2117 a	22.9 a,b	25.5 a	34.4 a,b	1.3 a	4.6 a,b
Disk	No	1998 a,b	21.4 a	23.7 a	35.0 a,b	1.3 a	4.6 a
No-till	Yes	1552 a,b	25.5 a	21.0 a	33.0 b	1.3 a	4.7 a
No-till	No	1230 b	22.1 a,b	23.8 a	33.3 b	1.3 a	4.4 b

* Values followed by different letters within columns are significantly different, $P<0.05$, according to Duncan's New Multiple Range Test.
[a] Flax-PP fiber yield is the percent of fiber separated from the dew-retted flax stalks.
[b] Shirley Analyzer yield is the percent of fine fiber separated from the Flax-PP cleaned fiber.
[c] Fibers properties determined using a modified test method (ASTM International, 1999a).
[d] Fibers properties determined using a modified test method (ASTM International, 1999b).

Table 4.
Flax yield and fiber quality on 64 cotton grid plot. Data are averaged over subsoiling *

Tillage	Dry yield (lb/ac)	Flax Pilot Plant yield [a] (%)	Shirley Analyzer yield [b] (%)	Strength [c] (grams/tex)	Elongation [c] (%)	Micronaire [d]
Chisel	1750 a,b	23.0 a	22.0 a	36.3 a	1.4 a	4.7 a
Disk	2057 a	22.1 a	24.6 a	34.7 a,b	1.3 a	4.6 a
No-till	1391 b	23.8 a	22.4 a	33.1 b	1.3 a	4.6 a

* Values followed by different letters within columns are significantly different, $P<0.05$, according to Duncan's New Multiple Range Test.
[a] Flax-PP fiber yield is the percent of fiber separated from the dew-retted flax stalks.
[b] Shirley Analyzer yield is the percent of fine fiber separated from the Flax-PP cleaned fiber.
[c] Fibers properties determined using a modified test method (ASTM International, 1999a).
[d] Fibers properties determined using a modified test method (ASTM International, 1999b).

GO BEYOND "T", MANAGE FOR "C"-- USING THE SOIL CONDITIONING INDEX TO ASSESS PROGRESS

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ABSTRACT

Cropland erosion control has long been considered to be sufficient when sheet and rill erosion rates are reduced to a level known as "T", or soil loss tolerance. This level supposedly maintains a steady-state condition in which productive capacity is maintained in perpetuity. While this is a very useful management target, there are questions as to whether "T" soil loss rates are sufficient. Further, it is not uncommon for organic matter levels to trend downward, even though erosion rates are at or below "T", because erosion removes disproportionate amounts of organic matter.

As we strive to streamline soil management and production systems, organic matter improvements are critical to realize both on and off-site benefits. For example, recent and on-going studies show a strong inverse relationship between soil organic carbon and soil bulk density. Also, soil aggregates are positively correlated to organic matter/glomalin levels, yielding on and off-site benefits.

Recent improvements to a soil condition evaluation tool, the Soil Conditioning Index, provides reasonable estimates as to whether the all-important soil organic matter level is trending upward, downward, or level. The degree of erosion control and the amount of plant biomass added are two of the three sub-factors used in a weighted calculation to estimate the trend. A recently completed 5-year demonstration using differing amounts of soil surface biomass with continuous no-till demonstrated the importance of these two factors for soil carbon accrual. A treatment with average annual additions of 2,330 lbs/ac biomass and an erosion rate of 3.0 tons/ac/yr (well below T) gave a -0.17 erosion sub-factor and a -0.46 organic matter sub-factor in the SCI. The overall SCI is barely positive, with only +0.2. The use of 8,140 lbs/ac biomass resulted in a +0.73 erosion sub-factor and a +0.1 organic matter sub-factor. The higher biomass additions gave a +2.0 overall SCI. These results show that soil carbon can be lost (or negligibly accrued) with acceptable erosion rates, even under no-till, without adequate additions of plant biomass.

While reducing soil losses to "T" is certainly a desirable goal, it is no longer appropriate to presume that this is sufficient for today's resource management needs. Fortunately, there is now a tool available to guide decision-makers in the selection and use of environmentally/economically sustainable systems. Calculations of the SCI are automatically made as a part of RUSLE2 soil loss calculations.

GEORGIA'S CONSERVATION TILLAGE EDUCATIONAL TASK FORCE: IMPROVING COUNTY EXTENSION AGENTS' UNDERSTANDING OF CONSERVATION TILLAGE SYSTEMS

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ABSTRACT

Farmer interest in conservation tillage has increased with rising fuel prices, the new Conservation Security Program, decreasing commodity prices and desire for improved resource stewardship. Research has shown that farmer's see maximum benefit to conservation tillage if it is part of a cropping system that includes cover crops and crop rotation. The conservation tillage system best suited for a particular operation will vary with the crop, the site, the soils, and other factors. Many county extension agents in Georgia indicated they needed further training to meet the informational needs of their farmers. Consequently, the University of Georgia College of Agricultural and Environmental Sciences created a multi-disciplinary conservation tillage educational task force to develop a training program. The College recognized the need for input from other agencies that had extensive experience in conservation and management of natural resources. The task force includes UGA-CAES faculty, USDA-NRCS personnel, USDA-ARS research scientists, and non-governmental representatives. A survey of the county agents was conducted to determine specific training needs and attitudes towards conservation tillage. The survey indicated most county agents had a positive attitude towards conservation tillage systems, but their knowledge was weak on the differences between conservation tillage systems and conventional systems in terms of inputs, equipment, changes in soil quality and fertility, effects on yields and quality of different commodities, and specifics on how to implement conservation tillage practices. The survey also indicated that more information on the economics of conservation tillage systems was needed. Agents preferred a combination of classroom and field training. The results of the survey are being used to develop specific training modules with the purpose of improving the knowledge level of county agents on conservation tillage systems.

USDA'S CONSERVATION SECURITY PROGRAM: PROVIDING INCENTIVES TO PROTECT AND ENHANCE NATURAL RESOURCES

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ABSTRACT

With the signing of the 2002 Farm Bill, President George W. Bush authorized the implementation of the Conservation Security Program (CSP), a conservation stewardship program. In describing the new program, Bruce Knight, Chief of USDA's Natural Resource Conservation Service, said, "CSP rewards the best and motivates the rest." CSP provides for payments to producers for maintaining effective conservation treatments on cropland and grasslands; implementing new conservation practices; and using resource treatment enhancements beyond the requirements of NRCS's conservation practice standards. For program eligibility the cropland/grassland must, as a minimum, treat soil quality and water quality concerns to meet NRCS quality criteria for resource protection. Base payments to the producer are greater if other resource concerns such as air quality, wildlife habitat, plant and animal health, irrigation water efficiency, and energy efficiency are also treated. In addition, incentives are provided for the implementation of treatment enhancements beyond the minimum requirements to meet resource quality criteria and the respective conservation practice standards. Examples include long-term no tillage systems, use of cover crops, precision ag systems, and integrated pest management. To assess resource conditions, NRCS uses several available models such as RUSLE2 and WEQ and numerous special assessment tools such as the soil conditioning index, pasture condition score, irrigation efficiency index, and the wildlife habitat index. The Conservation Security Program is a national program. However, because of fund limits, contracts were limited to eighteen selected river basin size watersheds in the pilot year (2004). With a significant increase in allocated funds, program participation has been extended to 202 additional watersheds for 2005.

Characterization of Soil Gas Efflux Patterns Associated with Tillage Implements

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Abstract

Soil disturbance can result in the rapid loss of carbon from soil in the form of carbon dioxide (CO_2). However, soil CO_2 loss characteristic of different farm implements has not been adequately investigated. Our objectives were to compare implement-induced short-term CO_2 loss from soil (using two chamber systems) and to characterize spatial changes in CO_2 flux from zones of soil disturbance caused by these implements. Four-row implements were used on a Norfolk loamy sand (Typic Kandiudults; FAO classification Luxic Ferralsols). The implements tested were two in-row subsoilers (a KMC-Kelly® Ripper and a Brown-Harden Ro-Till®) and a Kinze® planter. Gas flux measurements were made with a large canopy chamber (over the center two rows) for an integrated assessment of equipment-induced soil disturbance; a small soil chamber system was also used to characterize positional effects (i.e., in the row and trafficked and untrafficked row middles) on soil CO_2 efflux. The small chamber system showed that trafficked areas exhibited lower CO_2 efflux relative to in-row and untrafficked row positions. Comparable CO_2 flux patterns were noted between the large canopy and small soil chamber systems (averaged over all positions). Results from this study suggest that both chamber systems could successfully characterize implement-induced flux patterns on loamy sand soils and that consideration should be given to selecting equipment that conserves soil resources.

Introduction

The rise in atmospheric CO_2 level has received increased attention because potential changes in climate may increase temperature and drought over present agricultural production areas (Wood, 1990). Agriculture may play a critical role in sequestering carbon in soil (Lal et al., 1999), however, there is a need for direct measurements to quantify CO_2 fluxes as impacted by agricultural management practices. Descriptions of short-term CO_2 loss patterns associated with tillage activity have been reported, however, observed responses are dependent on such factors as the type of tillage tool being examined, soil type, season of the year, and regional location (e.g., Prior et al., 2000, 2004; Reicosky and Lindstrom, 1993; Reicosky et al., 1997). Consideration of such factors in conjunction with management decisions that affect tillage intensity are important in characterizing the potential of various cropping systems to store soil carbon.

Detailed information on the effects of the disturbance associated with different types of tillage equipment in terms of CO_2 release is lacking. The objectives of this work were to compare the effect of implement types on short-term soil CO_2 loss using two chamber systems (large and small) and to characterize short-term spatial changes in CO_2 flux from different zones of disturbance caused by these implements.

METHODS AND MATERIALS

This gas flux study using two chamber methods was conducted on a conventional tillage system and occurred concurrently with previously reported work on implement-induced gas fluxes from residue covered soils that used only the large chamber system (Prior et al., 2000). Three commercially available four-row implements (76-cm row spacing) were evaluated on a Norfolk loamy sand that had been in conventional tillage for 10 years at the E.V. Smith Research Center of the Alabama Agricultural Experiment Station in east central Alabama. Since subsoiling a narrow strip over-the-row is a common practice on Coastal Plain soils in the southeast, two in-row subsoilers were evaluated: a KMC-Kelly® Ripper (Kelly Manufacturing, Tifton, GA) and a Brown-Harden Ro-Till® (Brown Manufacturing Corporation, Ozark, AL). Both implements have a rippled coulter in front of the subsoiler shanks and were operated at a depth of 40 cm. The KMC had a 3.2-cm wide straight shank (~40° forward angle; 4.5-cm wide point) and was equipped with paired pneumatic tires to close the subsoil channel (10-cm wide disturbed surface zone). The Ro-Till had a 3.8-cm wide parabolic shank (5-cm wide point), paired fluted coulters and a rolling metal basket to close the subsoil channel (45-cm disturbed surface zone). We also tested a Kinze® planter (Williamsburg, IA) equipped with Martin® row cleaners (Elkton, KY) which uses a double-disk opener to make the seed furrow. The row cleaners consist of metal interlocking toothed wheels set to just clear the soil surface, effectively brushing residue aside (5- to 8-cm wide zone) in front of the seeding openers. A John Deere 4450® tractor (5781 kg, 104 kW) was used for all operations.

There was little rainfall preceding this study thus the soil was very dry. Therefore, 15-mm of irrigation was uniformly applied to study areas (10 m x 10 m) 24 h prior to tillage operations and gas exchange measurements. A dry reference area was also maintained. A total of six 20-cm cores were collected for soil moisture; after wet mass was determined, samples were dried at 105°C for 72 hr. Soil water values for dry reference and irrigated areas were ~37 and 60 g kg^{-1}, respectively.

Equipment-induced soil gas fluxes were measured at midday using two dynamic chamber methods: a large portable canopy chamber (area=2.71 m^2) (Reicosky and Lindstrom, 1993); and a small soil chamber (area=0.0071 m^2) (Prior et al., 1997). The large chamber system was housed on a small forklift that could be easily moved to plot locations. The small chambers system was hand portable. Three sets of gas exchange measurements were made with the large chamber (over the center two rows) for an integrated assessment of equipment-induced soil disturbance on all areas immediately following implement operations as well as on the reference areas. Spatial variation in CO_2 flux was assessed with a small chamber system (LI-COR 6000-09®; LI-COR Inc., Lincoln, NE). Three zones were evaluated: 1) undisturbed zone; 2) in-row disturbance zone (e.g., subsoiling); and 3) tire track zone (three measures per zone). Averaging flux values across all three positions allowed for a direct comparison of small chamber fluxes to those of the large chamber system. Flux readings were also taken in reference areas.

RESULTS AND DISCUSSION

The magnitude of CO_2 fluxes from a disturbed in-row zone, a trafficked interrow zone, and an untrafficked interrow zone were characterized with the small chamber system (Fig. 1). For the Kinze and KMC areas, CO_2 fluxes in the in-row disturbed zones and untrafficked interrow zones were higher relative to trafficked zones, indicating that recompaction from wheel traffic reduced soil CO_2 efflux. However, for the Ro-Till, in-row and untrafficked zone fluxes were lower in magnitude than those observed in the other implement areas. Although these Ro-till observations were unexpected due to greater degree of soil disturbance (vs. the other two implements), results of the small system were supported by findings from the large system (Fig. 2). It is possible that the vigorous soil disturbance from the Ro-Till may have resulted in an immediate release of soil CO_2

which was not detected. Another possible explanation is that the vigorous action of the rolling metal basket (used to close the subsoil channel) may have re-compacted the soil, thereby slowing CO_2 loss to the atmosphere. The Ro-Till implement left narrow undisturbed interrow zones in close proximity to disturbed in-row zones; this may explain the similar flux rates from these zones. Also, CO_2 flux rates in the disturbed in-row and undisturbed untrafficked interrow zones for the Kinze and KMC implements were similar to the reference irrigated area, suggesting that the higher flux rates compared to trafficked interrow zones were due to low soil consolidation and possibly higher microbial activity.

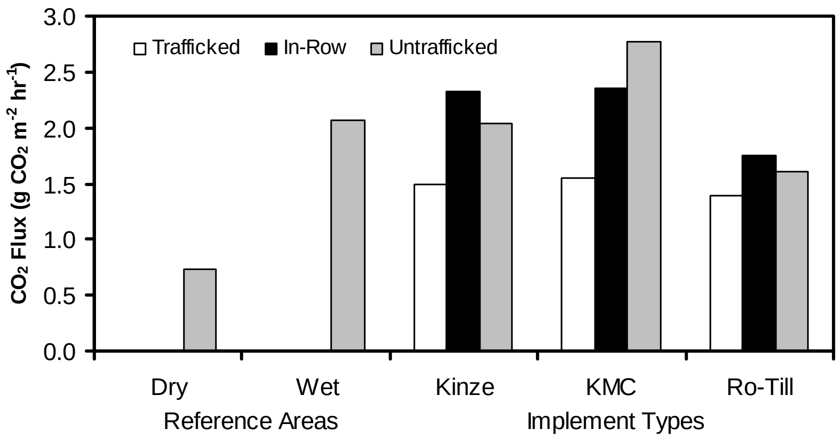

Figure 1. CO_2 fluxes immediately after implement operations using the small chamber system for each position (trafficked, in-row, and untrafficked zones); reference area fluxes also shown.

As noted with the small chamber system, large chamber flux differences between implements did not follow the expected trend with respect to soil disturbance (Fig. 2). Kinze and KMC areas had slightly higher flux rates (vs. Ro-Till) even though the Ro-Till area exhibited a greater degree of soil disturbance. In contrast, use of the large chamber system on residue covered soils (conservation system) found that the Ro-Till exhibited the greatest change in gas fluxes relative to the control plot (Prior et al., 2000).

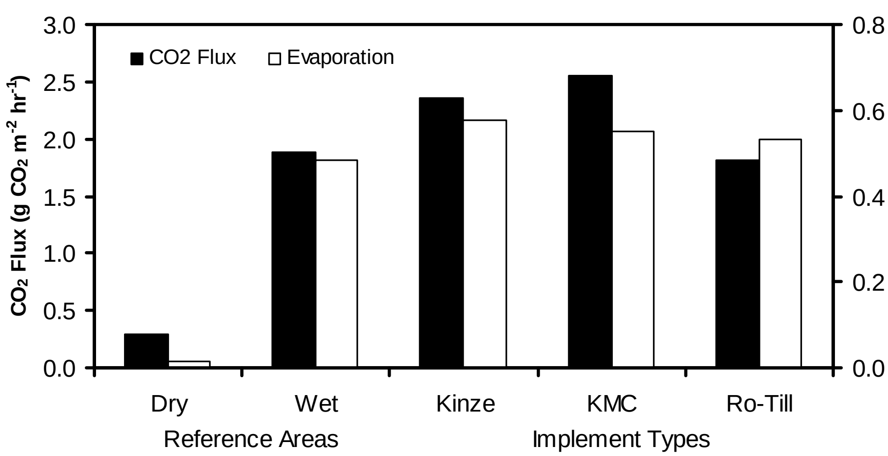

Figure 2. CO_2 and water fluxes immediately after implement operations using the large chamber system; reference area fluxes also shown.

The large system also measured water vapor losses which were similar to CO_2 flux patterns.

Further, with the large system it was clearly noted that irrigation increased both water vapor and CO_2 fluxes; similar CO_2 fluxes were also noted with the small system. Gas losses due to implement use were not substantially different from the irrigated reference area, suggesting that the largest effect on soil gas flux may be related to enhanced microbial activity. These large irrigation-induced fluxes were not seen on residue covered soils (Prior et al., 2000) thereby illustrating the importance of residue cover for enhancement of soil C storage and water availability for crop germination. Runion et al. (2004) suggested that no-till microbial communities are a younger, more viable growing population, while those under conventional tillage are a more mature, static community that can change toward a more active phase of growth as a result of tillage.

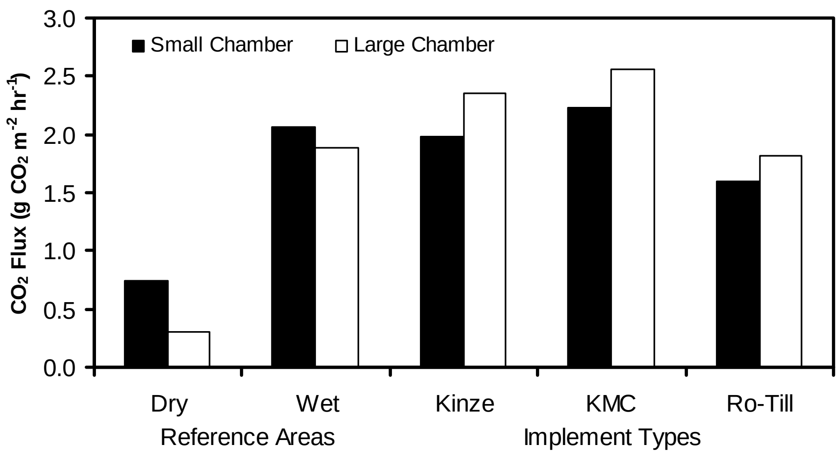

Figure 3. Comparison of CO_2 fluxes between the small and large canopy chamber systems for reference areas and implement types.

Similar temporal CO_2 flux patterns were observed with both the large and small soil chamber systems (Fig. 3). In general, the large chamber system gave slightly higher values which is likely reflective of an integrated assessment of a larger surface area. Although the smaller system assesses a smaller area, it has the advantage of detecting spatial differences. The general agreement between the two systems is in contrast to observations reported by Reicosky et al. (1997) using these systems. This discrepancy may be due to differences in soil type. The presence of soil cracks and air gaps precluded a representative measure of gas flux with the small system in the study on a Pellic Vertisol by Reicosky et al. (1997); these conditions did not exist for the sandier soil in our study.

CONCLUSIONS

This work demonstrated that implement operations can cause immediate loss of C from soil. Similar temporal gas flux patterns were observed with both chamber systems; spatial differences in CO_2 fluxes patterns from different zones following implement use were attributed to soil reconsolidation from tractor wheel compaction. Findings suggest that both systems could successfully characterize flux patterns on loamy sand soils and that consideration should be given to selecting equipment that conserves soil resources.

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AMMONIA VOLATILIZATION LOSSES DURING SPRINKLER IRRIGATION OF ANIMAL MANURE

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ABSTRACT

Recent work at Clemson University has provided 32 new data sets of ammonia volatilization losses during sprinkler irrigation of liquid manure. These 32 observations were pooled with 23 additional data sets that were available in the literature. The combined data includes losses from traveling gun, center pivot, and impact sprinkler irrigation of dairy, swine, and beef manure. Manure type did not affect volatilization losses. Total ammoniacal nitrogen (TAN = NH_3-N + NH_4^+-N) concentration differences between samples collected from the irrigated wastewater and samples collected in containers placed on the ground were measured as an estimate of ammonia volatilization loss. The TAN concentrations of the ground collected samples were not statistically different from TAN concentrations of the irrigated waste. In addition, it was determined that evaporation and drift were not major factors in the quantification of TAN losses. Therefore, volatilization loss from manure during the irrigation event was not found to be significant.

INTRODUCTION

Sprinkler irrigation of animal manure and wastewater onto crop, forage, and pasture land to recycle plant nutrients is a common practice in many regions of the United States. The total ammoniacal nitrogen (TAN = NH_4^+-N + NH_3-N) in liquid animal manure can account for 28% to 85% of the total Kjeldahl nitrogen (Chastain, et al., 2001; Montes, 2002) depending on the moisture content and animal species. A portion of the TAN can potentially be lost as a part of the land application process as ammonia volatilization. Ammonia volatilization loss during irrigation of manure and wastewater is an important issue due to the fact that regulatory agencies in the United States, Canada, and Europe either have prohibited the use of irrigation as a land application method or are considering the prohibition of this land application technique in order to reduce ammonia emissions from agriculture.

Volatilization losses can potentially occur during collection, transfer, storage, treatment, and land application. The majority of the volatilization losses are associated with storage, treatment, and land application of manure (MWPS, 1985; Chastain et al., 2001; and Montes, 2002). The ammonia-N losses associated with land application can occur during the application process, or over a 1 to 4 day period following application (Meisinger, and Jokela, 2000; Montes, 2002). The available data indicates that the majority of the volatilization losses associated with land application occur following the application event (Meisinger, and Jokela, 2000; Montes, 2002).

Many extension publications (e.g. MWPS, 1985; Dougherty et al., 1998) consider the ammonia loss due to irrigation to be greater than for land applied slurries and solid manure. However, extensive review of the literature (Chastain et al., 2001; Montes, 2002) and recent work on the ammonia losses following irrigation of lagoon effluent (Montes and Chastain, 2003) indicate that the losses following irrigation are no greater than for other land application methods. The volatilization losses following irrigation of dilute liquid manures, such as lagoon supernatant, are much lower than for other land application scenarios (≈ 2% of TAN applied). The mass of TAN lost is a function of the solids content of the manure, application depth, and the amount of manure intercepted by plant foliage or residue (Chastain et al., 2001; Montes, 2002).

The percentage of the TAN in the ammonia form is strongly dependent on pH. Most manure has a pH in the range of 7.0 to 8.0. About 8% to 10% of the TAN is in the ammonia form for most liquid manures (Jayaweera and Mikkelsen, 1990; Zhang, 1992; American Petroleum Institute, 1981; 1995; Ruxton, 1995; Cumby et al., 1995; Denmead et al., 1982). Therefore, only a small fraction of the TAN has the potential to be lost during the irrigation process.

Several studies have reported ammonia volatilization losses of 10 to 25% during irrigation of liquid swine manure (Sharpe and Harper, 1997; Westermann et al., 1995; Safley et al., 1992). Safley et al. (1992) attributed the majority of the irrigation losses to the influence of evaporation and drift. Earlier work by Welsh (1973), concluded that volatilization losses during the irrigation of dairy slurry, liquid swine manure, and effluent from an oxidation ditch were insignificant. Recent work at Clemson University (Montes and Chastain, 2000; Montes, 2002) supported the observations by Welsh.

Only three studies (Montes, 2002; Safley et al., 1992; and Welsh, 1973) had the quantification of ammonia losses during irrigation as a primary objective and the conclusions are mixed with regards to the importance of ammonia volatilization losses during the irrigation event. Only one of these studies (Montes, 2002) included rigorous statistical and error analyses.

The objectives of this paper are to:

- perform a pooled statistical analysis of the available data related to ammonia volatilization losses during irrigation of animal manure, and
- perform a critical analysis of the impact of evaporation and drift on volatilization losses during the irrigation event.

METHODS

A summary of the available data on ammonia volatilization losses during irrigation of animal manure is presented in Table 1. Ammonia volatilization losses were calculated from the data reported by the authors based on the difference in TAN concentration before and after irrigation. These losses ranged from -33% to 26%. The mean ammonia loss ranged from -2.5% to 13% with an overall mean of 4.0% of the TAN applied.

Negative ammonia loss values imply that NH_3 was gained during the irrigation process. While this is obviously impossible, it indicates a significant amount of uncertainty in the quantification of ammonia losses. The factors that have been proposed to affect the magnitude of ammonia loss during irrigation include: air temperature, relative humidity, irrigation pressure, drop diameter, spray velocity, TAN content of the irrigated manure, and pH (Pote et al., 1980; Denmead et al., 1982; Brunke et al., 1988; Sharpe and Harper, 1997). These factors have been suggested as the cause of the variability in measuring ammonia volatilization losses. However, most of the authors did not perform any type of error analysis on their data collection procedures.

Table 1. Summary of available data on volatilization losses during sprinkler irrigation of manure.

Description	Irrigated TAN (mg/L)	Irrigated (TS %)	pH	Ammonia Loss (%)	n	Reference
Big Gun: Dairy, Beef, Swine	187 to 850	0.3 to 8.4	7.4 to 7.9	-2.5 (-12.4 to 9.8)	5	Welsh (1973)
Center Pivot: Swine	299 to 327	0.14 to 0.17	7.4 to 7.5	4.9 (-2.1 to 18.4)	12	Safley et al. (1992)
Big Gun: Swine	214 to 510	0.11 to 0.37	7.1 to 7.7	2.9 (0.5 to 9.4)	6	Safley et al. (1992)
Big Gun: Swine	242 [1]	NR [2]	NR	5.7 (-5.0 to 24)	3	Westermann et al. (1995)
Solid Set: Swine	53 [1]	NR	NR	13	NR	Sharpe and Harper (1997)
Solid Set: Swine	109 to 1183	0.05 to 0.57	7.6 to 8.6	0.3 (-33 to 26)	32	Montes (2002)

[1] Not given directly, estimated from application data given in reference.
[2] NR = not reported

In the investigation by Welsh (1973), samples were taken from the manure storage structure before irrigation and from ground collected samples following the irrigation event. The difference in TAN concentration was used to estimate NH_3 loss due to the irrigation process. The study, conducted in Minnesota, included four different manure types with very different characteristics as is reflected by the large range in total solids and TAN concentration shown in Table 1. The average ammonia loss was -2.5% and was not significantly different from zero.

Safley et al. (1992) studied ammonia losses during sprinkler irrigation of swine lagoon effluent using center pivot and traveling gun irrigation equipment in North Carolina. Ammonia losses were estimated by calculating the difference in TAN concentration between samples taken from the lagoon and samples taken from liquid caught on the ground during irrigation. The TAN concentration difference between irrigated and ground collected samples in the data presented by Safley et al. (1992) ranged from -2.1% to 18.4% with a mean of 3.9%.

The studies by Westermann et al. (1995), and Sharpe and Harper (1997) did not include all of the data required to be included in the present study. The TAN concentrations in the irrigated manure were estimated from nutrient application rate information provided in the publications. Consequently, these data were not included in the pooled statistical analysis.

Montes (2002) collected similar ammonia volatilization data for sprinkler irrigation from two swine lagoons in South Carolina. Montes collected irrigated lagoon water samples from a sampling port in the irrigation pipe on the discharge side of the irrigation pump. The ground collected samples were the composite of samples collected in 8 locations within the irrigated plots.

The data from the studies by Welsh (1973), Safley et al. (1992), and Montes (2002) were pooled into common statistical analyses. The quantities that were included were: TS, TAN, TKN (total Kjeldahl nitrogen), and pH. The change in TS between the irrigated and ground collected samples was included to provide a measure of evaporation losses. Both TAN and TKN were included since a significant reduction in TAN during irrigation would also result in a reduction in TKN. Data on pH were included since the fraction of TAN that is in the ammonia form depends on manure pH.

ANALYSIS AND RESULTS

Pooled linear regression analyses were performed for the irrigated and ground collected concentrations of TS, TAN, and TKN. The least-squares best fit for each constituent was represented by the following equation form:

$$C_G = b\, C_I \, . \qquad (1)$$

Where:
C_I = the concentration of TS, TAN, or TKN in the irrigated material,
C_G = the concentration of TS, TAN, or TKN in the ground collected material, and
b = the slope of the line.

Theoretically, the intercept of equation 1 is zero in all cases and the intercept was not significantly different from zero for all three constituents. Therefore, the analysis was performed so as to force the equation through the origin.

An analysis of variance (ANOVA) was performed for each regression. The slope of the equation, b, was compared to 1 using a t-test at the 95% confidence level since a slope of 1 represents no change in concentration during the irrigation process. The results of the three analyses of variance are given in Table 2.

Table 2. Results of the analysis of variance of the regression using equation 1 for comparison of irrigated and ground collected concentrations of TS, TAN, and TKN.

Constituent	**R^2**	**n**	**RDF [1]**	**b**	**SE b [2]**	**C.I. (b) [3]**	**SE y [4]**
TS	0.9991	57	56	1.0244 *	0.004 %	± 0.008 %	0.046 %
TAN	0.9844	55	54	0.9999	0.010 ppm	± 0.021 ppm	39.3 ppm
TKN	0.9915	55	54	0.9846	0.009 ppm	± 0.018 ppm	56.0 ppm

1 Residual degrees of freedom.
2. Standard error of b.
3. 95% confidence interval about b.
4. Standard error of the y-estimate.
* Significantly different from 1 at the 95% level.

Influence of Irrigation on TS – Evaporation Loss

The correlation between the ground collected and irrigated concentrations of total solids is given in Figure 1. The ANOVA results are given in Table 2. A t-test on the slope for the TS relationship indicated that a slope of 1.0244 was significantly different from 1 (Table 2). Therefore, evaporation during irrigation increased the TS of the ground collected sample by 2.44%. Both empirical and modeling studies have shown that evaporation losses from irrigation systems vary from 1 to 3.5% (Heermann and Kohl, 1980; Thompson et al., 1993). The observation from this study is in agreement with the literature.

Influence of Irrigation on TAN

The affect of the irrigation process on the TAN concentration of animal manure is shown in Figure 2. The slope of the regression line was not significantly different from 1 at the 95% level (Table 2). As a result, the pooled analysis of 55 observations from 3 states (South Carolina, North Carolina, and Minnesota) indicated that ammonia volatilization loss during irrigation did not occur for manures with TS ranging from 0.04 to 8.4% TS, and TAN concentrations ranging from 11 to 1183 ppm.

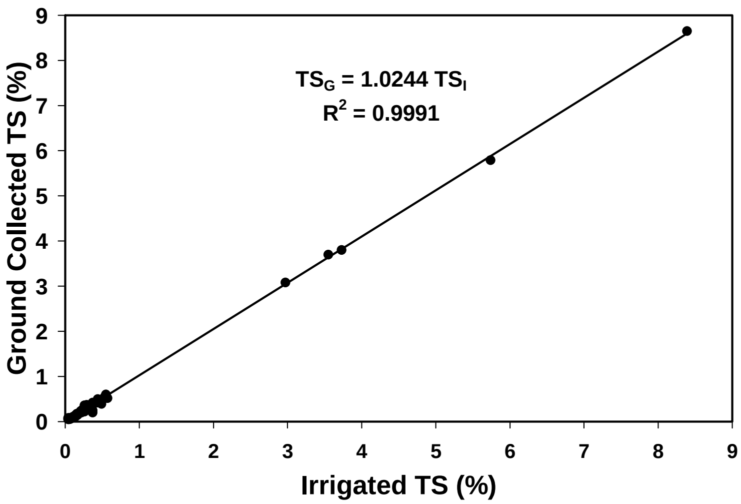

Figure 1. Change in TS concentration during irrigation of animal manure.

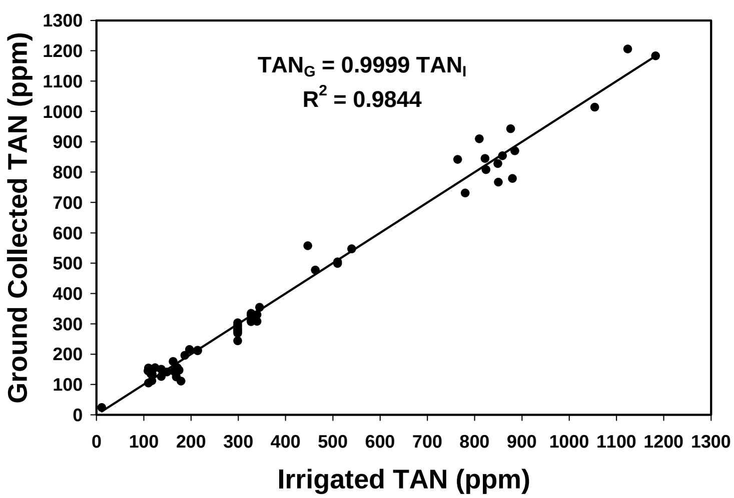

Figure 2. Variation of TAN as a result of irrigating animal manure.

Influence of Irrigation on TKN

Total Kjeldahl nitrogen is the sum of TAN and organic nitrogen. Therefore, the TKN concentration in the ground collected sample would be expected to be slightly higher even if ammonia volatilization did not occur due to small, but significant, evaporation losses. However, the data shown in Figure 3 and the statistical analysis (Table 2) indicated that the TKN concentration was not significantly affected by irrigation at the 95% level. In fact, TKN in the ground collected sample was slightly lower than TKN of the irrigated material on the average.

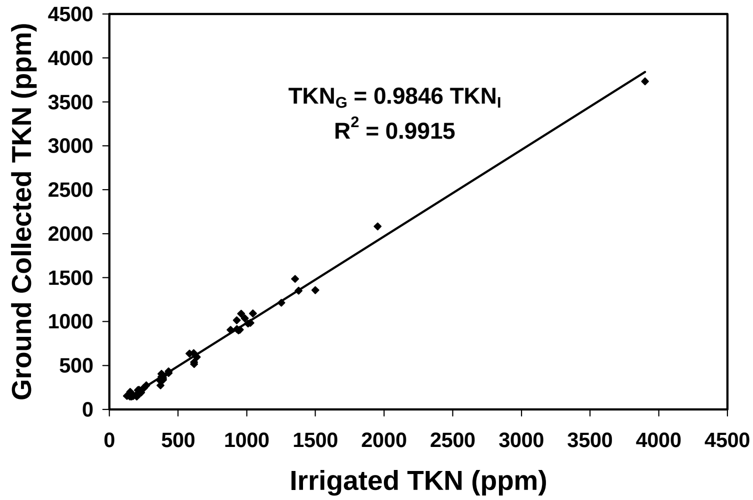

Figure 3. Variation of TKN as a result of irrigating animal manure.

Uncertainty in the Calculation of Volatilization Loss

The differences between TAN concentrations in irrigated and ground collected samples were sometimes negative as indicated in Table 1. Since it is impossible to gain TAN during irrigation, these negative values are due to the uncertainty, or lack of accuracy, in the measurements of TAN concentration.

The procedure to determine TAN concentration for irrigated and ground collected samples includes the following potential sources of error: sampling in the field, sub-sampling in the laboratory to prepare for chemical analysis, and executing the chemical analysis procedure. Each step has an associated error that contributes to the overall error in determining TAN concentration.

An estimate of the magnitude of overall error in determining TAN can be made based on the variability in TAN concentration of samples taken from similar materials and conditions. The estimate of uncertainty in TAN measurements was based on the pooled variance of 62 observations of TAN provided by Montes (2002). The pooled variance in TAN for the study by Montes (2002) was 965.3 (mg/L)^2. Therefore, the estimate of uncertainty in TAN concentration was the pooled standard deviation of ± 31.1 mg/L.

Calculation of the volatilization loss in percent requires taking the difference between the irrigated and ground collected concentrations. The uncertainty in the difference between two measured values can be estimated as (Taylor, 1997; Holman, 1993):

$$u_{(a-b)} = \sqrt{(u_a)^2 + (u_b)^2}\ . \tag{2}$$

Where:
$u_{(a-b)}$ = uncertainty in knowing the difference between *a* and *b*,
u_a = uncertainty in measuring *a*, and
u_b = uncertainty in measuring *b*.

Using equation 2, and the defined uncertainty for TAN, it can be shown that the uncertainty in percent difference in concentrations between irrigated and ground collected samples can be expressed as:

$$U_{\Delta TAN} = (\pm 44\ mg/L \div TAN_I) \times 100, \qquad (3)$$

Where:
$U_{\Delta TAN}$ = uncertainty in calculated loss of ammoniacal-N (%), and
TAN_I = concentration of TAN in irrigated manure (mg/L).

The uncertainty interval for TAN losses defined by equation 3 is plotted in Figure 4 with all of the data included in the present study. The upper and lower limits of the uncertainty band were limited to ± 100%. As a result a few points are not shown in the plot. These results indicate that volatilization losses were well distributed about zero. Only 10 of the 55 data points were not contained within the uncertainty interval for TAN. Furthermore, they were uniformly distributed about the line of zero difference. These results support the statistical conclusion and indicate that volatilization losses were zero within the errors induced by calculation of a percent loss and the errors associated with measurement.

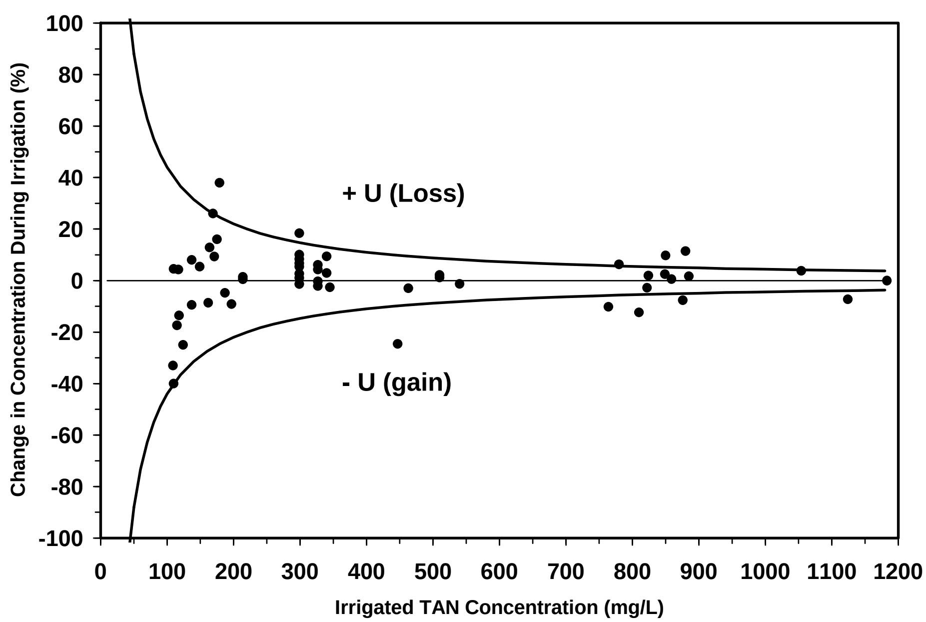

Figure 4. Comparison of the change in total ammoniacal nitrogen concentration during irrigation with the uncertainty associated with the calculation of percent differences (± U).

Influence of Evaporation and Drift

Safley et al. (1992) attempted to incorporate the influence of evaporation and drift losses into the estimation of ammonia losses during sprinkler irrigation using a center pivot. Safley reported that the ammonia losses during irrigation ranged from13.9% to 37.3 % if evaporation and drift were included. However, their concentration data indicated that volatilization losses averaged 4.9% (Table 1).

The irrigate-catch technique to estimate volume loss during irrigation was used by Safley et al. (1992). Volume loss results obtained by this technique need to be interpreted with caution since all errors are counted as an irrigation volume loss (Heermann and Kohl, 1980). The error in the irrigate-catch technique can be described as a recovery error defined as:

$$R_e = \left(1 - \frac{A_c}{A_T}\right) \times 100 . \tag{4}$$

Where:
R_e = recovery error (%),
A_c = measured application depth (cm),
A_T = theoretical application depth (cm) based on flow measurements in the main irrigation pipe and the application area, and
A_c/A_T = fraction recovered in containers on the ground.

The recovery error includes the following effects: (1) collection error, E_C; (2) error due to the lack of uniformity of the irrigation system, E_U; and (3) error caused by evaporation losses from the sprinkler spray, E_E.

The collection error, E_C, is caused by liquid that drifts away from the collection containers, liquid that strikes the collection containers but is not trapped, liquid lost by splashing out of the collection containers, and evaporation from the collection containers. A collection error related to the type of container used was explicitly measured by Kohl (1972). Kohl showed that the collection error for 76-mm diameter rain gages ranged from 85% at an application rate of 0.09 cm/h to 12% at a rate of 0.94 cm/h when compared with a precise collecting device ($E_C \approx 0$).

The error induced by lack of uniformity, E_U, is directly related to the design of irrigation equipment and the number and distribution of collection containers used to capture the spray. Center pivot irrigation equipment typically provides an application uniformity that varies between 70 to 90% (Kruse et al., 1990; Rolland, 1982). For design purposes, 80% is typically used as the application uniformity (Kruse et al., 1990; Valmont, 2000) which yields an E_U of 20%.

Evaporation loses from sprinkler spray, E_E, are considered insignificant when compared with the effects of irrigation uniformity (Heermann and Kohl, 1980). Evaporation losses from sprinkler spray have been typically overestimated when the difference between irrigated and collected volume is used. Empirical and modeling studies have shown that evaporation losses from irrigation systems vary from 1 to 3.5% (Heermann and Kohl, 1980; Thompson et al., 1993). The results of this study indicated an average value of 2.4%. Therefore, E_E is in the range of 1 to 3.5%.

The recovery error, R_e, was estimated from these three independent uncertainties as (Holman, 1997):

$$R_e = \sqrt{(E_C)^2 + (E_U)^2 + (E_E)^2} . \tag{5}$$

Safley used 95 mm rain gages to measure the application depth, A_C, from a Valmont Model 4871 center pivot irrigation system with an average application rate of 1.1 cm/h. The irrigation system was rated to give 80% uniformity according to the manufacturer (Valmont, 2000). Assuming a collection error of 12%, a uniformity error of 20%, and an evaporation error of 2% in equation 5 yields a recovery error of 23.4% for a center pivot irrigation system. Evaporation from the sprinkler spray accounts for only 0.7% of the total recovery error while uniformity error contributes 73%.

Setting R_e equal to 23.4% in equation 4, and solving for the fraction recovered (A_C / A_T) indicates that one would expect to recover 0.77 A_T for a typical center pivot irrigation system. However, only a tiny fraction of the total water applied would not reach the ground since the majority of the discrepancy is due to errors in the irrigate-catch technique and not a combination of evaporation and drift.

The average recovery fraction observed by Safley et al. (1992) was 0.77 indicating that their center pivot performed as expected. Safley erroneously attributed the 23% volume not collected, or recovery error, to evaporation and drift losses during irrigation using the following relationship:

$$TAN_L = \left[1 - \frac{A_c C_c}{A_T C_L}\right] \times 100 \quad . \qquad (6)$$

Where:
TAN_L = total ammonia loss (%),
A_c = collected application depth (cm),
C_c = TAN concentration in the captured liquid (mg/L),
A_T = theoretical application depth (cm), and
C_L = TAN concentration in lagoon supernatant (mg/L).

As shown in Table 1, the average change in TAN concentration for Safley's center pivot study was 4.9%, which makes C_C / C_L equal to 0.951, and the mean value of A_C / A_T was 0.77. As a result, the average TAN loss reported by Safley et al. (1992) using equation 6 was 26.8%. However, the majority of the average ammonia loss predicted using equation 6 was due to error in the irrigate-catch technique and not evaporation and drift as assumed by Safley et al. (1992).

The difference in total solids concentration between samples collected from the liquid before irrigation and samples collected in containers placed on the ground during irrigation is a more accurate method to estimate the volume loss due to evaporation. The data reported by Safley et al. (1992) indicated no significant difference in total solids concentration before and after irrigation (Montes, 2002). Therefore, evaporation loss was insignificant for their data set.

Influence of Irrigation on pH

The studies by Welsh (1973) and Safley et al. (1992) provided 24 paired observations of pH of irrigated and ground collected samples. The average pH of the irrigated manure was 7.47 and the average pH of the ground collected samples was 8.04. The pooled standard deviation of the data set was 0.19. The least significant difference at the 95% level was 0.109 (error df = 46, SE diff = 0.054). Therefore, the pH of the irrigated and ground collected samples was significantly different. Irrigation increased the pH of the manure by 7.6%.

Montes (2002) only measured the pH of irrigated lagoon supernatant. The pH of the two swine lagoons in the study by Montes ranged from 7.62 to 8.55 with a mean of 8.05 and pooled standard deviation of 0.23.

CONCLUSIONS

- Irrigation of animal manure increased the TS concentration by 2.4%. Evaporation was small but statistically significant.
- Irrigation of animal manure did not influence the concentration of TAN or TKN in the ground collected samples.
- Evaporation and drift does not contribute to ammonia volatilization losses.
- The pH of manure was increased by 7.6% during the irrigation process.
- Ammonia volatilization losses during irrigation was not significant at the 95% level.
- The percent difference between irrigated and ground collected TAN concentrations was within the errors associated with the calculation of percent differences.

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FORAGE AND TILLAGE SYSTEMS FOR INTEGRATING WINTER-GRAZED STOCKER CATTLE IN COTTON PRODUCTION

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ABSTRACT

Integrating livestock with cotton (*Gossypium hirsutum* L.) offers profitable alternatives for producers in the southeastern USA, but could result in soil water depletion and soil compaction. We conducted a 3-yr field study on a Dothan loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) in south Alabama to develop a conservation tillage system for integrating cotton with winter-annual grazing of stocker cattle under dryland conditions. Winter annual forages and tillage systems were evaluated in a strip-plot design where winter forages were oat (*Avena sativa* L.) and annual ryegrass (*Lolium mutiflorum* L.). Tillage systems included: moldboard and chisel plowing; and combinations of non-inversion deep tillage (none, in-row subsoil or paratill) with/without disking. We evaluated forage dry matter, N concentration, average daily gain, net returns from grazing, soil water content, and cotton leaf stomatal conductance, plant populations and yield. Net returns from winter-annual grazing averaged over 3-yr were between \$75 to \$81/acre/year. Soil water content was reduced 15% with conventional tillage or deep tillage compared to strict no-tillage, suggesting that cotton rooting was increased by these systems. Oat increased cotton stands an average of 25% and seed-cotton yield by 7% compared to ryegrass. Strict no-tillage resulted in the lowest yields; 30% less than the overall mean (3295 lb seed-cotton/acre). Non-inversion deep tillage in no-till (especially paratill) following oat was the best tillage system combination (3535 lb seed-cotton/acre) but deep tillage did not increase cotton yields in conventional tillage systems. Integrating winter-annual grazing can be achieved in the Coastal Plain using non-inversion deep tillage following oat in a conservation tillage system, providing producers extra income while protecting the soil resource.

SUMMARY

In the Southeastern states, 48 to 63% of cotton is grown in rotation. However, even in a rotation, only a limited number of crops, usually corn (*Zea mays* L.) or peanut (*Arachis hypogaea* L.) are utilized. Integrating animal production with row cropping systems, e.g., with cotton, may offer economic and conservation benefits, but it presents an even greater challenge to diversification than rotation with other row crops. Winter-annual grazing of stocker cattle could diversify market opportunities and offer potential for extra revenue for producers double-cropping cotton. However, winter-annual grazing can result in excessive soil compaction, which can severely limit yields of double-cropped cash crops like cotton.

The objectives of this study were to determine the feasibility of double-cropping cotton following winter-annual grazing of stocker cattle in the Southeastern Coastal Plain and to identify an optimal choice of forage and tillage system combination for animal performance, cotton productivity, soil conservation, and profitability. The results presented here focus on cotton productivity and system profitability.

The field study was conducted for 3-yr on a Dothan loamy in south Alabama. Winter-annual forages and tillage systems were evaluated in a strip-plot design of 4 replications. Forages were oat and annual ryegrass. Both forages were terminated prior to summer tillage with an application of glyphosate approximately 4-6 wk before cotton planting. Yearling steers of mixed breeding Angus × Simmental (initial weight 570 lb averaged over years) were stocked at 2-head/acre.

During the summer, the experimental area was divided into cotton and peanut areas, which were rotated each year. Tillage plots within these areas were 50-ft long and 24-ft wide with eight, 36-in rows. ‘Suregrow 125B/R’ cotton was grown in 2001 and ‘Suregrow 501 B/R’ was grown in 2002 and 2003. The eight summer tillage practices were: 1) moldboard plowing to a depth of 12-in + disk/level (4- to 6-in depth); 2) disk/level only; 3) chisel plowing to a depth of 8-in + disk/level; 4) in-row subsoil with a narrow-shanked subsoiler (KMC®, Kelley Manufacturing Co., Tifton, GA) to a depth of 14- to 16-in + disk/level; 5) in-row subsoil + no-tillage; 6) under-the-row paratill with a bent-leg subsoiler (Paratill®, Bigham Brothers, Inc., Lubbock, TX) to a depth of 17- to 19-in + disk/level; 7) paratill + no-tillage; and 8) no-tillage. All tillage operations were performed after the removal of cattle from the winter annual forages. Tillage and planting equipment were guided with a tractor equipped with a Trimble AgGPS® Autopilot automatic steering system (Trimble, Sunnyvale, CA), with 1-in level precision, which reduced equipment-induced compaction near the cotton row. Alabama Cooperative Extension System recommendations were used to apply all herbicides and insecticides. We evaluated soil water content, cotton leaf stomatal conductance, plant density, cotton yield, cotton net return, and total system annual net return.

Integrating winter-annual grazing with cotton provided additional income for producers ($75-81/acre/year) with only 80-d grazing. Soil water content during cotton bloom period was reduced an average of 15% with conventional tillage or non-inversion deep tillage, suggesting that cotton rooting was increased by these systems. Cotton stands following oat grazing were increased 25% compared to following ryegrass and yields following grazed oat were 7% greater than following grazed ryegrass. Strict no-tillage resulted in the lowest yields; 30% less than the overall tillage mean (3295 lb seed cotton per acre). However, non-inversion deep tillage in no-tillage systems (especially with the paratill) following grazed oat was the best system combination, averaging 3545 lb seed-cotton/acre over the three years. Deep tillage did not increase cotton yields in conventional tillage.

Our results demonstrate that doublecropping cotton following winter-annual grazing is possible in the Southeastern Coastal Plain, allowing for extra income without sacrificing cotton yields. Integrating winter-annual grazing can be achieved using non-inversion deep tillage, especially paratilling, following oat in a conservation tillage system. This conservation practice can reduce erosion potential, provide a much needed source of additional revenue, and still sustain competitive cotton yields on these soils.

FORAGE AND TILLAGE SYSTEMS FOR INTEGRATING WINTER-GRAZED STOCKER CATTLE IN PEANUT PRODUCTION

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ABSTRACT

The use of crop rotation systems involving winter annual grazing can help peanut (*Arachis hypogaea* L.) producers increase profitability, however, winter-annual grazing could result in excessive soil compaction, which can severely limit yields. We conducted a 3-yr field study on a Dothan loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) in south Alabama to develop a conservation tillage system for integrating peanut with winter-annual grazing of stocker cattle under dryland conditions. Winter annual forages [oat (*Avena sativa* L.) and annual ryegrass (*Lolium mutiflorum* L.)] and tillage systems were evaluated in a strip-plot design. Tillage systems included: moldboard and chisel plowing; and combinations of non-inversion deep tillage (none, in-row subsoil or paratill) with/without disking. We evaluated soil water content, peanut leaf stomatal conductance, plant density, peanut yield, peanut net return, and total system annual net return. Peanut following oat increased soil water extraction (15%), stands (12%) and yields (21%) compared to peanut following ryegrass. Strict no-tillage resulted in the lowest yields (2045 lb/acre, 42% less than the mean of the other tillage treatments) and non-inversion deep tillage (especially in-row subsoil) was required to maximize water use and yields with conservation tillage. Net return from annual grazing ($75/acre, 3-yr mean) represented 40% of the total return for the best treatment (no-tillage with in-row subsoil following oat, $187/acre). Integrating winter-annual grazing in this region using non-inversion deep tillage following oat in a conservation tillage system can benefit peanut growers, allowing extra income without sacrificing peanut yields.

SUMMARY

Peanut production has traditionally been a tillage intensive operation and peanut yields have not increased for a number of years, even with new varieties and technology. Under the 2002 market loan program (Farm Bill), which has resulted in lower prices, producers are forced to reduce costs and increase productivity to remain competitive.

Integrating winter-annual grazing with peanut production may offer producers increased potential for profits; however, grazing may result in excessive soil compaction, which can severely limit peanut yields. Tillage requirements following winter-grazing have not been researched, and there is producer concern that intensive tillage might be required following winter-grazing in order to achieve acceptable peanut yields. Adoption of conservation tillage has been limited by peanut producers and apprehension over compaction following winter-annual grazing could limit adoption even more. The objective of this study was to identify a practical forage and conservation-tillage system combination for peanut production following winter-annual grazing for Coastal Plain soils.

The field study was conducted for 3-yr on a Dothan loamy sand in south Alabama. Winter-annual forages and tillage systems were evaluated in a strip-plot design of 4 replications. Forages were oat and annual ryegrass. Both forages were terminated prior to summer tillage with an application of glyphosate approximately 4-6 wk before peanut planting. Yearling steers of mixed breeding Angus × Simmental (initial weight 570 lb averaged over years) were stocked at 2-head/acre.

During the summer, the experimental area was divided into peanut and cotton areas, which were rotated each year. Tillage plots within these areas were 50-ft long and 24-ft wide with eight, 36-in rows. 'Georgia Green' peanut was planted every year. The eight summer tillage practices were: 1) moldboard plowing to a depth of 12-in + disk/level (4- to 6-in depth); 2) disk/level only; 3) chisel plowing to a depth of 8-in + disk/level; 4) in-row subsoil with a narrow-shanked subsoiler (KMC®, Kelley Manufacturing Co., Tifton, GA) to a depth of 14- to 16-in + disk/level; 5) in-row subsoil + no-tillage; 6) under-the-row paratill with a bent-leg subsoiler (Paratill®, Bigham Brothers, Inc., Lubbock, TX) to a depth of 17- to 19-in + disk/level; 7) paratill + no-tillage; and 8) no-tillage. All tillage operations were performed after the removal of cattle from the winter annual forages. Tillage and planting equipment were guided with a tractor equipped with a Trimble AgGPS® Autopilot automatic steering system (Trimble, Sunnyvale, CA), with 1-in level precision, which reduced equipment-induced compaction near the peanut row. Alabama Cooperative Extension System recommendations were used to apply all herbicides, insecticides, and fungicides. We evaluated soil water content, peanut leaf stomatal conductance, plant density, peanut yield, peanut net return, and total system annual net return.

Peanut following oat increased soil water extraction (15%), stands (12%) and yields (21%) compared to peanut following ryegrass. We speculate that improved plant populations and increased rooting and soil water extraction of peanut following oat, compared to following ryegrass, could be associated with greater N depletion by ryegrass, increased peanut root restriction under ryegrass, and possible ryegrass allelopathic effects on peanut. We found no clear effect of forage species or tillage system on peanut leaf stomatal conductance. Strict no-tillage resulted in the lowest yield (2045 lb/acre averaged across years). Strict no-tillage reduced peanut plant populations 47%, soil water extraction 15%, and yields 42% compared to the mean of the other seven tillage systems. Oat appeared to be a better choice than ryegrass for peanut grown following winter-annual grazing and non-inversion deep tillage was necessary to maximize soil water extraction and yields in no-tillage systems. Deep tillage in conventional surface tillage systems did not increase peanut yield. Within no-tillage systems, peanut yields were greater with in-row subsoiling using the narrow-shanked implement compared to paratilling (3688 lb/acre vs. 3429 lb/acre, respectively).

Oat together with in-row subsoiling for peanut production had the greatest total annual net return ($187/acre) and net returns from animal production ($75/acre) represented 40% of the total system return. In conclusion, integrating winter-annual grazing with peanut using non-inversion deep tillage in conservation tillage systems can increase profitability for producers in the Coastal Plain without sacrificing peanut yields.

DISTRIBUTION OF THE RED IMPORTED FIRE ANT, *SOLENOPSIS INVICTA* BUREN (HYMENOPTERA: FORMICIDAE) UNDER VARYING CROPPING PRACTICES

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ABSTRACT

This study evaluated the effects of contrasting cropping systems on red imported fire ant (*Solenopsis invicta* Buren) mound size and distribution. Over a seven year period (1998 - 2004), fire ant mounds were located and marked using GPS in a 14 - acre, split-field comparison of a conventional tillage production system and a conservation tillage system. The conservation tillage system included narrow row spacings, no surface tillage, site-specific P application, and broadcast deep tillage. The conventional system included disking and cultivating the soil surface, in-row subsoiling, and traditional row spacings. Results of this study indicate that the conservation tillage system, while beneficial to the environment, may result in increased fire ant density. Colony size was also found to be larger with the conservation tillage system, as determined by soil disruption.

FACTORS AFFECTING BURNDOWN CONTROL OF ITALIAN RYEGRAS WITH GLYPHOSATE

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ABSTRACT

Studies were conducted during the spring of 2004 to evaluate factors such as type of formulation, application timing, herbicide rate, and use of ammonium sulfate as an additive on burndown control of Italian ryegrass (*Lolium multiflorum*) with glyphosate. The different glyphosate formulations generally provided similar level of ryegrass control, yet there were a few differences in control due to formulation. Increasing the glyphosate rate from 0.75 to 1.125 lb ae/A tended to improve control, particularly when treatments were applied during early spring Application timing tended to have the most impact on burndown control of ryegrass, with April applications usually providing faster and slightly better control than March applications. AMS did not enhance ryegrass control, except in a few instances.

SUMMARY

Italian ryegrass is a cool-season annual that has become a problem weed in no-till corn in Kentucky. Plants are easily controlled when in the seedling stage in the fall; however, once they have overwintered and developed multiple tillers, they tend to become more difficult to control with a single burndown application in the spring. There has been increased interest in using glyphosate as a component in burndown treatments, due to its ability to translocate in plants, but results with this herbicide have been variable. Studies were conducted in 2004 at University of Kentucky Research and Education Center near Princeton to evaluate such factors as product formulation, application timing, herbicide rate based on acid equivalent (ae), and use of ammonium sulfate (AMS) at a rate of 3.7% (v/v) as an additive with glyphosate on burndown control of ryegrass. Burndown control of ryegrass from early preplant (EPP) treatments was evaluated periodically during the first 4 weeks after application.

The first study compared seven glyphosate products based on the following formulations: isopropyl amine salt as 3 lb ae/gal (ClearOut 41 Plus, Glyphomax Plus, and Honcho;) diammonium salt with 3 lb ae/gal (Touchdown IQ); isopropyl amine salt with 3.73 lb ae/gal (Roundup UltraMax); potassium salt with 4.17 lb ae/gal (Touchdown Total); and potassium salt with 4.5 lb ae/gal (Roundup WeatherMAX). Glyphosate was applied in all treatments in this study at 0.75 lb ae/A in combination of S-metolachlor at 1.3 lb active ingredient (ai)/A plus atrazine at 1.6 lb ai/A. The height of ryegrass averaged 3 inches on March 13 for EPP-1 treatments and 6 inches on April 14 for EPP-2 treatments.

Ryegrass response was substantially slower when treatments were applied at EPP-1 than at EPP-2. Average control ratings across all glyphosate treatments at EPP-1 were 3, 47, and 77% compared with 47, 80, and 86% for EPP-2 treatments at 9, 16, and 24 days after treatment (DAT), respectively. The fact the average temperature for the first 24 days after application was 53^0 F for EPP-1 treatments, compared with 64^0 F for EPP-2 treatments, may have contributed to the

difference in speed of response. The use of AMS as an additive did not enhance the speed of control with the EPP-1 treatments. However, the addition of AMS to ClearOut 41 Plus tank mixture applied at EPP-2 increased ryegrass control for 43 to 53 % at 9 DAT, but did not enhance control of other glyphosate products when combine with S-metolachlor plus atrazine. AMS did not enhance ryegrass control of any glyphosate treatment when evaluated at 16 and 24 DAT.

Applying Touchdown Total plus S-metolachlor plus atrazine at EPP-1 provided 90 and 92% ryegrass control at 24 DAT, with and without AMS, respectively. The use of Roundup UltraMax at EPP-1 resulted in 83 and 77% control with and without AMS, respectively. The other glyphosate treatments at EPP-1 provided an average of 74% control at 24 DAT, regardless whether or not AMS was included as an additive.

The second study compared Roundup WeahterMAX and ClearOut 41 Plus at 0.75 or 1.125 lb ae/A applied either alone or with AMS. The average height of ryegrass was 6 inches on March 15 for EPP-1 treatments and 11 inches on April 5 for EPP-2 treatments.

The environmental effects associated with application timing on ryegrass control were similar to those observed in study 1 and were more important than rate of herbicide or use of AMS as an additive. The cooler temperatures associated with EPP-1 treatments caused ryegrass to respond slower relative EPP-2 treatments. Control ratings made at 7, 14, and 30 DAT and averaged across both glyphosate products and both rates for EPP-1 treatments were 7, 38, and 71% compared with 48, 82, and 94% for EPP-2 treatments, respectively.

Roundup WeahterMAX and ClearOut 41 Plus provided similar ryegrass control, however there were as few instances where differences in control occurred. When 0.75 lb ae/A was applied alone at EPP-1 timing, Roundup WeahterMAX provided 63% control at 30 DAT compared with 50% for ClearOut 41 Plus. Including AMS as an additive with glyphosate at 0.75 lb ae/A resulted in 77% control for Roundup WeatherMAX but only 53% for ClearOut 41 Plus.

Increasing the glyphosate rate from 0.75 to 1.125 lb ae/A improved ryegrass control in 3 of 4 instances for EPP-1 treatments and 1 of 4 instances for EPP-2 treatments

EVALUATION OF A MECHANICAL ROLLER-CRIMPER AND REDUCED GLYPHOSATE RATES ON COVER CROP DESICCATION IN COTTON.

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ABSTRACT

An integral component of conservation-tillage systems in cotton is the use of a high-residue winter cover crop; however, managing such cover crops is a challenge. Black oat (*Avena strigosa* Schreb.), rye (*Secale cereale* L.), and wheat (*Triticum aestivum* L.) winter cover crops were established in early November at the E.V. Smith Research and Extension Center located near Shorter, AL in the fall of 2003 and 2004. Additionally, wheat was established in early November 2004 at the Tennessee Valley Research and Extension Center near Bella Mina, AL and at a grower's field near Robertsdale, AL. In mid-April in both years each cover was flattened with a straight-blade mechanical roller-crimper alone or followed by three rates of glyphosate (0.75, 0.38, 0.19 lb ae/ac). Additionally, glyphosate alone at each rate and a non-treated check were included to complete the factorial treatment arrangement. Cotton was then established after within-row sub-soiling at E.V. Smith and no-till at Tennessee Valley in four row (40 in. spacing) plots while in the grower's field, eight row plots established no-till were utilized. At 3 weeks after treatment in 2004, averaged across covers, rolling plus glyphosate at 0.75 or 0.38 lb/ac terminated the reproductively mature covers ≥ 96%. Rolling plus glyphosate at 0.19 lb/ac resulted in 89% rye and black oat termination, a 44% increase compared to glyphosate alone. Rolling alone killed wheat 96%. Cotton yield was unaffected by treatment in 2004, likely due to adequate early-season soil moisture and the use of a within-row subsoiler prior to cotton planting.

EFFECTS OF ROLLING/CRIMPING RYE DIRECTION AND DIFFERENT ROW-CLEANING ATTACHMENTS ON COTTON EMERGENCE AND YIELD

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ABSTRACT

Cover crops have been recognized as a vital part of conservation systems and they should produce maximum biomass to be effective. Because of the large amounts of residue produced by cover crops, they must be managed appropriately and not create problems for producers. Roller-crimpers have been used to manage cover crops by rolling them down and creating a thick cover over the soil surface. This study was conducted to determine the effect of different rolling directions and different commercial row cleaners on cotton emergence and yield. Two locations for this study were chosen (central and northern Alabama) to account for different climate and soil conditions. Each experiment was a completely randomized block design with four replications. Presented results cover the first 2003/2004 growing season. Rye (Secale Cereale L.) was chosen as a cover crop because rye produces a large amount of biomass and is popular with Alabama producers. Rye was rolled at the soft dough stage and terminated using glyphosate. Preliminary data showed that parallel rolling direction with respect to planting direction for cotton produced the highest emergence and yield at both locations. Likewise, the best commercially available row cleaner was the Yetter attachment, at both locations. The worst rolling pattern was perpendicular to cotton rows.

INTRODUCTION

Cover crops have been known to provide important environmental and economical benefits such as improved soil quality, reduced soil erosion and runoff, weed suppressor, increased infiltration, and improved soil fertility by increasing organic carbon content (Reeves, 1994; Ashford and Reeves, 2003; Dinnes et al., 2002; Kasper et al., 2001). Cover crops must produce large amounts of biomass to create an effective soil cover. Large amounts of cover crop residue can create problems with any tillage practice that must be conducted in the spring, prior to planting operations. Thus, crops must be managed appropriately to prevent planting problems. The most common problem is “hair-pinning”, where residue is pushed into the soil rather than being cleanly sheared. Hair-pinning creates a condition where the seeds are unable to have good seed-soil contact. As a result, skips in rows of the cash crop can occur, thus negatively impacting emergence and yield. Another major problem is accumulation of cover crop residue on planting units, which causes frequent stops to clean the equipment.

One effective way to manage cover crops is mechanical termination using rollers/crimpers. Rolling technology originated in Brazil, and rollers have been used successfully for many years in that region in conservation systems (Derpsch et al., 1991). Rollers consist of a steel drum with attached crimping bars equally spaced on the drum’s perimeter. Using rollers alone to flatten the cover crop and prevent multiple-direction lodging is beneficial. To properly manage the cover crop, in terms of maximizing its benefits and to minimize interactions between planter and cover crop, there is a need to determine the best rolling direction and evaluate different row cleaning attachments installed on the planter. Therefore, the objective of this study was to determine the effect of different rolling directions relative to the planting rows and evaluate different commercially available row-cleaner attachments on cotton emergence and yield.

MATERIALS AND METHODS

Two experimental sites were chosen for study: The Tennessee Valley Research and Extension Center (TVS) at Belle Mina (northern Alabama) and the E.V. Smith Research and Extension Center at Milstead (central Alabama) with different climates and soils. Rye (Secale cereale L.) was planted at both locations in the fall of 2003 using a small grain planter with row spacing of 7.5 inches. Rye was rolled/crimped in the spring (mid-April) of 2004 at the soft dough growth stage, which is a desirable period for termination (Nelson et al., 1995). A three-section, 13.5-feet wide roller (Bigham Brothers Lubbock, Texas**) with long straight crimping bars was used (Fig. 1).

The experiment was a completely randomized block design with four replications for each treatment (Fig. 2). Four different treatments for rolling directions were used with respect to planting direction of rye and cotton: (1) Parallel, (2) Perpendicular, (3) Diagonal at 45-degrees, and (4) No-roller (standing rye).

Four treatments of commercially available row cleaning attachments were used: (1) No-row cleaner, (2) Dawn TM row cleaner, (3) Dawn TM row cleaner without coulter, and (4) Yetter TM row cleaner.

Figure 1. Three-section roller with straight crimping bars 13.5 feet wide.

On the day of rolling the cover crop, the standing height of rye was measured and samples of biomass were collected. The average height of rye was 47-in with an average dry mass of 2.9 tons/acre. Cotton was seeded into rolled rye residue using a John Deere 4-row Max Emerge Plus Vacuum Planter to which different row cleaners were attached. Cotton was harvested in the fall of 2004 and cotton yield was determined.

Data were analyzed with SAS (2001) using the ANOVA procedure. A significance level of $P \leq 0.05$ was chosen to separate treatment effects.

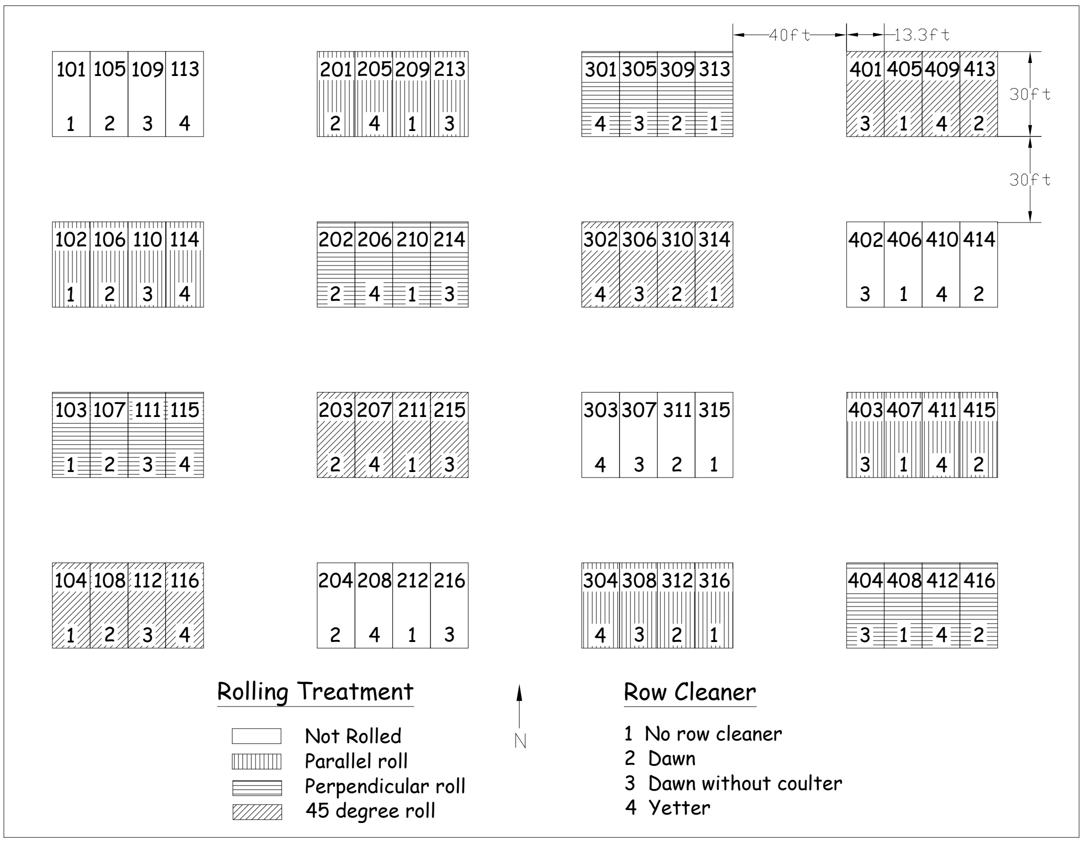

Figure 2. Experimental layout: a completely randomized block design with four replications for each location.

RESULTS AND DISCUSSION

Results were based on the first year of data. Preliminary data showed consistency in cotton emergence for rolling treatments and row type cleaner at both locations.

a. Cotton emergence and rolling direction

Significant differences in cotton emergence were found for all rolling direction treatments at E.V. Smith (LSD=1.46). The highest cotton emergence was found with the parallel rolling direction and the worst direction was perpendicular (Fig. 3). At TVS, the highest emergence was found with parallel and no-rolled cover crop, however there were no significant differences (LSD=1.59) between these rolling treatments (Fig 4). The perpendicular pattern had the worst cotton emergence, similar to the EV Smith location.

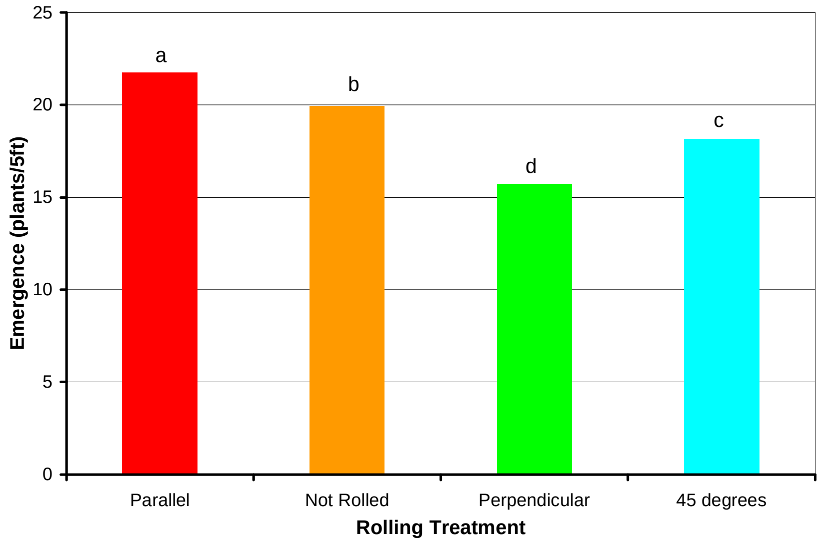

Figure 3. Rolling pattern direction and cotton emergence relationship at the E.V. Smith location (LSD = 1.46).

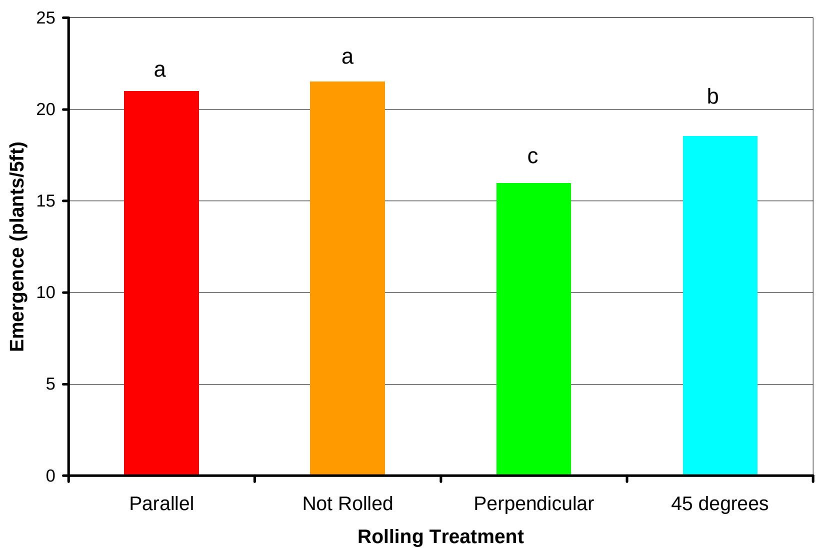

Figure 4. Rolling pattern direction and cotton emergence relationship at the TVS location (LSD=1.59).

b. Cotton yield and rolling direction

At the E.V. Smith location, the highest and significantly different cotton yield (857 lbs/Ac) was found with the parallel rolling direction when compared with other rolling patterns (LSD = 72.9). However, yield was severely reduced by Hurricane Ivan in 2004 which occurred during the harvesting period. The yield at the EV Smith station was only 25% of the yield that was recorded at TVS. The worst rolling pattern was the diagonal (45^o) rolling direction (Fig 5). At TVS, the highest cotton yield (3354 lbs/Ac) was observed with the parallel and no-rolling treatments, and no significant difference was found between these treatments (LSD = 103.96). Significantly lower cotton yield was found with perpendicular and diagonal (45^o) rolling patterns, however, there was no significant yield difference between these patterns (Fig 6).

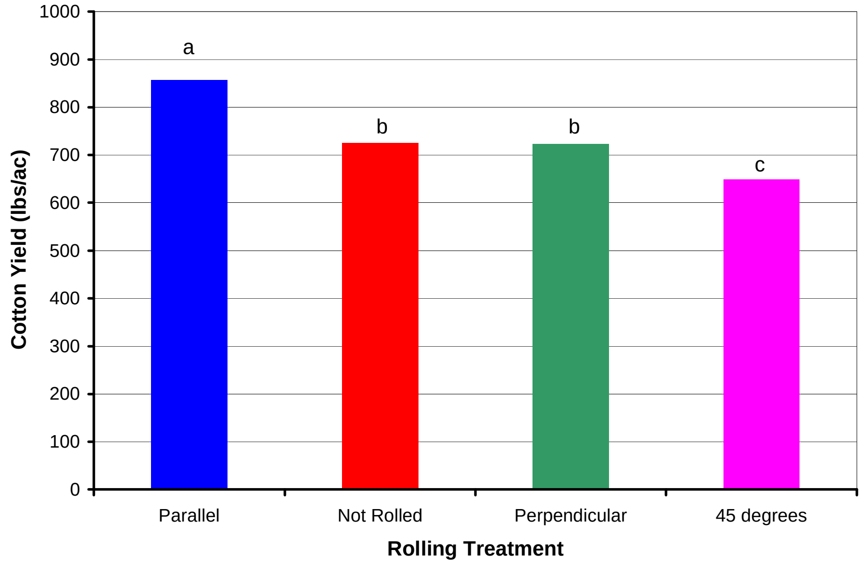

Figure 5. Rolling pattern direction and cotton yield relationship at the E.V. Smith location (LSD = 72.9).

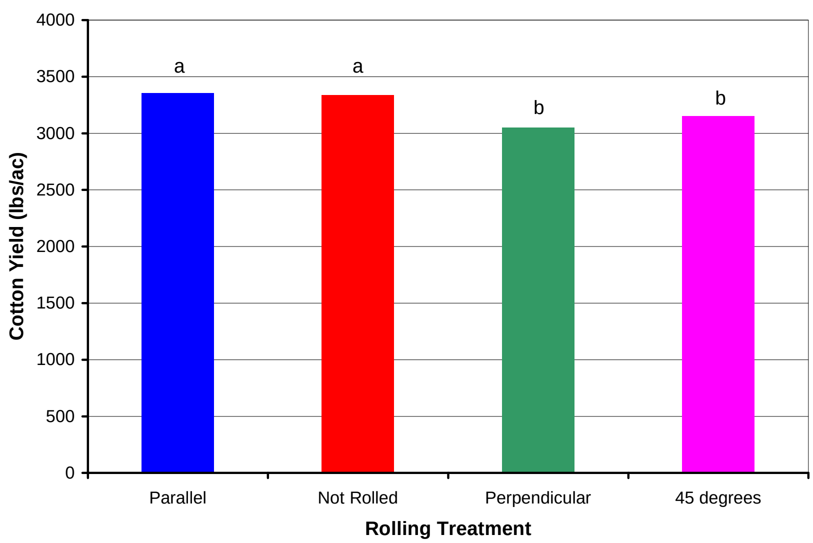

Figure 6. Rolling pattern direction and cotton yield relationship at the TVS location (LSD = 103.96).

c. Cotton emergence and type of row cleaner

No significant differences were found among the Yetter, Dawn and Dawn with no-coulter at E.V. Smith (Fig. 7), however the highest cotton emergence was found with the Yetter attachment. The lowest cotton emergence was found with no-row cleaner attachment (LSD = 1.45). At TVS, the highest and significantly different seed emergence rate was found with Yetter in comparison with other row cleaner treatments (Fig 8).

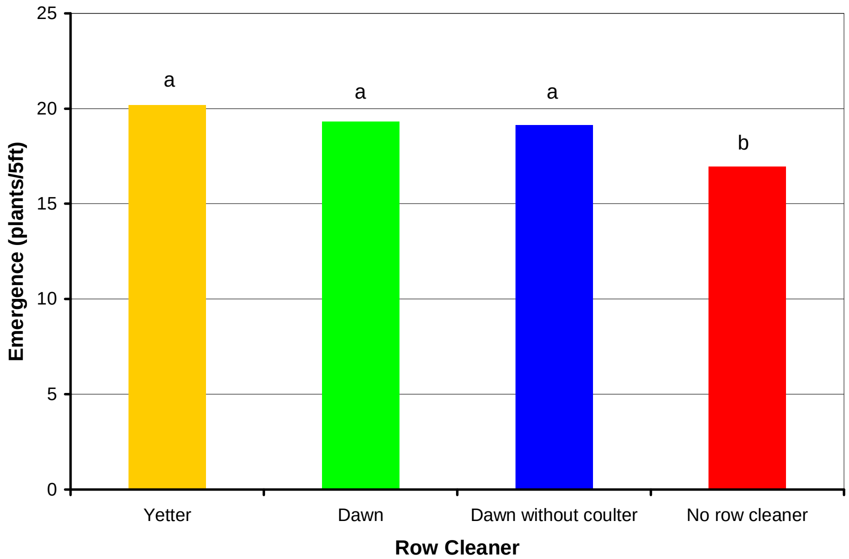

Figure 7. Row cleaner type and cotton emergence relationship at the E.V. Smith location (LSD = 1.46).

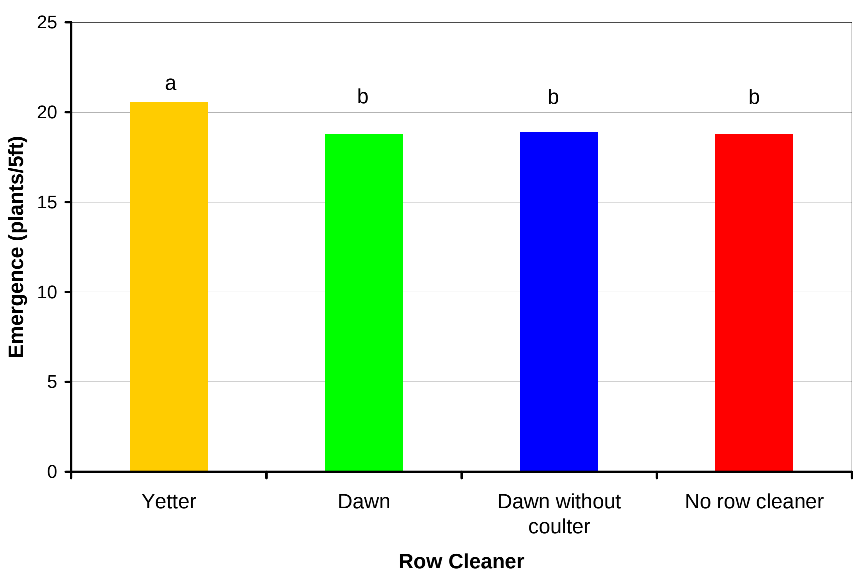

Figure 8. Row cleaner type and cotton emergence relationship at the TVS location (LSD = 1.59).

d. Cotton Yield and type of row cleaner

At the E.V. Smith location, no significant differences were found between the Yetter, Dawn, and Dawn with no-coulter attachments, with the highest cotton yield found with Yetter (LSD = 72.9). The no-row cleaner on the planter produced the lowest cotton emergence and yield (Fig 9). As mentioned previously, the yield at E.V. Smith was severely reduced by Hurricane Ivan in 2004 harvesting season. Because the Hurricane Ivan significantly reduced cotton yield, no comparison was made between the two locations. At TVS, the highest yield was found with Yetter and Dawn without coulter row cleaners (LSD = 103.96). The lowest and significantly different cotton yield was found with Dawn and no row cleaner (Fig 10).

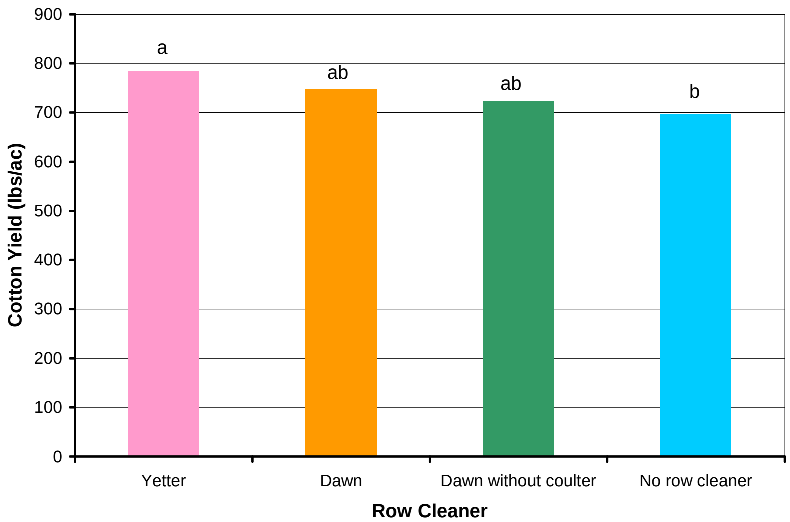

Figure 9. Row cleaner type and yield relationship at the E.V. Smith location (LSD =72.9).

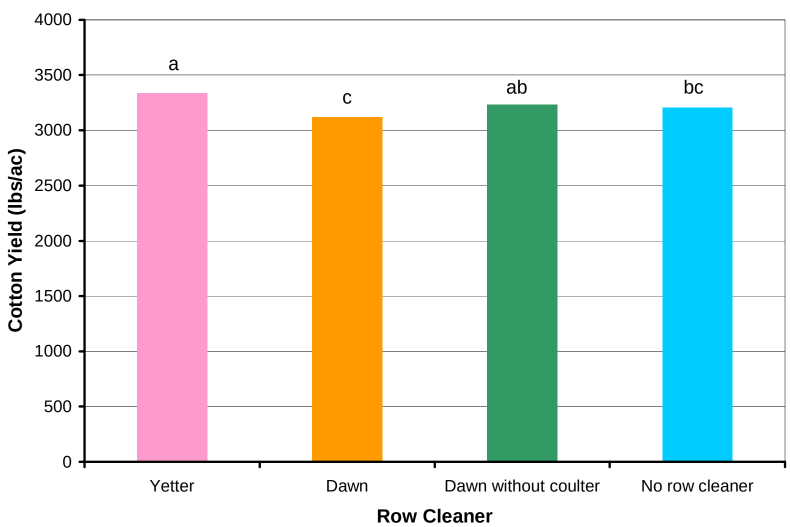

Figure 10. Row cleaner type and cotton yield relationship at the TVS location (LSD = 103.96)

To determine the correlation between seed emergence and cotton yield, simple regression analyses were performed. There was a poor correlation between seed emergence and cotton yield for the E.V. Smith location (Fig. 11). This poor correlation can be explained by reduction of cotton yield that was caused by Hurricane Ivan. In contrast, at TVS there was a strong correlation between seed emergence and cotton yield for rolling direction treatments (Fig. 12).

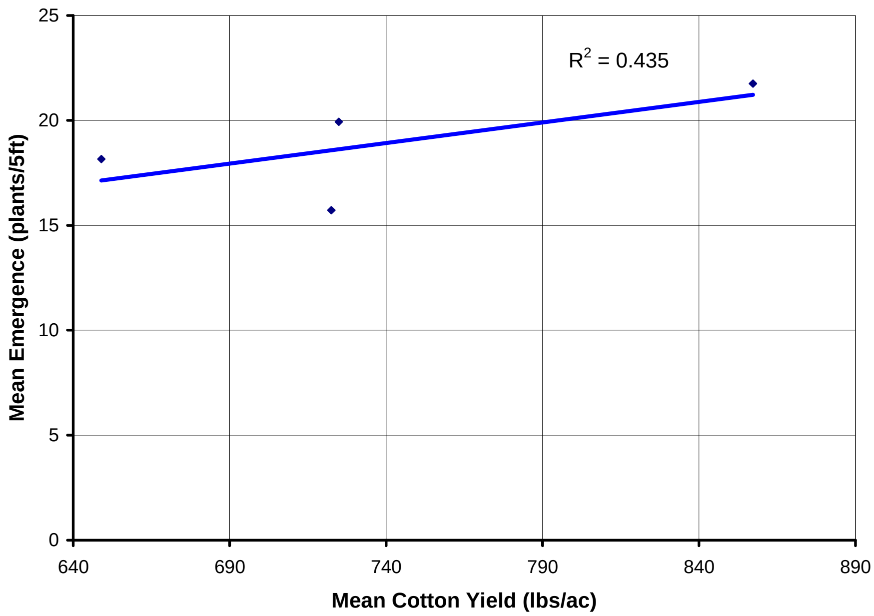

Figure 11. Mean cotton yield vs mean emergence at the EV Smith.

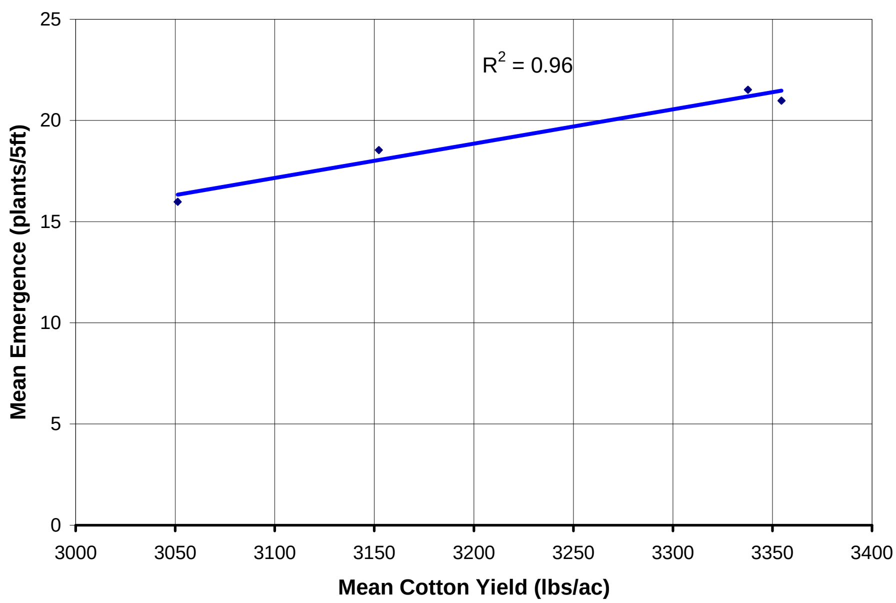

Figure 12. Mean cotton yield vs mean emergence (rolling direction) at theTVS location.

CONCLUSION

Based on preliminary results (2004 data), the greatest plant emergence and the highest yield were found with parallel rolling pattern and Yetter row cleaner at E.V. Smith and TVS.

The worst results came with the perpendicular and 45 degree rolling patterns, and no–row cleaner, also at these two locations.

Poor correlation between seed emergence and cotton yield was found at the E.V. Smith, whereas a strong correlation between seed emergence and cotton yield was found at the TVS location.

DISCLAIMER

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

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CROPPING SEQUENCE AND BIOCOVER EFFECTS ON SOIL ORGANIC CARBON UNDER NO-TILL PRODUCTION.

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ABSTRACT

Farmland under no-till can be a sink for atmospheric carbon. However, the rate of carbon storage in any given acre is uncertain because time, climate, soil texture, fertilization, crop rotation, and winter cover can all affect carbon cycling. The goal of this research is to compare temporal changes in soil carbon among different systems of no-tillage production. To do this, combinations using different crop sequences of Roundup Ready© corn, cotton, and soybean and biocovers of wheat, vetch, poultry litter, and winter weeds were used at the Milan Experiment Station and the Middle Tennessee Experiment Station. These two sites are in different physiographic regions of Tennessee. Soil samples were taken before cropping sequence and biocover treatments began and after two years of crops and biocovers had been applied.

Preliminary results based on a subset of the data show no significant difference in the changes in soil carbon over time between the different systems. However, an initial trend of decreasing carbon levels over all the treatments was seen. Results from the analysis of the full data set will be presented.

COMPARISON OF COMBUSTION, CHEMICAL, AND NEAR-INFRARED SPECTROSCOPIC METHODS TO DETERMINE SOIL ORGANIC CARBON

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ABSTRACT

As interest in soil carbon dynamics and sequestration grows, so does the need for a rapid, accurate, and inexpensive method for quantifying soil organic carbon (SOC). Soils were collected from 14 sites and three depths. All samples were analyzed via dry combustion (CC) and Walkley-Black chemical (WB) methods. In addition, samples were air-dried and processed to give five surface roughness levels. Near infrared reflectance (NIR) spectra were obtained using a LabSpec Pro® near infrared spectrometer. The effect of surface roughness on signal quality was ascertained. Partial least squares regression was used to develop a model able to predict SOC as measured by NIR. Results from the three methods; CC, WB, and NIR, were compared to assess the reliability of NIR determination of SOC. Both NIR and WB analysis correlated well (greater than 0.9) with SOC as determined by combustion. NIR proved to be a viable alternative method of SOC analysis for the wide range of Tennessee soils used in this study.

INTRODUCTION

Due to increasing atmospheric CO_2 concentrations, interest in carbon dynamics and sequestration has increased. Soil carbon sequestration has the potential to be an inexpensive, widely utilized form of carbon storage. However, the size and nature of SOC pools can be affected by a variety of factors including local management practice, climate, and soil type. Therefore, studies across a wide array of systems must be undertaken to understand soil carbon sequestration. To accomplish this a rapid, accurate, and inexpensive method for quantifying SOC is needed.

One method that has recently demonstrated the potential to fulfill this demand is NIR. NIR-based technology has been successfully used in grain characterization for almost 35 years (Ben-Gera, and Norris, 1968) and has recently been expanded to other areas. In 1986, Dalal and Henry had used an NIR technique to predict organic matter in soil and in 1995, Ben-Dor and Banin had achieved high correlations between NIR signal intensity at certain wavelengths to specific soil organic matter functional groups. More recently Reeves and McCarthy (2002) presented refined analytical and statistical techniques resulting in a NIR model with r^2 value of 0.90 encompassing a range of Midwestern soils. However, one drawback of NIR is that machine signals require calibration using a library of soils with known carbon contents. It has also been shown that calibration accuracy is dependant on both precise NIR techniques and the local origin of the soil calibration library (Confalonieri, et. al., 2001). ***The objective of this research was to evaluate the potential of near infrared reflectance (NIR) spectroscopy to determine SOC content in a variety of soils collected from across Tennessee.***

METHODS

Sampling

Two soil sample subsets were used. Subset 1 consisted of a group of 55 samples taken from those obtained by landowners from across Tennessee and submitted to the University of Tennessee Soil Test Lab in Nashville. These were selected to represent a wide range of soil types and carbon levels. Subset 2 consisted of soil samples taken from specific, predetermined locations with a soil probe. These soils were sampled from 14 selected sites across Tennessee. They were taken from the following depths: 0-2", 2-6", and 0-6". Samples were then air dried, lightly ground, and sieved into five particle size classes (see Table 1), resulting in 210 individual samples.

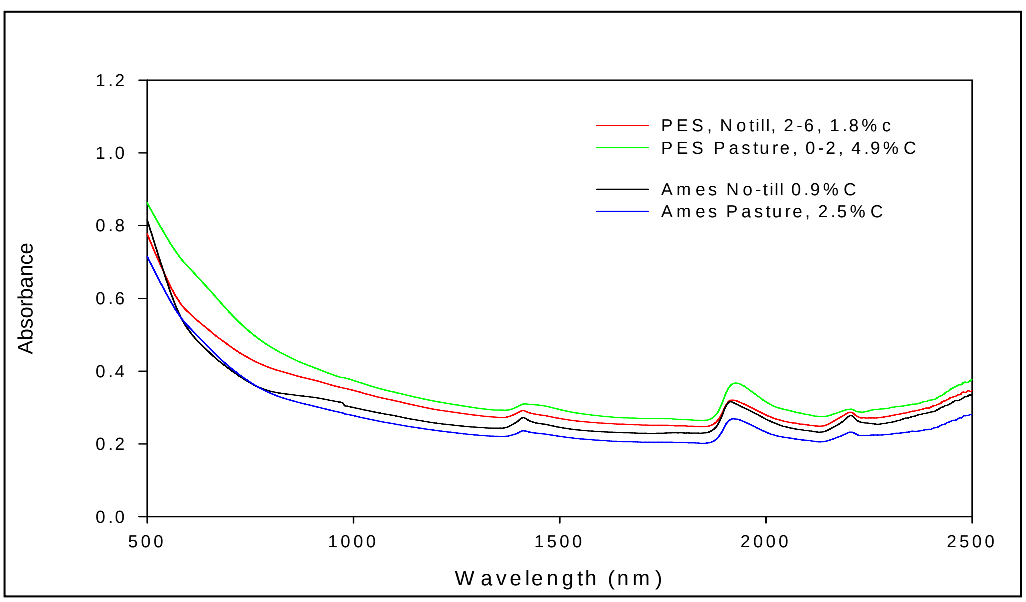
Table 1. Particle size separation treatment designations.

Particle Size (s)	Ground s<.01"	mix of s<0.08" and s<.01"	.01"<s> 0.08"	s<.08"	Sifted s<.01"
Treatment	A	B	C	D	E

Analysis

CC was measured using carbon combustion (FlashEA 1112 NC Analyzer, Thermo Electron Corp.). Organic matter (OM) was measured using a modified Walkley-Black chromic acid oxidation method (Walkley and Black, 1934). NIR spectra were made with an Analytical Spectral Devices (ASD) Field Spectrometer at wavelengths between 500-2400 nm, using a rotating sample cup. Light was provided by a DC lamp set at 30º above the sample, directed towards the samples' center. A fiberoptic probe placed 2.76" above the surface gave an optical scanning field with 1.4" diameter. Captured spectra were then transferred from the ASD to an Unscrambler® file (CAMO technologies, 2003). Five spectra per sample were collected and averaged into one. The data set was further reduced by averaging spectral data collected from 1nm intervals to intervals of 4nm to reduce file size and time required to compute partial least squares (PLS) models. Then, reflectance (R) was transformed to absorbance, A=log (1/R) and a mean normalization transformation was performed. To improve peak discrimination, the Norris derivative was taken of each 4nm segment. PLS models were then constructed and a cross-validation was performed.

Figure 1. NIR spectra of four soils.



RESULTS

Figure 1 shows NIR spectra of selected soils. It can be seen that the spectra have unique but similar shapes, with signal peaks of different soils at the same wavelengths. These spectral characteristics allow correlations with soil chemical properties to be determined. Analysis resulted in a strong (r=0.90) overall relationship between CC and NIR (Figure 2). Early in the model development process it was observed that models for higher carbon (CC> 7%) samples did not apply well to those for lower carbon samples (CC<7%). Because most of the samples were low in carbon, further analysis was directed towards these low C samples only. This caused the omission of 9 of the 235 samples, but improved model performance greatly. Because model predictions are restricted to sample population, results do not apply to the omitted high carbon soils. Table 2 shows in detail the correlations, standard errors, and fitting parameters between the different sample groups, NIR signal, CC and OM. Generally, NIR correlated better with CC than OM. All particle size groups had very high (>0.95) model correlations for CC (Figure 3) while similar correlations for OM were lower (>0.80). Standard errors displayed trends similar to the correlations with those of CC being smaller (0.11%-0.25% C) than those of OM (0.36%-0.9%). The fully cross-validated models followed the same trends, with accordingly lower correlations and higher standard errors. Cross-validated NIR correlations with CC were 0.80 or above with standard errors of prediction ranging from 0.16% to 0.53%. NIR showed lower correlation with OM than CC (r>0.65) with standard prediction errors being higher (0.4% to 1% C).

It should be noted that while the subset 1 samples showed the same NIR prediction trends for CC relative to OM, overall model quality was much lower than those based on subset 2. This may be due to a number of factors including more variability within each individual sample in subset 1 or the fact that this subset represents a wider spatial and taxonomic variety than subset 2. However, when the subset 1 samples were combined with subset 2, overall model quality was improved to a 0.90 correlation and 0.42% C standard error of prediction for the validated model. Data for 0-2” and 2-6” depth increments were used for model development, but comparisons between C detection methods at depths are not shown. Accuracy between methods followed similar trends for each depth as that which was seen in the overall model development shown in Table 2.

The overall linear regression of Walkley-Black determined OM to WBC correlation was 0.87 with a standard error of 0.59%. All NIR predictions of CC, which had a correlation of 0.9 and a 0.42% standard error compared favorably to the Walkley-Black chemical method of soil carbon determination (Table 3, Figure 4).

Table 2. Model fit, error, and parameters.

	NIR Prediction of Combustion C				NIR Prediction of OM				OM Prediction of Combustion C			
Sample Set	r	Slope	Offset	RMSEC (%C)	r	Slope	Offset	RMSEC (%C)	r	Slope	Offset	RMSEC (%C)
Subset 1	0.665	0.429	1.250	0.939	0.878	0.771	0.616	0.750	0.879	0.77	0.46	0.58549
Subset 2	0.952	0.906	0.152	0.277	0.864	0.746	0.700	0.693	0.870	0.756	0.391	0.444
Subsets 1+2	0.902	0.813	0.323	0.424	0.806	0.650	0.930	0.845	0.848	0.719	0.488	0.538

Cross-Wise Validation												
	NIR Prediction of Combustion C				NIR Prediction of OM				OM Prediction of Combustion C			
Model Set	r	Slope	Offset	RMSEP (%C)	r	Slope	Offset	RMSEP (%C)	r	Slope	Offset	RMSEP (%C)
Subset 1	0.535	0.362	1.410	1.060	0.653	0.568	1.220	1.240	0.862	0.757	0.524	0.622
Subset 2	0.933	0.882	0.185	0.325	0.839	0.729	0.706	0.750	0.846	0.748	0.403	0.453
Subsets 1+2	0.866	0.785	0.371	0.492	0.765	0.617	1.017	0.919	0.840	0.712	0.499	0.550

† Abbreviations correspond to the following: near-infrared reflectance (NIR), carbon (C), organic matter (OM), correlation (r), Root mean standard error of correlation (RMSEC), and root mean standard error of prediction (RMSEP).

Table 3. Comparison of SOC determination methods.

Sample Site	Depth (in)	CC (%)	W-B OM (%)	OM Pred of CC (%)	NIR Pred of CC (%)
TES Upland Forest	0-6	2.21	3.5	2.41	2.35
TES Pasture Sideslope	0-6	1.44	2.7	1.32	1.36
TES Pasture Sideslope 2	0-6	1.75	3.2	1.76	1.76
TES Depression Pasture	0-6	1.69	3.0	1.67	1.68
TES Sideslope Tilled	0-6	0.98	1.9	0.68	0.78
TES Upland Tilled	0-6	0.90	1.3	0.56	0.68
Ames Forest	0-6	1.61	2.6	1.56	1.58
Ames 100 yr Pasture	0-6	1.49	2.3	1.40	1.43
Ames No-till Soy-corn	0-6	0.83	1.4	0.47	0.59
Ames Tilled Soy	0-6	0.98	1.5	0.68	0.78
PES Forest	0-6	2.74	3.8	3.15	3.02
PES Fescue Pasture	0-6	2.83	4.7	3.27	3.13
PES No-till Corn	0-6	1.83	3.3	1.86	1.85
PES Tilled Potatoes	0-6	1.16	1.8	0.93	1.01

†Abbreviations correspond to the following: UT Tobacco Experiment Station (TES), UT Plateau Experiment Station (PES), Walkley-Black (W-B), organic matter (OM), combustion carbon (CC), near-infrared reflectance (NIR) and prediction (Pred).

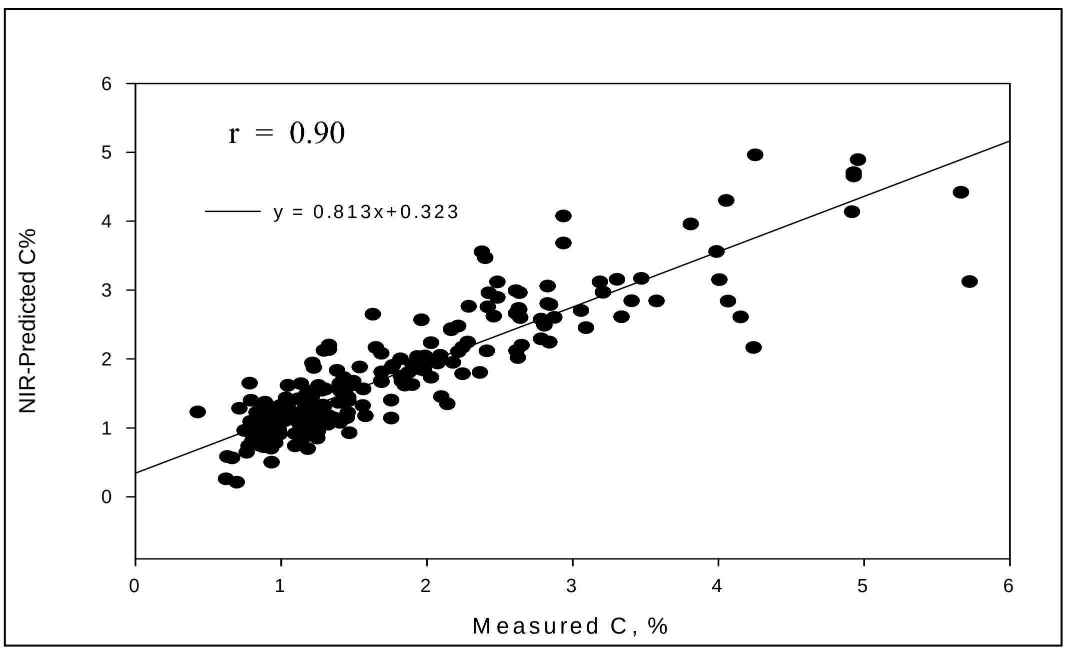


Figure 2. Plot of CC Vs. NIR predicted C.

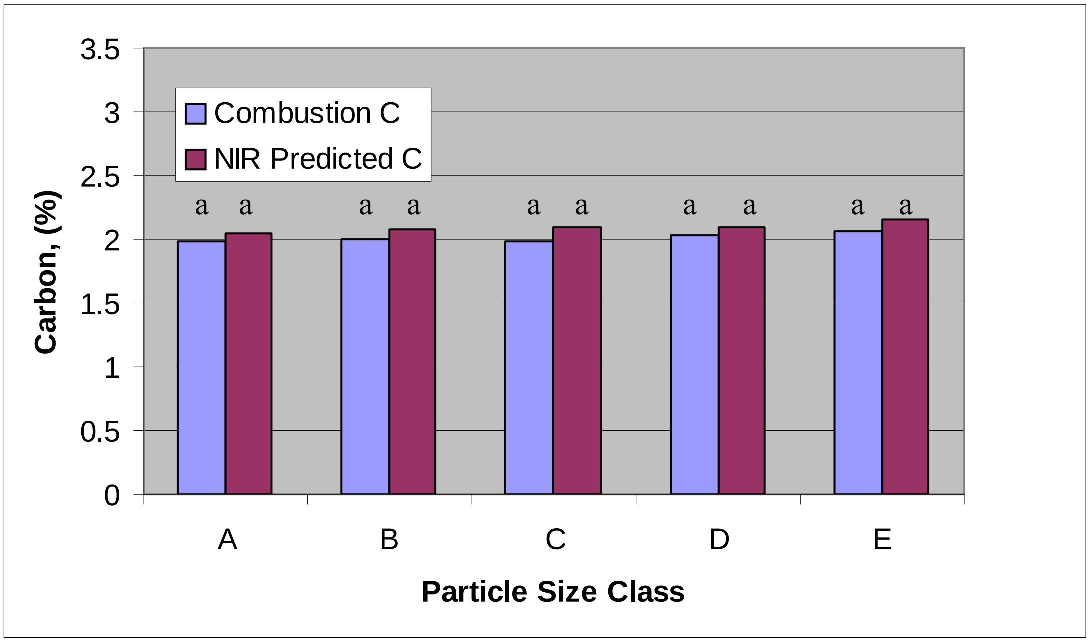


Figure 3. Effect of particle size class on NIR prediction of combustion carbon.
† Columns topped by the same letter in each pair are not significantly different.

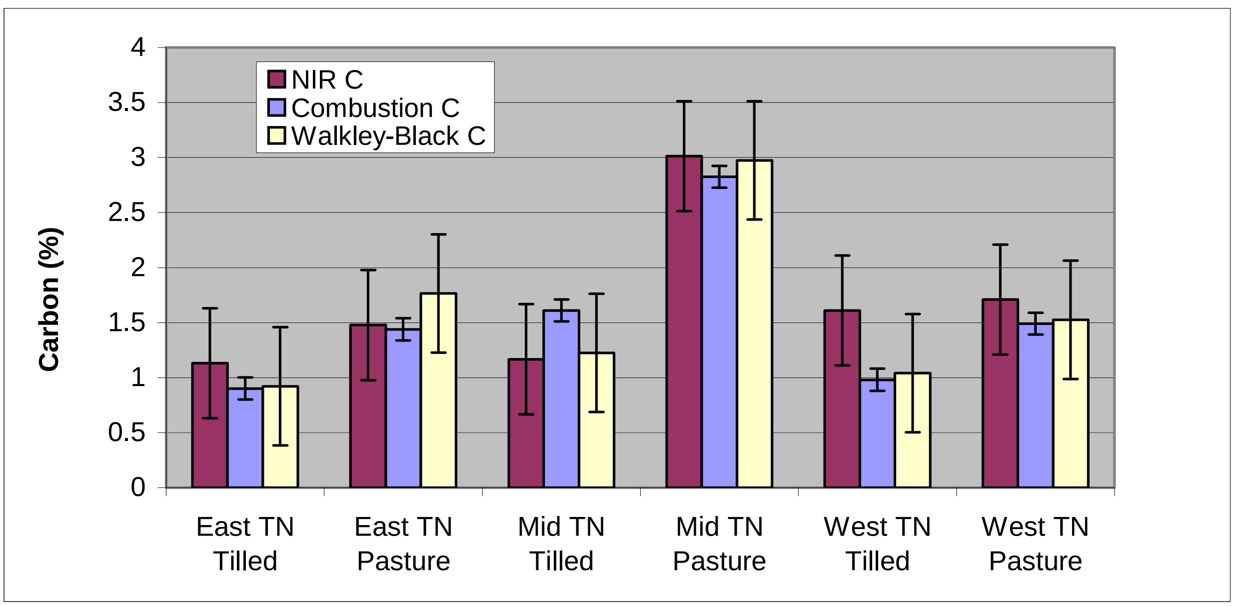


Figure 4. Comparison of SOC determination methods with six Tennessee soils at a depth of 0-6”.

CONCLUSIONS

● NIR derived model parameters were generally insensitive to sample particle size, so differing sample preparation techniques did not adversely effect the quality of NIR measurements.

● Combustion carbon can be more accurately predicted than Walkley-Black organic matter using this NIR technique.

● NIR presents a viable alternative to the Walkley Black method for carbon determination for the soils used in this study.

Benefits of NIR with respect to combustion and Walkley-Black methods:

-Faster analysis time

-No toxic chemical byproducts

-No reagents

-Equipment has proven to be durable and relatively low maintenance

Limitations of NIR:

-Model development requires some statistical knowledge to avoid over-fitting and interpretation errors.

-Analyses are restricted to soil types that are similar to those used in model creation

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PEANUT RESIDUE AS A NITROGEN SOURCE FOR CONSERVATION TILLAGE RYE AND COTTON

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ABSTRACT

Previous research highlights benefits of utilizing legumes in rotations with non-leguminous crops. Leguminous summer cash crops can contribute nitrogen (N) to succeeding crops. This study assessed the contribution of N from peanut (*Arachis hypogaea* L.) residues to a rye (*Secale cereale* L.) cover crop and subsequent cotton (*Gossypium hirsitum* L.) crop in a conservation system on a Dothan sandy loam (Fine-loamy, kaolinitic, thermic Plinthic Kandiudults). Treatment structure was a split plot in a randomized complete block design, with main plots of peanut residue retained or removed from the soil surface, and subplots as N application rates (0, 30, 60 and 90 lb acre^{-1}). In-season N uptake by rye and cotton differed with N rate. Peanut residue had no effect on rye biomass and N uptake, seed cotton yields, cotton N uptake, or cotton dry weights. Our results indicate that peanut residue does not contribute significant amounts of N to succeeding crops, however, retaining residue on the soil surface provides other benefits to soils in southeastern US.

INTRODUCTION

Management systems that maintain crop residues on the soil surface have several attractive features, including reduced erosion, less on-farm energy use, more available soil water (Unger and McCalla, 1980), and improved soil nutrient status (Kuo et al., 1997). Use of legume crop residues to increase crop production is an old farming practice (Hargrove, 1982). The benefits of legumes are usually associated with N contribution to subsequent crops. Nitrogen fixed by legumes in symbiosis with *Rhizobium* bacteria contributes to succeeding non-fixing crops upon decomposition of legume top and root material (Bruulsema and Christie, 1987; Touchton et al., 1984).

Corn (*Zea mays*) grown without N fertilizer following crimson clover (*Trifolium incarnatum* L.) yielded as much as corn grown following rye with 98 lb N acre^{-1} (Mitchell and Teel, 1977). Bruuselma and Christie (1987) reported 123 lb N acre^{-1} contribution from alfalfa residues that resulted in a 107 bu acre^{-1} corn yield and 124 lb N acre^{-1} contribution from red clover residues that resulted in a 113 bu acre^{-1} corn yield. Hargrove (1986) observed that crimson clover can replace as much as 105 lb acre^{-1} of N fertilizer. Peanut residues were reported to release 37 lb N acre^{-1} to a succeeding maize crop (Mubarak et al., 2002). McDonagh et al. (1993) reported 80% greater corn grain N and 65% higher corn grain dry weight in plots where peanut residue was incorporated compared with plots where it was removed.

Field experiments suggest that yield responses to residues are equivalent to those obtained by application of fertilizer N at a rate equal to two thirds of the N yield of the residues (Groya and Sheaffer, 1985). Yano et al. (1994) reported that peanut residue contributed 11.2% of its total N to a succeeding wheat (*Triticum aestivum* L.) crop upon decomposition. This was comparable with application of 66 lb N acre^{-1} as fertilizer. The objective of our study was to estimate N contributed by peanut residues to a succeeding rye crop and cotton crop in a conservation tillage system.

MATERIALS AND METHODS

This two-year experiment was established in October 2002 at the Wiregrass Research and Extension Center in Headland, AL on a Dothan sandy loam. The experimental design was a split-plot in a randomized complete block (replicated four times). Main plots consisted of retention or removal of peanut residue on the soil surface. Subplot treatments were N rates (0, 30, 60, and 90 lb N acre^{-1}) hand-applied in the fall to the cover crop and again in the spring after cotton planting. The designated rate was applied to the same plot in the fall and spring. The N source was ammonium nitrate. Nitrogen was applied to the rye cover crop on 21 November 2002 and 14 November 2003 and to cotton on 15 May 2003 and on 12 July 2004. Plot dimensions were 24 ft. wide (8-36 in. rows) and 40 ft. long.

Rye was planted (1.5 bu acre^{-1}) on 20 November 2002 and 30 October 2003. Soil samples were collected in the surface 6 in. for initial inorganic N concentrations and soil pH determination. Composite soil samples were taken from each plot by collecting 15 cores randomly and compositing. Selected initial characteristics of soil samples are presented in Table 1.

Rye dry matter production was measured the following spring on 14 March, 28 March, and 23 April in 2003 and on 11 March, 25 March and 8 April in 2004 by hand harvesting a 2.7 ft^2 area selected at random from each plot. These samples were dried at 140 ^{o}F for 24 h, and weighed for dry matter yield. A sub sample was ground to pass a 1.0-mm sieve, and analyzed for total N using a LECO CHN-600 analyzer as described by Hue and Evans (1986). Rye was chemically terminated on 23 April 2003 and 30 April 2004 by mechanically rolling the crop followed by glyphosate application.

Cotton was planted at 3.5 seeds ft^{-1} approximately 3 wk after rye termination. Cotton planted in 2004 was damaged by *Rhizoctonia* and was replanted on 21 June. Prior to fertilizer application, composite soil samples were taken again from each plot using the procedures described above. Seed cotton yield was determined by mechanically harvesting the two center rows of each plot. Samples were collected two times during the growing season (i.e. first square and mid-bloom). A sample of 50 fully opened cotton leaves were randomly picked per plot and bulked for leaf N analysis. Petioles were separated from leaves. All above ground plant parts were removed from a 3.28 ft randomly selected strip within each plot to determine whole plant dry matter production. All plant tissue samples were dried at 65 ^{o}C for 24 hours, ground to pass a 39 mil (1.0 mm) sieve and analyzed for N and C using a LECO CHN-600 analyzer. Whole plant dry weights were recorded for dry matter determination. Chlorophyll meter readings were taken on 30 randomly selected leaves per plot using a chlorophyll meter (SPAD 502, Minolta Co. Ltd).

All data were analyzed using the PROC MIXED procedure of the Statistical Analyses System (SAS Inst., 2001). Treatments were considered significant if P>F was less than or equal to 0.05

RESULTS AND DISCUSSION

Peanut residue biomass collected during the 2003-2004 growing season was 2816 lb acre^{-1} at harvest. Nitrogen concentration in peanut residue averaged 1.5%, comparable to that reported by Mubarak et al. (2003) and Balkcom et al. (2004). Peanut total N accumulation averaged 42 lbs acre^{-1}. This N accumulation was comparable to values reported by Yano et al. (1994) but less than those reported by McDonagh et al. (1993). Okito et al. (2004) reported an average peanut N accumulation of 36 lb acre^{-1} at harvest.

The effects of peanut residue and N rate on rye biomass and N uptake are shown in Table 2. Maximum rye biomass production was measured for the highest fertilizer N rate applied for all three sample times during both growing seasons. Peanut residue had no effect on rye biomass production. Research conducted in Brazil by Okito et al. (2004), reported higher corn yields when corn followed peanuts with residues retained in the field, however, background soil N was low compared to observed N concentrations at our site (Table 1).

Nitrogen uptake in rye was also affected by N rate at all sampling times with the greatest uptake measured following the highest N rate (Table 2). An interaction (P=0.0248) was observed between residue and N rate in the first year at the first sample time (Table 2). Rye N uptake owing to peanut residue retention and application of 30 lb N acre^{-1} was 80% higher than when residue was removed, however, at higher N rates (60 and 90 lb N acre^{-1}) no effects were observed (Fig. 1).

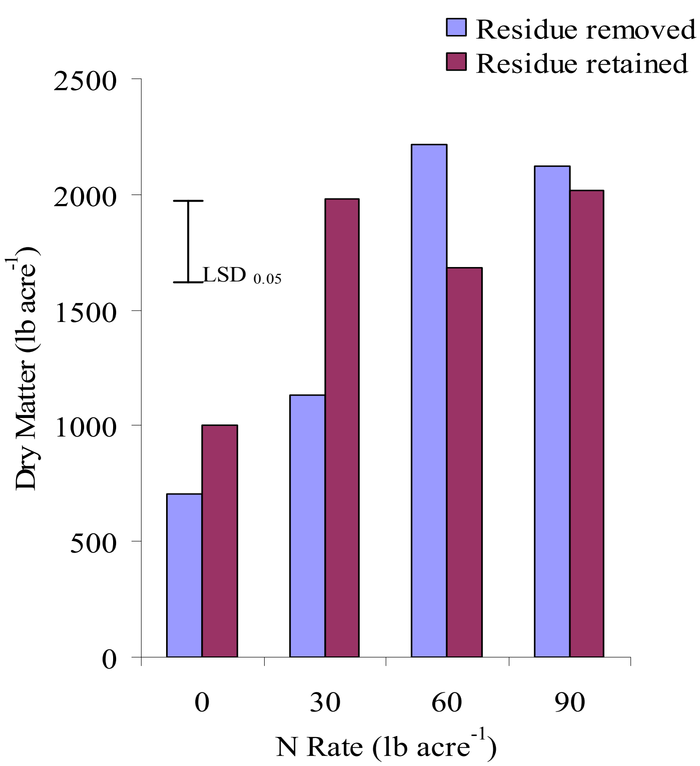

Figure 1. Rye biomass measured on 11 March 2004 following removal and retention of peanut residue and application of nitrogen (N) fertilizer at different rates.

Seed cotton yields did not respond to peanut residue during either year, but there was a response to applied N during the second year (Table 3). In the 2003-2004 growing season, seed cotton yield following an application of 90 lb N acre^{-1} was double the yield measured with no N applied. Seed cotton yields also increased with each increasing N rate.

The effect of peanut residue and N rate on cotton dry weights and N uptake during the 2003-2004 growing season are shown in Table 4. Peanut residue had no effect on dry weights or N uptake at either growth stage. The highest cotton dry weights followed the 90 lb N acre^{-1} application for both growth stages, which also corresponded to the highest N uptakes observed for both growth stages.

CONCLUSION

Rye biomass yield, N uptake and cotton dry biomass, N uptake and seed yield (in 2003-2004 experiment) responded to applied N. Peanut residues did not contribute significant amounts of N to the rye cover crop or subsequent cotton crop. However, maintaining residue in the field could help increase organic matter contents over time, which can provide positive benefits for these soils.

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Table 1. Background soil pH, NO_3-N and NH_4-N (composite of 15 individual cores) prior to rye and cotton establishment.

Year	pH	NO_3-N		NH_4-N	
		Rye	Cotton	Rye	Cotton
		----------------lb acre^{-1}--------------------			
2002	5.5	0.6	2.3	25.6	5.0
2003	6.1	0.2	20.5	5.5	9.8

Table 2. Rye dry weight and N uptake measured following removal or retention of peanut residue and application of nitrogen (N) fertilizer rates on three dates during 2003 and 2004.

	Dry biomass						N uptake					
	2003			2004			2003			2004		
Treatment	14 March	28 March	23 April	11 March	25 March	28 April	14 March	28 March	23 April	11 March	25 March	28 April
Residue treatment	lb $acre^{-1}$											
Residue removed	1540	3600	4700	2050	3720	4430	32	46	34	43	47	41
Residue retained	1660	3200	4290	2420	4040	4520	34	52	43	36	48	43
N rate, lb $acre^{-1}$												
0	1780	1780	1050	1930	1050	2160	18	25	22	28	23	22
30	3220	3220	1920	3230	1920	4310	28	36	32	34	36	38
60	4220	4260	2500	4440	2500	5120	40	60	47	35	56	50
90	4500	4500	3580	5910	3580	6140	46	75	54	62	76	59
	Analysis of Variance (P>F)											
Residue treatment	0.2944	0.2944	0.2667	0.0615	0.3993	0.8374	0.4747	0.3965	0.2562	0.2945	0.7316	0.7881
N rate, lb $acre^{-1}$	0.0004	0.0004	0.0002	<0.0001	<0.0001	0.0002	<0.0001	0.0012	0.0072	0.0136	<0.0001	0.0009
Residue x N rate	0.4559	0.4559	0.1392	0.4227	0.9883	0.7718	0.0248	0.4264	0.5404	0.8668	0.9743	0.801

Table 3. Seed cotton yield measured following removal and retention of peanut residue and application of nitrogen (N) fertilizer rates in 2003 and 2004.

Treatment		2003	2004
Residue treatment		-------------lb acre^{-1}---------------	
Residue removed		977	1944
Residue retained		942	2208
N rate, lb acre^{-1}			
Fall	Spring		
0	0	968	1320
30	30	924	2112
60	60	994	2262
90	90	950	2614
		Analysis of Variance (P>F)	
Residue treatment		0.4459	0.1025
N rate, lb acre^{-1}		0.7863	0.0001
Residue x N rate		0.3225	0.5116

Table 4. Cotton dry weights measured following removal and retention of peanut residue and application of nitrogen (N) fertilizer rates in 2004.

		Dry weights		N uptake	
Treatment		First square	Mid-bloom	First square	Mid-bloom
Residue treatment		-------------------lb acre^{-1}---------------------			
Residue emoved		739	2498	27	59
Residue retained		751	2686	27	58
N rate, lb acre^{-1}					
Fall	Spring				
0	0	534	1555	14	27
30	30	724	2658	23	45
60	60	768	2984	31	79
90	90	955	3168	42	84
			Analysis of Variance (P>F)		
Residue treatment		0.8912	0.4534	0.987	0.8693
N rate, lb acre^{-1}		0.0173	0.0009	0.0001	<0.0001
Residue treatment x N rate		0.5246	0.9151	0.7244	0.6665

SOIL ORGANIC CARBON SEQUESTRATION IN COTTON PRODUCTION SYSTEMS

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ABSTRACT

Conservation tillage, crop intensification, sod-based rotations, and judicious application of fertilizers and herbicides are agricultural practices that are not only agronomically sound, but could increase soil organic C (SOC) sequestration. These practices have great potential for adoption by cotton (*Gossypium hirsutum L*) producers in the southeastern USA. We calculated potential SOC sequestration under different management scenarios of five major land resource areas in the southeastern USA using the Soil Conditioning Index (SCI), a decision tool currently used by USDA-Natural Resources Conservation Service. The SCI will be used to determine payments to farmers enrolling in the Conservation Security Program. All cotton cropping systems with conventional tillage would lead to loss of SOC. Growing cotton in monoculture with no tillage could lead to a small loss, no change, or a small increase in SOC, depending upon major land resource area, slope, and soil texture. The SCI predicted larger changes in SOC whenever no-tillage management was combined with cover cropping and cotton was rotated with high-residue-producing crops. Cotton producers in eligible watersheds of the Conservation Security Program could expect to receive an average of $3.36/acre, with payments up to $8/acre, depending on practices employed and soil conditions. Soil organic C is important to maintain high soil quality, to improve crop productivity, and to mitigate greenhouse gas emission. Further agricultural research and extension activities are needed to capture the full benefits of SOC sequestration for agronomic, environmental, and economic sustainability.

INTRODUCTION

With sound soil and crop management, the potential for SOC sequestration in the southeastern USA may be higher than in more temperate regions of North America (Franzluebbers, 2005), because the warm and humid climate with a long growing season allows for high cropping intensity and biomass production, which translates into high potential for photosynthetic C fixation (Reeves and Delaney, 2002). Surface residue management is especially critical in the southeastern USA, because soils are highly erodible and high-energy rainstorms occur during the growing season (Blevins et al., 1994). Soils of the region have low SOC, partly because of the prevailing climatic conditions and soil mineralogy (Jenny, 1930), but also due to historical mismanagement that exposed the soil surface to rapid biological oxidation and extreme soil erosion (Trimble, 1974; Harden et al., 1999). Cotton is one of the most important crops in Alabama, Georgia, Mississippi, and Texas. Cotton production has high potential profitability, but historically has been detrimental regarding sustainability of natural resources for the region (Reeves, 1994).

Conservation tillage

When crop residues and cover-crop mulch are left on the surface, they protect the soil against erosion, increase water infiltration, decrease soil water evaporation, and increase SOC at the surface. Plant residues decompose slower on the soil surface than when incorporated into soil. Conservation tillage coupled with efficient management of inputs could lead to sequestration of SOC and greater cotton lint and seed yield. Reviewing literature comparing SOC under no tillage compared with conventional tillage in cotton production systems of the southeastern USA, Causarano et al. (2005) obtained an average rate of 428 lb C/acre/yr.

Crop Rotation and Cover Cropping

When practiced in monoculture or even in double cropping, conservation tillage is an imperfect and incomplete system. Perhaps more than any other crop, good residue management is critical in cotton, because of its sparse residue production. Good residue management can be achieved with a sound crop rotation and use of cover crops in combination with conservation tillage. Unfortunately, higher profitability of cotton in relation to other cropping alternatives often leads to cotton monoculture (Reeves, 1994). The 'Old Rotation' experiment at Auburn University was initiated in 1896 to determine (1) the effect of rotating cotton with other crops to improve yields and (2) the effect of winter legumes in cotton production systems (Mitchell and Entry, 1998). Seed cotton yield during a 10-year period from 1986-1995 was greater in rotation with corn (*Zea mays* L.) and winter legumes than under monoculture cropping. Mitchell and Entry (1998) demonstrated a positive association of SOC with cotton seed yield, suggesting that higher biomass inputs from cover crops and corn in rotation with cotton improved SOC sequestration and cotton productivity. With the introduction of conservation tillage to the experiment in 1995, the benefits of crop rotations and cover crops to cotton productivity and SOC concentration have been enhanced (Mitchell et al., 2002; Siri-Prieto et al., 2002).

Fertilizers and Manures

Fertilizer or manure application would be expected to increase SOC, because of greater C input associated with enhanced primary production and crop residues returned to the soil. Using available data from six literature sources of various crops in the region, Franzluebbers (2005) estimated that the net C offset due to N fertilization could be optimized at 214 lb C/acre/yr with the application of 95 lb N/acre/yr. This N rate is within the range of extension recommendations for cotton in most southeastern USA states.

Nutrients from animal manure (e.g. poultry litter, confined dairy, or beef cattle) represent a valuable agricultural resource that is not currently widely and fully utilized. Nyakatawa et al. (2001) suggested that poultry litter application to cropping systems with winter annual cover crops could be an environmentally suitable practice to reduce reliance on commercial fertilizer and dispose of large quantities of waste from a burgeoning poultry industry. Endale et al. (2002) found that combining no tillage with poultry litter application produced up to 50% greater cotton lint than conventionally tilled and fertilized cotton in the Southern Piedmont. Application of dairy manure increased SOC (1.2 tons/acre) in a cotton-corn rotation with cover crops in the Coastal Plain (J. Terra, unpublished data).

Sod-Based Crop Rotation

Soil organic C sequestration under grass management systems in the southeastern USA can exceed sequestration rates observed under crop management systems. From 12 observations of various grass establishment studies, SOC sequestration was 917 $\pm$ 802 lb C/acre/yr during an average of 15 years of investigation (Franzluebbers, 2005). Rotation of crops with pastures could take advantage of high SOC and promote higher productivity under ideal condition, because surface soil would be enriched in soil organic matter and organically bound nutrients, some weed pressures could be reduced, soil water storage could be enhanced, and disease and pest pressures could be reduced. Successful crop and pasture rotation systems have been developed with conservation tillage in South America (Diaz-Zorita et al, 2002; Garcia-Prechac et al., 2004). These studies have demonstrated that SOC can be preserved following rotation of pasture with crops when using conservation tillage. At the Wiregrass Research and Extension Center in Alabama, SOC concentration of the surface 2 inches in a long-term cotton-peanut (*Arachis hypogaea L*) rotation (initially 0.76 %) increased to 0.94 % following introduction of winter annual pasture [oat (*Avena sp*) or ryegrass (*Lolium sp*)] for three years (G. Siri-Prieto, unpublished data). Winter-annual grazing in rotation with cotton also increased net returns.

PREDICTING SOIL ORGANIC C CHANGES IN COTTON PRODUCTION SYSTEMS

The Soil Conditioning Index (SCI) is a tool currently used by the USDA-Natural Resources Conservation Service to predict trends in SOC, as affected by cropping system and tillage management (Hubbs et al., 2002). The SCI has been incorporated into the Revised Universal Soil Loss Equation (RUSLE2) to assist district staff members of the Natural Resources Conservation Service working with local producers to plan and design crop and residue management practices for overcoming issues of low soil organic matter, poor soil tilth, and other soil quality-related problems. When SCI is negative, SOC is predicted to decline. When SCI is positive, SOC is predicted to increase. The magnitude of the SCI value is more related to the probability of achieving a change rather than determining an absolute value of that change. The SCI is being used by the USDA–Natural Resources Conservation Service to calculate payments to landowners enrolled in the Conservation Security Program. In the following, we present some scenarios of common crop and tillage management systems being used in five major land resource areas of the southeastern USA. All cropping systems included cotton as a primary crop, either in monoculture or in rotation with other common crops of the region.

Appalachian Ridges and Valleys (Tennessee Valley)

Continuous cotton production in the Tennessee Valley of northern Alabama would cause loss of SOC under both chisel plow and conservation tillage (Table 1), although the extent of loss would likely be greater with inversion tillage than with conservation tillage. By including a cover crop in a cotton-corn rotation, SOC would more likely increase. Even with soil disturbance with a bent-leg subsoiler (paratill) prior to cotton planting, including a cover crop in the cropping system could help to promote SOC sequestration. Soil compaction can be a problem in the Tennessee Valley region, where soils have platy structure, leading to high penetration resistance, especially under no tillage. Cotton yield reductions were common under no tillage and jeopardized the adoption of this technology in the early 1990s when the common practice was to plant without tillage directly into cotton stubble with no winter cover crop. It was later demonstrated that non-inversion tillage under the row in the autumn coupled with a rye cover crop to reduce compaction and provide moisture-conserving surface residue could increase yield (Raper et al. 2000a, b; Schwab et al., 2002).

Table 1. Management scenarios and soil conditioning index (SCI) for the Appalachian Ridges and Valleys region.

Location	Soil Series	Soil Texture [a]	Slope (%)	Scenario	SCI
Belle Mina AL	Decatur	SiL	3	Continuous cotton, fall chisel plow	-2.60
				Continuous cotton, no tillage	-0.36
				Cotton/rye cover-corn/rye cover	0.17
				Cotton/rye cover-corn/rye cover, paratill prior to cotton	0.09

[a] SiL is silt loam.

Coastal Plain

All conventional-tillage scenarios in the Coastal Plain region would cause loss of SOC (Table 2). Soil management strategies to increase SOC sequestration included the use of conservation tillage, greater cropping diversity with high residue-producing crops such as corn and cover crops, application of animal manure, and inclusion of sod-based rotations. Subsoiling with paratill has been found to help alleviate soil compaction due to traffic and natural reconsolidation, which can constrain root growth in many Coastal Plain soils. However, when paratill was simulated in monoculture cotton with conservation-tillage planting at Shorter AL, SOC was predicted to decline. Only in a cotton-corn rotation was SCI positive when paratill was performed.

Table 2. Management scenarios and soil conditioning index (SCI) for the Coastal Plain region. CT is conventional tillage and NT is no tillage.

Soil Series	Slope (%)	Soil Texture [a]	Location / Scenario	SCI: Monoculture Cotton CT	SCI: Monoculture Cotton NT	SCI: Rotated Cotton [b] NT
Bendale	2	SL	Brewton AL	-1.2	0.21	0.50
Norfolk	3	LS	Florence SC	-0.41	0.44	0.60
Norfolk	4	LS	Goldsboro NC	-0.62	0.31	0.58
Dothan	2	SL	Headland AL	-0.94	0.23	0.54
Bama	2	SL	Shorter AL, no manure, no paratill	-0.84	0.28	0.54
			With manure, no paratill	-0.63	0.47	0.60
			No manure, with paratill	-0.84	-0.27	0.45
			Intensive rotation [c], no paratill			0.65

[a] LS is loamy sand, SL is sandy loam. [b] Base rotation is cotton / rye cover – corn / rye cover.
[c] Similar rotation to that described in Reeves and Delaney (2002): corn / sun hemp cover / wheat – cotton / white lupin + crimson clover cover.

Mississippi Valley: Silty Uplands and Alluvium Land Areas

All conventional-tillage scenarios in the Mississippi Valley region would cause loss of SOC (Table 3). Steep slope in Senatobia MS contributed to the large negative SCI under conventional tillage and small negative SCI even under no tillage. With silt loam texture of soils in the region, these soils are highly susceptible to C loss by erosion. Conservation tillage and rotation of cotton with high residue-input crops such as corn and cover crops are key management tools for maintaining adequate infiltration and reducing soil erosion. Mutchler et al. (1985) measured 33 ton/acre/yr of soil loss from conventional-tillage cotton, but only 5 ton/acre/yr) of soil loss from reduced-tillage and no-tillage cotton. Triplett et al. (1996) found that seed-cotton yield was greater under conventional tillage during the 1st year, but was greater under no tillage during the 2nd through 4th years. These data suggest that the benefits of conservation tillage on productivity and SOC can be successfully developed with time due to a change in soil physical, chemical, and biological properties.

Table 3. Management scenarios and soil conditioning index (SCI) for the Mississippi Valley region. CT is conventional tillage and NT is no tillage.

Soil Series	Slope (%)	Soil Texture [a]	Location	SCI Monoculture Cotton CT	SCI Monoculture Cotton NT	SCI Rotated Cotton [b] NT
Grenada	5	SiL	Senatobia MS	-8.4	-1.9	0.07
Gigger	2	SiL	Winnsboro LA	-1.9	0.03	0.11
Dundee	2	SiL	Stoneville MS	-1.9	0.36	0.42
Commerce	2	SiL	St. Joseph LA	-1.5	0.08	0.52

[a] SiL is silt loam. [b] Cotton / wheat cover – corn / wheat cover

Southern Piedmont

All conventional-tillage scenarios in the Southern Piedmont region would cause loss of SOC (Table 4). Monoculture cotton production with conservation tillage would increase SOC, but including a winter cover crop or grain in the rotation would enhance SOC sequestration even further. Increasing crop rotation complexity with short-term sod would have high potential for SOC sequestration. In the Southern Piedmont, cotton was the dominant crop for more than 150 years and soil-erosion scars in this sloping physiographic region suggest that crop residues were poorly managed during this period (Langdale et al., 1994). Despite adequate rainfall, high water runoff and crusting contribute to low soil water storage under conventional tillage. Hence, maintaining sufficient residue cover is particularly important for reducing surface sealing, water runoff, soil loss, and runoff of agricultural chemicals (Raczkowski et al., 2002). Research on these soils has demonstrated that conservation tillage leads to greater SOC storage, improvement in soil quality, and greater cotton yield (Franzluebbers et al., 1999; Schomberg et al., 2003). Deep tillage (such as subsoiling without inversion of soil) may be required only initially during transition to conservation tillage management to overcome the lack of soil structure following decades of intensive tillage.

Table 4. Management scenarios and soil conditioning index (SCI) for the Piedmont region.

Location	Soil Series	Soil Texture [a]	Slope (%)	Scenario	SCI
Watkinsville GA	Cecil	SL	4	Monoculture cotton, spring-chisel tillage	-1.10
				Monoculture cotton, no tillage	0.12
				Cotton – corn – corn – tall fescue pasture	0.61
Auburn AL	Marvyn	LS	3	Monoculture cotton, fall-disk tillage	-0.82
				Monoculture cotton, no tillage	0.27
				Cotton / grazed rye cover, no tillage	0.42

[a] LS is loamy sand, SL is sandy loam.

Eastern Texas: Blackland Prairie, Gulf Coast Prairies, and Lower Rio Grande Plain Land Areas

All conventional-tillage scenarios in the eastern Texas region would cause loss of SOC (Table 5). Adoption of conservation tillage would enhance SOC in these fine-textured soils. Rotating cotton with corn using conservation tillage would lead to even greater potential for SOC sequestration. The relatively small difference between monoculture cotton and rotated cotton using conservation tillage is probably because no cover crop was simulated. Although the drier climatic condition in this region might limit the successful incorporation of a cover crop in the rotation, efforts to develop this technology would probably be beneficial for potential SOC sequestration.

Table 5. Management scenarios and soil conditioning index (SCI) for the eastern Texas region.

				Scenario		
				Monoculture Cotton		*Rotated Cotton* [b]
Soil Series	*Slope (%)*	*Soil Texture* [a]	*Location*	*CT*	*NT*	*NT*
Houston Black	*2*	*C*	*Temple TX*	*-1.10*	*0.55*	*0.53*
Orelia	*2*	*CL*	*Corpus Christi TX*	*-0.71*	*0.26*	*0.36*
Hidalgo	*2*	*SCL*	*Weslaco TX*	*-0.70*	*0.41*	*0.51*

[a] *C is clay, CL is clay loam, SCL is sandy clay loam.* [b] *Base rotation is cotton – corn.*

INCENTIVE PROGRAMS TO FOSTER SOIL ORGANIC C SEQUESTRATION

Current government incentive programs do not specifically address SOC sequestration. The following two programs are administered by the USDA–Natural Resources Conservation Service and indirectly address SOC sequestration in agricultural production systems.

Environmental Quality Incentives Program (EQIP)

Provides financial and technical assistance to farmers and ranchers who adopt environmentally sound practices on eligible agricultural land. National priorities addressed by EQIP are:

- reduction of non-point source pollution such as nutrients, sediment or pesticides
- reduction of groundwater contamination
- conservation of ground and surface water resources
- reduction of greenhouse gas emissions
- reduction in soil erosion and sedimentation from unacceptable levels on agricultural land
- promotion of habitat conservation for at-risk species

Contracts provide incentive payments and cost-sharing to implement conservation practices subject to technical standards adapted for local conditions.

Conservation Security Program (CSP)

This voluntary program provides financial and technical assistance to agricultural producers who conserve and improve the quality of soil, water, air, energy, plant and animal life, and support other conservation activities. Soil and water quality practices include conservation tillage, crop rotation, cover cropping, grassed waterways, wind barriers, and improved nutrient, pesticide, or manure management. Maximum annual payments vary from $20,000 to $45,000, depending on the tier of participation. Contracts are valid for 5 to 10 years.

In fiscal year 2004, the CSP provided funding to 18 watersheds in the USA. About 27,300 farms and ranches were within these watersheds, covering 14 million acres. In the southeastern USA, three watersheds were targeted: (1) Hondo River in Texas, (2) Little River in Georgia, and (3) Saluda River in South Carolina. An enrolled landowner in one of these watersheds would receive a payment of the SCI value for practices employed times $11.60/acre, up to a maximum SCI value of 2.5. Cotton farmers using conservation tillage could be expected to receive anywhere from no payment to $8/acre with an average of $3.36/acre based on SCI values derived from Tables 1-5.

CONCLUSIONS

Current and future agricultural management systems could help to mitigate greenhouse gas emission by sequestering greater quantities of C in soil organic matter with the adoption of conservation practices. Using the Soil Conditioning Index (SCI) to predict changes in soil organic C (SOC), almost all cotton cropping systems with conventional tillage would lead to loss of SOC. Growing cotton in monoculture with no tillage could lead to a small loss, no change, or a small increase in SOC, depending upon major land resource area, slope, and soil texture. The SCI predicted larger changes in SOC whenever no-tillage management was combined with cover cropping and cotton was rotated with high-residue-producing crops. The SCI will be used to determine payments to farmers enrolling in the Conservation Security Program, administered by the USDA–Natural Resources Conservation Service. Cotton producers in eligible watersheds could expect to receive an average of $3.36/acre, with payments up to $8/acre, depending on practices employed and soil conditions.

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COMPARISON OF NITROGEN MINERALIZATION FOLLOWING US AND BRAZILIAN COVER CROPS FOR A SOUTHERN PIEDMONT SOIL

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ABSTRACT

Conservation tillage is used on over 40 percent of the 24 million cropland acres in the southeastern USA. Black oat (*Avena strigosa* Schreb) and oilseed radish (*Raphanus sativus* L.) could be useful alternatives to crimson clover (*Trifolium incarnatum* L.) and winter rye (*Secale cereale* L.) cover crops in the southeast to increase cropping system diversity and reduce the potential for disease and pest buildup. Successful adoption of new cover crops in conservation tillage systems requires understanding of their influences on N availability. We compared black oat and oilseed radish to crimson clover, and rye for effects on N mineralization from fall 1998 to 2002 at the USDA Agricultural Research Service, J. Phil Campbell, Sr., Natural Resource Conservation Center, Watkinsville, Georgia. Rye produced 40 to 60% more biomass while N contents were similar to the other cover crops. Oilseed radish and black oat N contents were similar to crimson cover. Black oat, oilseed radish and crimson clover C:N ratios were less than 30 while rye averaged 39. Amount of N mineralized in 90 days measured with in situ soil cores was 1.3 to 2.2 times greater following black oat, crimson clover, and oilseed radish than following rye. Variability of N mineralization measurements was greater for two years we planted cotton probably associated with N fertilizer application. The rate of N mineralization (k) was 20 to 50% slower following rye than the other three cover crops. The combination of rye residue amount (larger than other cover crops) and its greater C:N ratio, N demand by soil microorganisms following rye caused net immobilization. This supports the recommendations of others to increase N fertilizer for summer cover crops following rye. Soil N mineralization dynamics following black oat and oilseed radish were similar to that following crimson clover which indicates they could be used as cover crops in the southeast without changes in N recommendations.

CHANGES IN SOIL P LEVELS WITH INNOVATIVE AND TRADITIONAL CROPPING SYSTEMS

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ABSTRACT

Most agricultural fields on the southeastern Coastal Plain contain a diversity of soil types, resulting in a wide-range of crop productivity and consequently, soil fertility levels across the landscape. Conservation tillage results in the accumulation of P near the soil surface, thereby making it susceptible to offsite movement in runoff water. Thus, low-yielding areas of fields planted with conservation tillage may be a significant source of P in runoff water. However, these areas should also show the greatest benefit from the precision application of P fertilizer. In this study, we monitored site-specific changes in soil fertility levels resulting from the use of conservation-tillage (CT) and traditional-tillage (TT) systems. This study was conducted from 1998 through 2005 using a split-field comparison at the Clemson University Pee Dee Research and Education Center in Florence, SC. A 14-acre field was split in half, with one half of the field receiving traditional production practices (disking, in-row subsoiling, traditional herbicides) and the other a conservation-tillage production system (no surface tillage, broadcast deep tillage, Roundup Ready herbicide program). Phosphorus was precision applied on the CT side of the field based upon soil samples taken on a 50-ft grid basis and applied on the TT side of the field at a rate based upon a bulk soil sample taken across that side of the field. Corn (*Zea mays* L.) was planted in the study in 1999, 2001, 2003 and cotton (*Gossypium hirsutum* L.) in 2000, 2002, 2004. Phosphorus was the only nutrient we found that could be precision applied. Initially, there were areas high in soil P (greater than 100 lbs/acre) on both sides of the field. These were either low-yielding areas or areas where water ponded after major rainfall events. On the TT side, those areas remained high in soil P for the duration of the study. Other areas in the TT side became deficient in soil P over time. In contrast, areas of the CT side became more uniform in soil P over time, near the 50 to 60 lb/acre level. Results showed precision application of P can effectively reduce soil P to acceptable levels when conservation tillage practices are used on the southeastern Coastal Plain.

ALABAMA CROPMAN: A USER FRIENDLY INTERFACE FOR CROP PRODUCTION SIMULATIONS

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ABSTRACT

The impact of cropping and tillage systems on agriculture production is very complicated, making it very difficult to predict the economic and environmental consequences of changes in agronomic practices. To better understand the potential consequences of agriculture practices, a user-friendly computer simulation model, "Alabama CroPMan", has been developed to be used under Alabama conditions. To validate the model for Alabama conditions, a data base of cotton, corn, and peanut crop yields (from 1997 - 2001) was collected using the variety testing data from three Alabama Agriculture Experiment Stations, representing southern, central, and northern portions of the state (Wiregrass, Prattville, and Tennessee Valley). At each of these locations, the soil type, historical weather data during that time period, and agronomic cultural practices where the study was conducted were utilized for the model simulations. At the Wiregrass Experiment Station, simulation of peanuts was also conducted, using the variety test yields for early, middle, and late maturing varieties. Results from the validation study indicated that the model performed very well in predicting the actual measured yields for corn, cotton, and peanut. The overall objective for the development of this model is to have it be used as a tool to promote the adoption of best management practices for farm production in the Southeast. The model was found to be very useful to derive predictions of not only crop yields, but also the economic and environmental consequence of agriculture production.

INTRODUCTION

The influence of cropping and tillage systems systems on agriculture production is complicated by the diverse and distinctive soil and weather conditions found in any given location and year. While years of agriculture research have resulted in a greater understanding of agronomic processes, the complexity of these systems and the variability resulting from varying soil and weather conditions makes it difficult to predict the economic and environmental consequences of changes in agronomic practices. In order to better understand these complex systems, scientists have developed computer simulation tools that track the varying environmental conditions and agronomic forces that impact agriculture production. One such model is the Crop Production and Management Model (CroPMan).

CroPMan was developed by scientists at the Blackland Research and Extension Center, Texas A&M University, to help agricultural practitioners optimize crop production, to identify limitations to crop yield, and to identify best management practices that minimize the impact of agriculture on soil erosion and water quality. It is a windows-based application of the Environmental/Policy Integrated Climate model (EPIC) (formerly Erosion-Productivity Impact

Calculator) which was originally developed by USDA-Agriculture Research Service (USDA-ARS) to simulate the interaction of natural resources and crop management practices (Williams, 1995). While the EPIC model has been successfully used to simulate agriculture production in Alabama (Mullins and Hajek, 1997), it requires extensive database development for utilization. The purpose of the CroPMan model was to extend the usefulness of the EPIC model by developing a decision aid easier to use and to set up for analyses of complex farming practices. This manuscript will describe the effort to expand the CroPMan model to the conditions found in Alabama, by developing the management options and appropriate databases to make the model functional under Alabama and other southeastern US regional conditions.

MATERIALS AND METHODS

Alabama CroPMan

The National Soil Dynamics Laboratory, in cooperation with scientists at the Texas A&M Blackland Research and Extension Center, has developed "Alabama CroPMan" that is applicable to the conditions for the state of Alabama. The engine for the model is EPIC, developed by the USDA-ARS and utilizes databases developed by the USDA-National Resource Conservation Service (USDA-NRCS). The major components in EPIC are weather, hydrology, erosion-sedimentation, nutrient cycling, pesticide fate, plant growth, soil temperature, tillage, economics, and plant environment control (Williams, 1989). CroPMan is a user-friendly interface that will allow scientists, farmers, and farm advisors to utilize the EPIC model to examine the environmental and economic consequence of crop production decisions (Gerik et al., 2003).

The model is to be used as a tool to promote the adoption of best management practices for farming in Alabama by allowing for the assessments of agronomic practices. For example, the model will allow strategic assessments to: 1) identify best management practices for site-specific circumstances to minimize cropping impact on soil erosion, water quality, and runoff; 2) identify production constraints and alternative practices to maximize yield, profit, and production efficiency; and 3) determine fertility/nutrient requirements and nutrient and pesticide fate. CroPMan also extends EPIC's capabilities with "Projected Runs", which allows for the stopping of the model at any point in time (usually the current time), providing for updates to selected soils, crops, and management practices, and projecting between 40 and 100 weather scenarios through the remaining growing season to estimate probability distributions of outcomes. This will allow the model to perform real-time analyses to assist in decisions such as: late planting, replant decisions, fertilizer optimization, estimates of yield and profit, and soil/nutrients/ pesticides in runoff.

EPIC is a continuous, daily time step simulation model that can be used to determine the effect of management strategies on agricultural production and soil and water resources. The drainage area considered by EPIC is generally a field-sized area of about 250 acres. Weather, soils, and management systems for the entire field area are assumed to be homogeneous. A method for estimating costs of operating farm machinery has been added to CroPMan as a subroutine. Costs were taken from the USDA-NRCS CARE budget generator. The subroutine calculates the operation and depreciation costs per area covered for over 500 pieces of equipment including the tractor(s) used and calculates costs for all operations scheduled at the start of the simulation. The economics of each analysis are calculated according to the computing standards of the American Agricultural Economics Association for variable costs, depreciation, and profits.

The database provided with the Alabama CroPMan program includes actual soils and weather stations from across the state of Alabama (Fig. 1). The 48 different weather stations contain 40 years of historical weather data from that location. The soils database is provided for each county in Alabama and soil characteristics are populated from the Soils-5 database, which was created and is maintained by the USDA-NRCS.

To develop the Alabama CroPMan, "typical" crop operation budgets were developed for the major crops in Alabama, including cotton (*Gossypium hirsutum* L.), peanut (*Arachis hypogaea* L.), soybean (*Glycine max* L.), corn (*Zea mays* L.), grain sorghum (*Sorghum bicolor* L.), and wheat (*Triitcum aestivum* L.). For each of these crops, a typical operation budget was developed for a conventional tillage, a reduced tillage, and a no tillage system. Also, several cropping rotation systems common to Alabama were included. These budgets included a complete listing and timing of agronomic cultural practices needed for that production system and included practices such as fertilization, planting dates, land preparation (such as plowing equipment and frequency), pesticide application, irrigation, and harvesting. Figure 2b shows an example of the budget developed for conventional tillage corn production under dry-land conditions. Input for developing these budgets were collected from various sources such as the Budgets for Major Row Crops in Alabama (Crews et. al., 2001) and Southern Agriculture Digest (Gonitzke et al., 2003). All of the cropping systems can be altered to provide the specific conditions of interest to the user. More specific details as to the operation and specifics of the model simulation can be found in the CroPMan Users Manual (Gerik et al., 2003).

Alabama Validation

To validate the model for Alabama conditions, a database of crop yields was acquired and used from the variety testing studies, which are collected each year from across the state of Alabama by the Alabama Agriculture Experiment Stations. Three Alabama Agriculture Experiment Stations were chosen to represent the southern, central, and northern portions of the state (Fig. 1). In south Alabama, the Wiregrass Research and Extension Center in Headland, Henry County, AL was chosen. In central Alabama, the Prattville Agricultural Research Unit in Prattville, Autauga County, AL was chosen. In north Alabama, the Tennessee Valley Research and Extension Center, in Belle Mina, Limestone County, AL was chosen. At each of these locations, the variety testing data were collected for corn and cotton for a five-year period, from 1997 through 2001. At each of these locations, the actual soil type where the study was conducted and the historical weather data collected at the site during that time period was utilized for the model simulation. Also, the actual agronomic cultural practices used in the variety test experiments at each site was used in the simulation, including the soil fertility and land preparation system. The average for all of the varieties tested each year was used as a surrogate for yield potential for those conditions each year. At the Wiregrass Experiment Station, simulation of peanut was also conducted, using the variety test yields for early, middle, and late maturing varieties.

RESULTS AND DISCUSSION

Initial evaluation of the Alabama CroPMan model indicates that it could be a very successful adaptation, which provides a user-friendly interface for the EPIC model. At the initial setup window (Fig 2a), the user selects the Alabama County of interest, which then allows for all of the soils that have been mapped in that county to be selected from drop down windows. In the setup window there is a list of the 48 available weather stations from across the state, which can be selected to provide 40 years of historical weather data. Also included is a drop down window, which includes the list of cropping systems, which will provide the “typical” cropping systems for the state of Alabama.

After the initial specifications of interest are selected, the model can be run to provide output across the years of simulation. The output includes variables such as crop yield and profit (Fig. 2c and d). The output includes stresses that impacted the production of the crop, including such things as drought, excess water, temperature, N, and P. The model also provides output for losses from the cropping systems, such as soil, N, and P losses in runoff. This output is provided in clear graphical form (Fig. 2), which can be seen by selecting the variable of interest.

In addition to the standard model runs, the Alabama CroPMan also provides comparison runs (Fig. 2a). In the comparison runs, the output from two different standard runs can be compared. With this tool, the potential consequence of production decisions can be observed in graphical form. For example, Figure 2e demonstrates the differences in potential yields between conservation tillage and a no tillage cropping systems. The model can also be used to provide projected runs. In this mode, the model is run as a standard run with actual weather data to a designated point. Following this, the model can be restarted to provide 40 to 100 years of projected weather conditions that would be potentially found within the area of the selected weather station (Fig. 2f). In this manner, the potential risk of a specified management choice can be ascertained, and by subsequent runs, the potential differences in management choices (such as replanting) can be determined.

Results from the validation of the CroPMan model indicated that the model performed very well to predict the actual measured yields for corn, cotton, and peanuts (Figs. 3, 4, and 5). The validation data for corn yield is shown in Figure 3. A wide distribution in corn yields was observed across the state during this 5-year period due to both the wide variability in the soils used and the variable weather conditions, which occurred during the study period. This provided a wide scale of conditions under which the model validation was conducted. The model did a good job of predicting the observed corn yields, as can be observed in Figure 3. The figure presents the regression analysis of the predicted vs. measured yields. The resulting regression line falls almost exactly on the 1:1 line of the graph and has a very good R^2 value (0.7157), indicating that the model performed well with the variability of the measure yields.

The validation data for cotton lint yield is shown in Figure 4. With cotton lint, the distribution of yields was also very great across the state during the 5-year period, and provided a very good data set for validation purposes. The model did an adequate job of predicting the measured yields (Fig. 4). Again in Figure 4, the regression line falls almost exactly on the 1:1 line of the graph for the regression of predicted vs. measured yields. In the case of cotton lint, the variability of the model to predict yields were greater than was observed with corn, as indicated by a R^2 value of 0.3698. This was likely due to the nature of cotton production being much more variable and subject to potential limitation from disease and insect damage than corn, which the model does not simulate. Nevertheless, the result of this validation exercise indicates that the model does an adequate job of predicting the measured cotton lint yields.

The validation data for peanut yield is shown in Figure 5. With peanut, the yield distribution was relatively small compared to the corn and cotton, but was sufficient to provide an adequate data set for validation (Fig. 5). In Figure 5, as was observed with the corn and cotton, the regression line for predicted vs. measured peanut yield falls almost exactly on the 1:1 line of the graph. In the case of peanut, the variability explained by the model, as indicated by the R^2 value of 0.5915, was excellent. As with the corn and cotton, the results of this validation exercise indicates that the model does an adequate job of predicting the measured peanut yields.

SUMMARY

The initial evaluation of the Alabama CroPMan model indicates that the model performs well for its designed purpose. To validate the model for Alabama conditions, a database of cotton, corn and peanut crop yields was collected using the crop variety testing data from across the state. Data was collected from the Wiregrass Experiment Station in south Alabama, the Prattville Experiment Station in central Alabama, and the Tennessee Valley Experiment Stations in northern Alabama. Results from the validation study indicated that the model performed very well to predict the actual measured yields for corn, cotton, and peanut. The Alabama CroPMan model was found to be very user friendly and provide a wide variety of agronomic, economic, and environmental information regarding agricultural practices and production. The Alabama CroPMan model has a very good potential to be used as a tool to increase the understanding of agriculture and to promote the adoption of best management farming practices in the Southeast.

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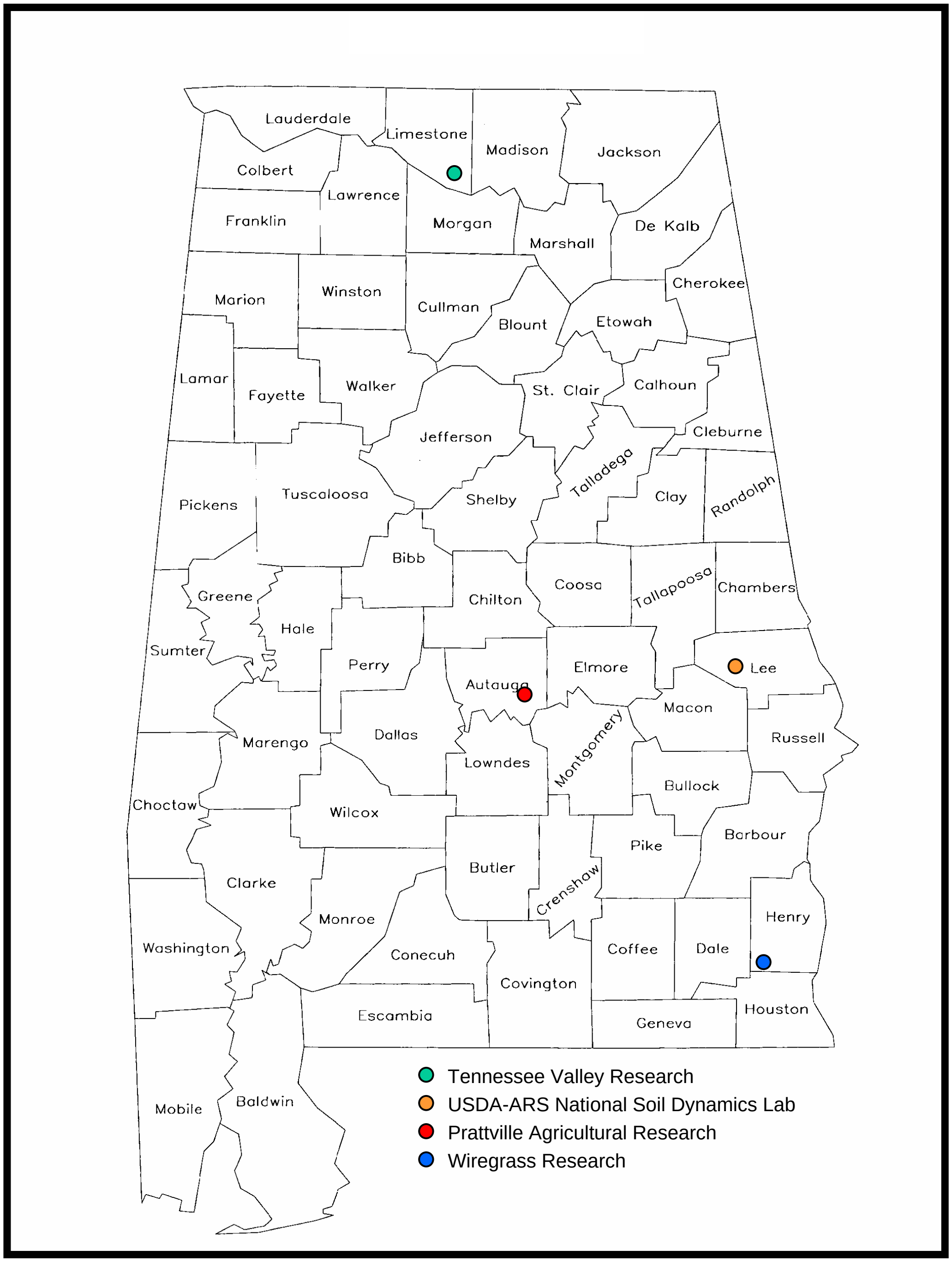

Fig. 1. Map of Alabama counties and the location of Alabama Agriculture Experiment Stations where validation research was conducted.

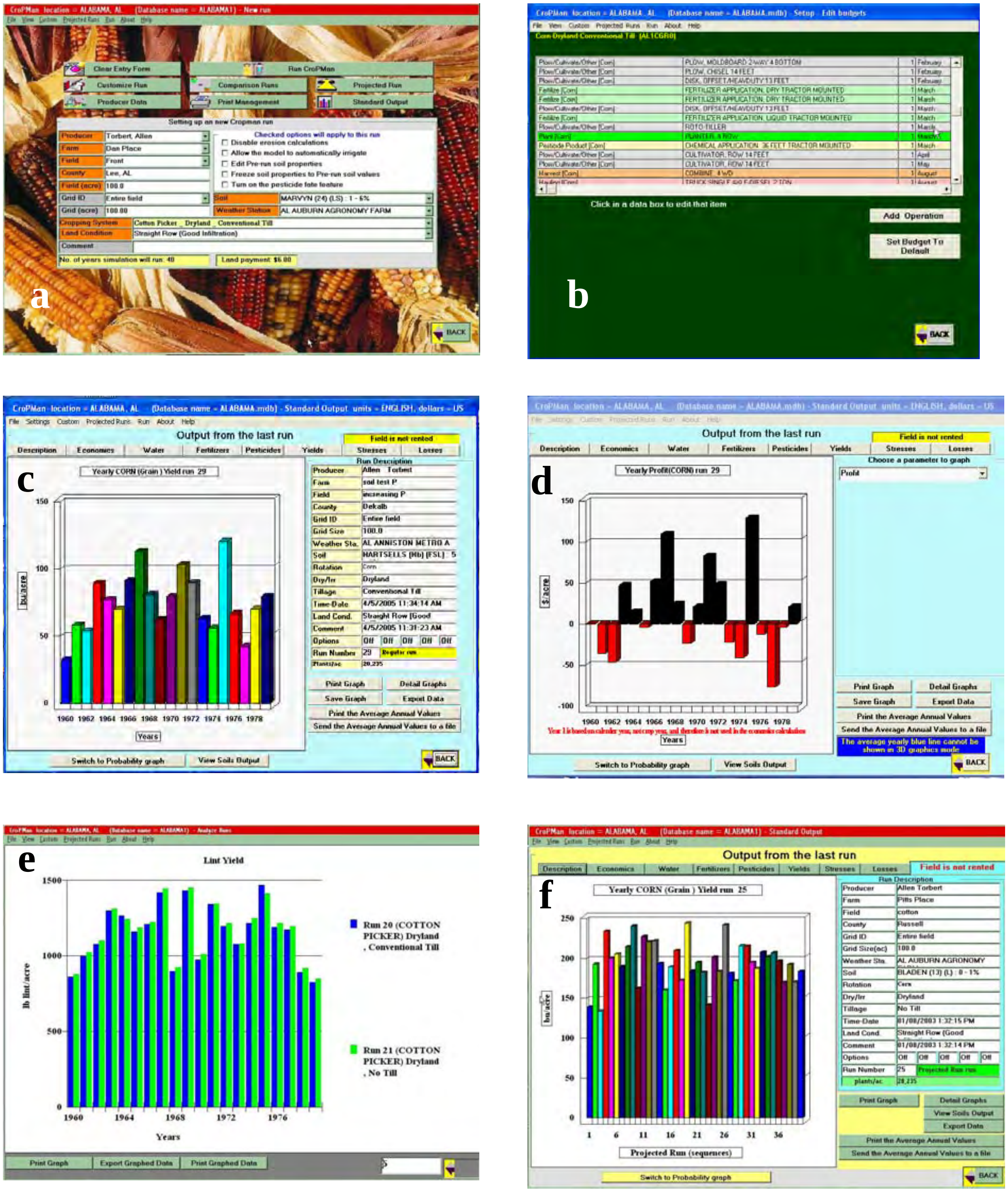

Fig. 2. Alabama CroPMan views: a) standard run setup, b) cultural practice setup c) output yield, d) output profit, e) output comparison yield f) output projected yield.

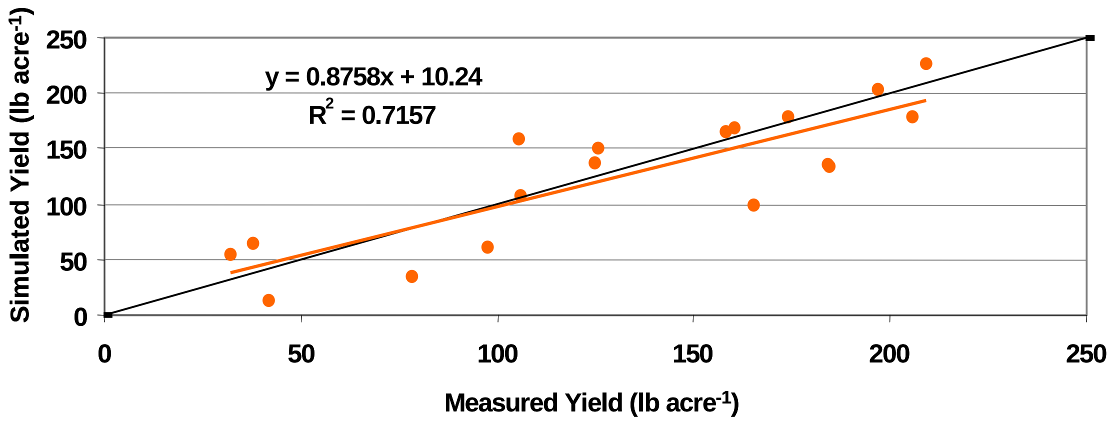

Fig. 3. Validation of corn yield in Alabama, simulated vs. measured corn yield.

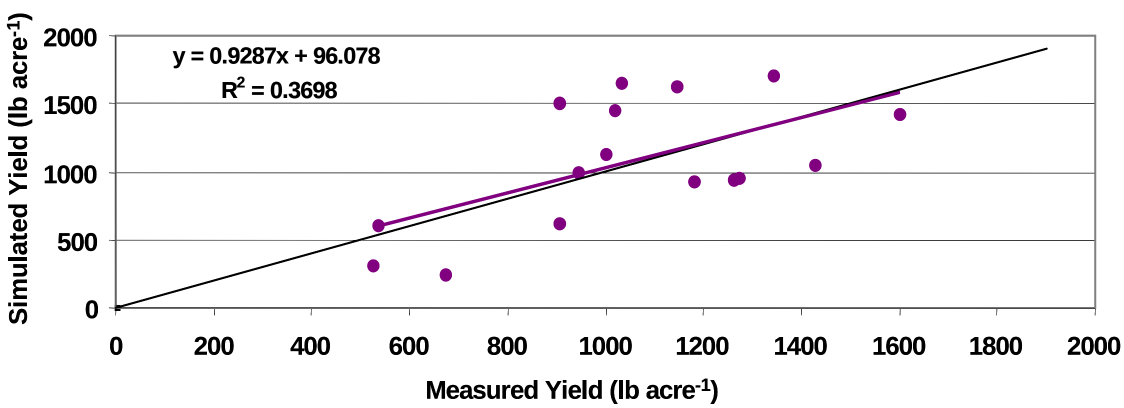

Fig. 4. Validation of seed cotton picker yield in Alabama, simulated vs. measured seed cotton yield.

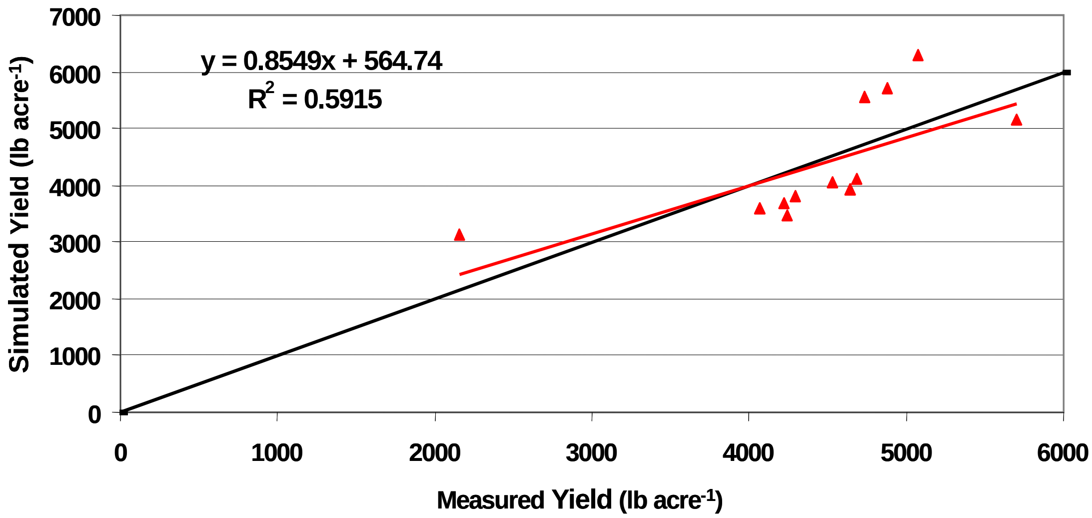

Fig. 5. Validation of peanut yield in Alabama, simulated vs. measured peanut yield.

USING GIS TO ESTIMATE THE IMPACT OF THE CONSERVATION TILLAGE PRACTICES IN GEORGIA

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ABSTRACT

Surface residue management coupled with conservation tillage is a viable management tool for producers in the Coastal Plain region of Georgia. Reduced tillage and residue management improves infiltration and sedimentation, organic carbon sequestration, and plant available water. Yet, there is a general lack of knowledge regarding the regional impact conservation tillage has on water resources and sustainable agricultural practices. The objective of this study was to estimate water savings associated with conservation tillage in two predominant physiographic regions in Georgia. Total acreages by crop (cotton and corn) and tillage (conventional and conservational) were obtained via the Conservation Tillage Information Center (CTIC) for 2004. The CTIC provides estimates of tillage and residue management practices on a county basis. Currently available data regarding the impact of tillage regime on plant available water content was obtained via recent field scale rainfall simulation studies conducted in the Coastal Plain and Piedmont physiographic regions. Rainfall simulations were conducted during minimal canopy cover, using an oscillating nozzle rainfall simulator at a constant intensity (50 mm hr^{-1}). Previous rainfall simulation study results indicate that conservation tillage can improve plant available water contents by 30-50 %. Rainfall simulation data will be integrated with county level tillage estimates in a geographic information system and used to evaluate the potential water savings (as irrigation) that is attributable to adoption of conservation tillage.

USING YIELD VARIABILITY TO EVALUATE THE ECONOMIC POTENTIAL FOR PRECISION TECHNOLOGIES IN COTTON

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ABSTRACT

When asking the question "Will precision technologies pay on my farm?", one the of the first things to consider is the level of within-field yield variability present – if the field conditions are uniform there is no benefit from variable rate management. In order to estimate the level of yield variability needed to signal an economic benefit, a simple decision aid was developed. The decision aid requires a minimal amount of input information: high and low yields within a given field; total production costs; lint price; and size of the field being considered. Assuming yield variation in the field is normally distributed (user supplied yield range is assumed to encompass 95% of the yield variability present), 100 yield observations are generated and then the percentage of the field that has a positive net income is calculated. To make an estimate of potential savings from precision farming, the current analysis assumes those areas with a negative net income are not planted and thus the savings is equal to the sum of areas with negative net incomes. The predicted precision savings from the decision aid were compared to data from five actual cotton yield maps (one from Arizona, and four from southern Georgia) at a fixed lint price of $0.52 per acre across a range of production costs. In most cases, the difference in predicted precision savings based on the decision aid results were a reasonable estimate of those from the yield maps (errors rarely greater than $4.00 per acre).

Paratilling Frequency Effects on Runoff and Sediment Yields for No-till Systems in the Tennessee Valley region of Alabama

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Abstract

Erodible soils of the Tennessee River Valley in northern Alabama are susceptible to soil consolidation and compaction, especially under conservation tillage systems. Paratilling, a non-inversion deep tillage technique, eliminates soil consolidation and compaction in conservation tillage systems, yet is expensive and time-consuming. Our objective was to quantify runoff and sediment yields associated with time since paratilling in no-till (NT) systems on a Dewey silt loam. Five NT treatments representing paratilling (P) frequency were evaluated: NT without paratilling (NT-P), NT with paratilling 6 months previous (NT+P6), NT with paratilling 18 months previous (NT+P18), NT with paratilling 36 months previous (NT+P36), and NT with paratilling 42 months previous (NT+P42). NT plots had winter fallow (no cover crops) which was burned down with Roundup prior to simulating rainfall. Rainfall simulation plots ($6m^2$, 2 m wide x 3 m long) were established on three (of four) NT treatments, and exposed to simulated rainfall (50 mm h^{-1} for 60 min). Infiltration and runoff, each expressed as a percent of rainfall, decreased and increased respectively with decreased paratilling frequency. Differences between infiltration and runoff percentages for a given treatment ranged from 55% (NT+P6) to 0% (NT-P). Maximum runoff rate (R_{max}) steadily increased with decreased paratilling frequency, ranging from 19 (NT+P6) to 40 mm/h (NT+P42). R_{max} values significantly increased with decreased partilling frequency for the first 36 months. No significant trends were found between paratilling frequency and soil loss, however, the NT-P treatment had the greatest soil loss, soil loss rate, and shortest time to maximum soil loss rate compared to other paratilled NT treatments. Paratilling soils in the Tennessee valley is a beneficial practice for farmers of this region because paratilling increases rainwater infiltration and decreases runoff, thus promoting more efficient water utilization.

COMPARISON OF A CONVENTIONAL, ROUNDUP READY, AND STACKED GENE CULTIVAR IN SOLID AND SKIP-ROW PATTERNS IN A NO-TILL SYSTEM

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ABSTRACT

Continued low cotton (*Gossypium hirsutum* L.) prices have precipitated the evaluation of production systems with lower input costs. The objectives of this study were to evaluate the performance of conventional and transgenic cultivars and to compare solid and skip-row planting patterns in a no-till system. A field experiment was conducted on a Bosket very-fine sandy loam soil (fine-loamy, mixed, active, thermic Typic Hapludalf) from 2003 to 2004. Treatments were row pattern, row spacing, and cultivar. Row patterns were solid and 2 x 1 skip-row. Row spacings were 30-in. and 40-in. rows. Cultivars were ST 474, ST 4793R, and ST 4892BR. Cotton planted solid produced 20 and 17% more lint compared to skip-row planted cotton on a land-acre basis for 2003 and 2004, respectively. There were no differences in lint yield between 30-in. and 40-in. row spacings. Lint yields were similar for cultivars in 2003. In 2004, ST 474 had a lower lint yield compared to the transgenic cultivars. Overall, fiber qualities were not significantly impacted by row spacing or row pattern. Differences observed in fiber strength and micronaire were largely attributed to cultivar.

FLUE-CURED TOBACCO IN A STRIP TILL PRODUCTION SYSTEM

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ABSTRACT

A four-year study was conducted at Pee Dee Research and Education Center (PDREC) to compare the effects of conservation tillage tobacco production under crop rotation to conventionally produced tobacco on a South Carolina Coastal Plain soil. A separate two-year study was conducted to define the impact of in-row cultivation and nitrogen application rate on conservation-tillage tobacco production. Flue-cured tobacco was planted into strip till without bedding or into a conventional bedded production system. All plants received in-row subsoiling. In-row cultivation of strip tilled tobacco and conventionally produced tobacco were evaluated under three nitrogen levels: recommended, recommended + 15 lb/A, and recommended + 30 lb/A. Other than the tillage system and differences noted, traditional PDREC production, harvesting, and curing practices were performed. Conservation tillage tobacco production resulted in a negative impact on tobacco yield, quality, and lodging. The negative attributes of strip till tobacco production can be partially overcome by cultivation. Increased nitrogen tended to improve yields, but at the expense of leaf quality and chemistry. These studies indicate the need for additional research in conservation-tillage tobacco production.

SEASON-LONG SOIL WATER DISTRIBUTION IN COTTON GROWN WITH CONSERVATION TILLAGE

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ABSTRACT

Knowing seasonal distribution of soil water content profiles under conservation tillage will provide knowledge needed to help improve management practices and may provide insight for developing improved crop cultivars for this system. Our objective was to measure water uptake by soil depth for two cotton (*Gossypium hirsutum* L.) cultivars differing in relative maturity. DPL 555 (full-season cultivar) and DPL Paymaster 1218 (short-season cultivar) were grown with conservation tillage in replicated plots. In two replicates for each cultivar, Sentek frequency domain reflectometry sensors were installed at 4-inch depth intervals to 40 inches. Soil water content was recorded by depth at 30-minute intervals throughout the 2004 growing season. Most evapotranspiration was from the surface 12 inches of the profile. Rooting depth (depth of detectable water extraction by plant roots) of both cultivars was limited to the surface 20 inches. There were no differences between the cultivars in the distribution of soil water in the profile through the season. This study will be conducted again in 2005.

INFILTRATION AND EVAPOTRANSPIRATION FOR COTTON GROWN WITH REDUCED TILLAGE ON GOLDSBORO LOAMY SAND

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ABSTRACT

Despite abundant rainfall, southeastern sandy Coastal Plain soils can be droughty because of their low water holding capacity. A frequency domain reflectometry sensor was used to measure amount of rainfall that infiltrated into the soil and was taken up by roots of cotton grown in reduced tillage. Sensors measured volumetric soil water content at 30-min time steps and 4-inch depth intervals to 40 inches. Changes of soil water content were separated into infiltration, evapotranspiration, deep percolation, and runoff using rain gauge measurements and software designed specifically for this experiment. At mid-season, cumulative infiltration was 75 to 85% of the rainfall with spikes up to 90% during storm peaks when water would have ponded on the soil surface. Later in the season, during a wet period, cumulative infiltration dropped to 60% because the lower part of the profile was full, unable to accept infiltration. Evapotranspiration, measured as reduction of soil water content that did not drain deep into the profile, was highest in the top foot and decreased exponentially below that depth. Even though the soil dried out easily and even though it was disrupted deeply under the row to disrupt a hard layer and promote root growth below it, most water for plant growth came from the top foot, the zone that had been tilled.

INTRODUCTION

In the southeastern Coastal Plains, except for years of drought which can be devastating (http://nc.water.usgs.gov/ and http://sc.water.usgs.gov/), rainfall is abundant, averaging more than 45 in y^{-1} (http://www.dnr.state.sc.us/climate, http://www.nc-climate.ncsu.edu/). Yet water is the limiting growth factor almost every year because crops normally experience periods of no rain for two weeks or more (Sheridan et al., 1979) which in these low-water-holding-capacity sandy soils (0.08 g g^{-1}) can cause yield-reducing stress (Sadler and Camp, 1986). Uptake of water and nutrients is further inhibited by a root restricting hard layer located just below the Ap horizon (Busscher et al., 2002).

Effective rainfall is the amount of rainfall that is held in the soil profile for plant root uptake. Effective rainfall can be estimated in a table lookup procedure (http://www.fao.org/documents/) or by calculation (http://aben.cals.cornell.edu/faculty/walter/GreenAmpt v4.doc). It can also be measured by determining differences in water content with time as roots take water from the soil. These measurements can be made with a number of devices that quantify soil matric potential or soil water content as it changes with time, such as time tensiometers, time domain reflectrometry sensors, or neutron probes (Wiedenfeld, 2004; Burt et al., 2005). We used a Sentek EnviroSCAN sensor (Sentek Pty Ltd, Stepney, SA, Australia) that uses capacitance probes to measure volumetric soil water content with frequency domain reflectometry. Our objective was to use water content measured on half-hour basis and rainfall measured at a nearby weather station to calculate infiltration and crop uptake throughout the growing season.

MATERIALS AND METHODS

In May 2005, two varieties of cotton were planted in plots at the Pee Dee Research Center of Clemson University near Florence, SC using reduced tillage methods: no surface tillage, in-row deep (14 in) tillage with a KMC (Kelley Manufacturing Co, Tifton, GA) subsoiler on 38 in row widths in plots that were 25 ft wide and 50 ft long.

Plots were located on a Goldsboro loamy sand. Goldsboro was a moderately permeable, deep, moderately well drained soil that formed in Coastal Plain marine sediments. Goldsboro typically had 20- to 30-in depths to seasonally high water tables. It had Ap and E horizons that were 12 to 14 in deep with 2 to 8% clay content and 0.5 to 2% organic matter. These horizons typically had 1 to 3 meq per 100 g cation exchange capacity. Without deep disruption with a subsoiler, the E horizon can have strengths that restrict root growth. Below this was a Bt soil horizon, a sandy clay loam with 18 to 30% clay content and 0 to 0.5% organic matter. The B horizon typically had 2 to 4 meq per 100 g cation exchange capacity with more structure than the Ap and E.

In late May, cotton was planted with Case-IH series 900 planters (Case IH, Racine, WI) at a rate of 4 plants ft^{-1}. Nitrogen (80 lbs N a^{-1} as ammonium nitrate) was applied in a split application - half at planting and half one month later. Nitrogen was banded approximately 2 in deep and 6 in from the rows. Lime, P, K, S, B, and Mn were applied as needed, based on soil test results and Clemson University Extension recommendations. Weeds were controlled with roundup. Insects were controlled by applying aldicarb (0.75 lbs ai a^{-1} of 2 methyl 2 (methylthio)propionaldehyde O methylcarbamoyloxime) in furrow for thrips [Frankliniella occidentalis (Pergande)]; other insecticides were applied as needed.

In mid October, cotton was chemically defoliated. In November, seed cotton yield was harvested using a two-row spindle picker and bagged. Each harvest bag was subsampled, and the subsample was saw-ginned to measure lint percent. Lint percentage was multiplied by seed cotton yield to estimate lint yield.

EnviroSCAN sensors (Syntek Pty Ltd, Stepney, South Australia) were installed in two replicates of each variety to scan water contents every half hour at 4 in depth intervals to 40 in. Sensor data were stored in a CR21X (Campbell Scientific, Inc, Logan UT) and downloaded weekly. Rainfall data were collected from weather station Site Number 2037 of the National Water and Climate Center of the National Resources Conservation Service of USDA that was located about 400 yards away from the sensors. Data from the weather station were collected on an hourly basis.

Soil water content data were analyzed using mass balance in a simple QBasic program to calculate infiltration, evapotranspiration from the profile, upwelling from below the zone of measurement, and deep percolation to soil below the zone of measurement. Data were collected starting on day of year 153 (June 1) to day of year 259 (September 15), the cotton growing season. Any subsurface lateral flow that might have added water to the zone of measurement was assumed equal to flow out of the zone. Because of discrepancies in the data, the lower three zones (28 to 40 in) were ignored unless otherwise specified.

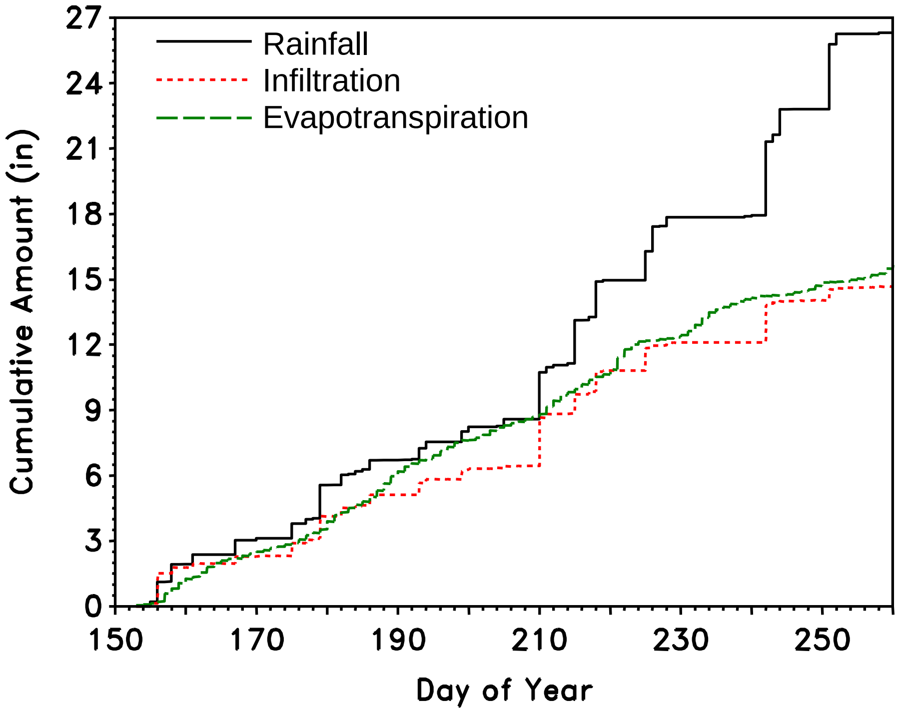

Figure 1. Cumulative amounts of rainfall, infiltration, and evapotranspiration for cotton calculated at plot #1.

Infiltration was calculated as an increase in soil water content during or near a rainfall event filling the soil at the surface and continuing down the profile. Deep percolation was calculated as loss of water out the bottom of the profile without changes in water content above. Upwelling was calculated as a gain of water in the bottom of the profile without losses in water content immediately above. Evapotranspiration was calculated as loss of water content from the profile that was not deep percolation. Data were fit to simple equations using Tablecurve 2D (Systat, Point Richmond, CA), EXCEL (Microsoft, Corp., Redmond, WA), and SAS (SAS 2000).

RESULTS AND DISCUSSION

Rainfall, infiltration, and evapotranspiration were calculated as cumulative amounts to smooth out any differences in time measurement between weather station and the soil sensor data collection (plot #1 of the 4 measured plots shown as an example in Figure 1). Infiltration throughout days 153 to 210 generally ranged between 75 to 85% of rainfall (plot #1 shown as an example in Figure 2) with spikes during storm peaks when water would have ponded on the soil surface. After day 210, the lower part of the profile was usually full of water as a result of tropical storms and tropical depressions passing through the area. Since the profile was relatively full, less water was able to infiltrate; more of it ran off the surface or evaporated. This lowered the cumulative (Figure 1) and average (Figure 2) amounts of infiltration from 75 to 85% down to 55 to 70% for all 4 plots.

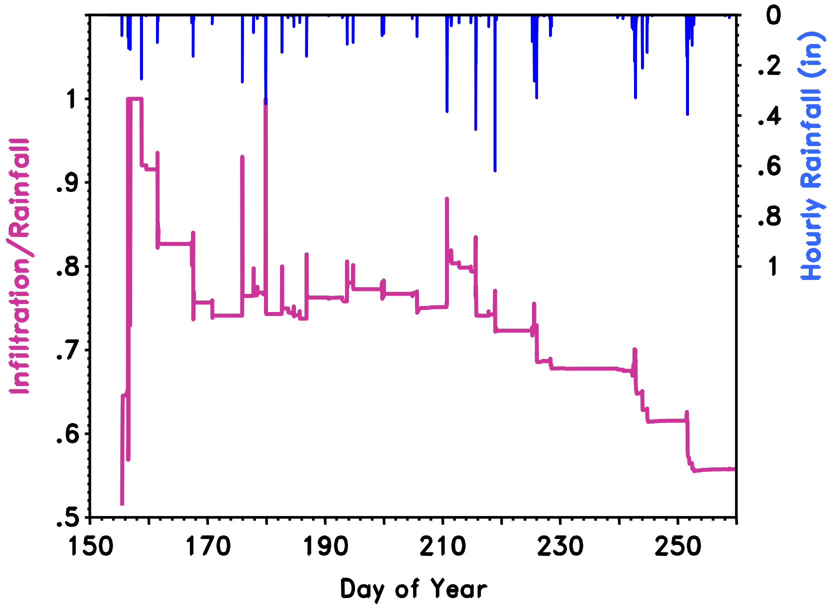

Figure 2. Ratio of infiltration to rainfall and hourly rainfall totals as a function of day of year from May 31 to September 16, 2004.

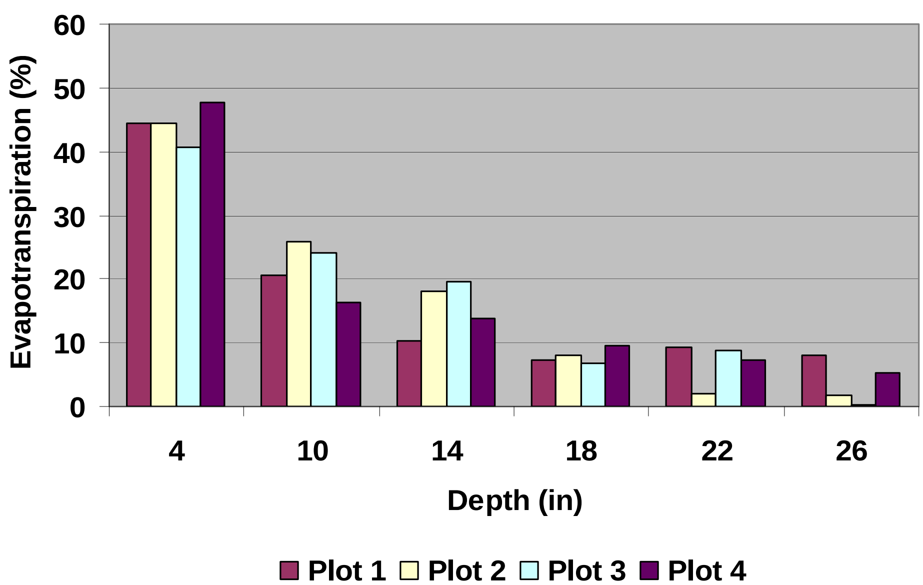

Figure 3. Changes in water content with depth used to calculate evapotranspiration.

Evapotranspiration from the soil was mainly (41 to 48%) from depths 0 to 8 inches (Figure 3); next highest was 16 to 26% from depths 9 to 12 inches; below that it diminished exponentially with depth. Season long upwelling from the wetter, lower part of the profile into the upper dryer part of the profile was calculated to be from 1 to 1.5 in and movement of water upward in the profile as a result of root activity (upwelling that appeared to bypass sections of the profile) was calculated to be less than .05 in.

CONCLUSIONS

Mid-season cumulative infiltration was 75 to 85% of the rainfall with rates topping 90% as a result of ponding during storms. Cumulative infiltration dropped to 60% after the lower part of the profile filled with water as a result of late-season tropical storms. Evapotranspiration was highest in the top foot which contributed 64 to 70% of plant root uptake; it decreased exponentially below that. Since the soil had been deep tilled to break up the hard genetic layer in the rows in these soils, we expected water to be taken from deep in the profile, below the zone of tillage; however, two-thirds of the water for plant growth came from the top foot where the soil had been subsoiled. This may have been a result of the wet weather during the growing season.

DISCLAIMER

Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agriculture does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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CONSERVATION TILLAGE REDUCES THE INCIDENCE OF TOMATO SPOTTED WILT IN FLUE-CURED TOBACCO

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ABSTRACT

Conservation tillage production systems are gaining popularity in the southeastern USA on many row crops. Reduced tillage minimizes soil erosion, off site movement of nutrients, improves water percolation, and contributes to soil organic matter accumulation. Conservation tillage may alter the incidence of Tomato Spotted Wilt (TSWV) in tobacco. The effects of strip tillage on the incidence of TSWV was evaluated in a 2 x 4 factor factorial design experiment where main blocks were tillage (conventional vs. strip till) and subplots were actigard, admire and actigard + admire treatments. Strip tillage plots were planted into a rye cover that had been treated with glyphosate (Roundup ultra 3.5 l/ha). Admire 2F was applied as a tray drench (83 ml/1000plants) 5 days prior to planting. Actigard 50 W was applied as a tray drench (2 g/1000) 5 days prior to transplanting with three foliar sprays (35 g/ha) applied on a 10-day spray interval starting at transplanting. Conservation tillage reduced TSWV incidence 22% and 38% for year 1 and 2, respectively when averaged across admire and actigard applications. In year 1, significant tillage (P = 0.03), and treatment (P = 0.0001) effects were observed. In year 2, a significant tillage (P = 0.001), treatment (P = 0.001) and treatment by tillage interaction (P = 0.001) were observed. In actigard treated plots (year 2) conservation tillage did not reduce TSWV (P = 0.05). Generally, incidence of TSWV was lower in plots grown under conservation tillage systems where the soil was covered with light colored mulch. Conservation tillage systems such as strip tillage may provide suppression of TSWV in tobacco.

IMPACT OF TILLAGE PRACTICES, ROW WIDTHS, AND HERBICIDE PROGRAMS ON WEED SPECIES SHIFTS AFTER FOUR YEARS

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ABSTRACT

A long-term field experiment was initiated near Blackville, SC in 2001 to assess the impact of tillage type, crop row width, and herbicide programs on shifts in the weed spectrum. The test site was planted to soybean in 2001 and 2003 and corn in 2002 and 2004. In 2000, prior to initiating the experiment, the test site was planted to conventionally tilled corn. In all years, conventional tilled plots were disked while conservation tilled plots were strip tilled and deep tilled with an in-row shank or deep tilled with a ParaTill with no surface tillage. The test site at initiation of the experiment mainly contained large crabgrass and Palmer amaranth, with minimal perennial weeds. The soil seedbank was evaluated following the 2003 crop through exhaustive germination of soil cores. Conventional tilled, narrow-row plots from a 0- to 2-inch depth averaged 45,000 Palmer amaranth seed/acre compared with 377,000 Palmer amaranth seed/acre in reduced tilled plots. At the same depth, carpetweed numbers in narrow rows were 1.9 million seed/acre in conventional tilled plots compared with 3.6 million seed/acre in the absence of surface tillage. In wide rows (38 inch), strip tillage generally lowered weed seed numbers compared with conventional tilled plots. Weed biomass in glyphosate-treated plots averaged over row widths in the fall of 2004 was 18 and 71 lb/acre in conventional and conservation tillage systems, respectively. In non-glyphosate plots, weed biomass averaged 312 and 740 lb/acre in conventional and conservation tillage systems. The greater weed biomass in conservation tilled plots was mainly due to a shift in the weed spectrum to common bermudagrass and Carolina horsenettle in the absence of glyphosate. This research shows that glyphosate is needed to minimize perennial weed occurrence in conservation tilled corn and soybean production systems in the southeastern United States.

SUSTAINABLE LAND MANAGEMENT DEMONSTRATION & RESEARCH FOR WILDLIFE

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ABSTRACT

The USDA Farm Bill conservation practices for wildlife, focusing on the Wildlife Habitat Incentive Program (WHIP), are voluntary programs that encourages creation of high quality wildlife habitats that support wildlife populations of National, State, Tribal, and local significance. Through WHIP, the Natural Resources Conservation Service (NRCS) provides technical and financial assistance to landowners and others to develop upland, wetland, riparian, and aquatic habitats on their property. WHIP has been reauthorized by the Farm Security and Rural Investment Act of 2002. Funding for WHIP comes from the Commodity Credit Corporation.

Since WHIP began in 1998, nearly 11,000 participants have enrolled more than 1.6 million acres into the program. Most efforts have concentrated on improving upland habitat, such as native prairie, but there is also an increasing emphasis on riparian and aquatic areas. NRCS provides cost-share payments to landowners that are usually 5 to 10 years in duration.

Our research is to implement and manage the eight farm and forest wildlife habitat management practices established by NRCS to be used in WHIP and other programs; evaluate these practices according to vegetative structure and composition during different stages of growth; evaluate these practices according to use by wildlife (herpetofauna, avifauna, and small mammals); evaluate farmer and landowner prospective on using these practices; provide NRCS staff and biologists with results and recommendations for modifying, or improving practices for wildlife; and provide public outreach to demonstrate these practices by whatever means possible. All of these practices have been implemented (or are in the starting phases of being implemented) at the Pee Dee Research and Education Center near Florence, SC.

Environmental Management Tools

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Abstract

Resource management is critical to our future well-being. Solving dynamic resource management issues incorporates applied precision technology, which is the coordinated use of global positioning systems (GPS), geographic information systems (GIS) software, and computer controlled application machinery integrated by software and standards.

The South Carolina Applied Precision Technology Consortium (SCAPT) was formed by representatives of the Certified Crop Advisor Certification Program (CCA), Clemson Public Service Activities research (CU-PSA), Clemson University Cooperative Extension Service (CU-EXT), USDA -Natural Resources Conservation Services (NRCS), and the University of South Carolina's Earth Sciences and Resources Institute (ESRI-USC). The purpose of SCAPT is to apply the complementary expertise of these cooperators to develop solutions to resource management issues through the use of precision technologies. Specific goals of this consortium are to:

1) Identify currently unaddressed resource management issues that can be solved by precision technologies.
2) Provide the educational and technological support to promote the adoption of precision technology.
3) Develop new computer software and application hardware to expand the potential of precision technology.

The increase of precision technology options has introduced confusion and a lack of compatibility between (1) software packages, (2) spatial data, and (3) peripheral hardware. In addition, experienced natural resources professionals are technically proficient to accomplish natural resources planning tasks, but are often not trained to use the tools (hardware, software, and data) that are available to assist them.

The strong linkages among these organizations between research and development and education and adoption are expected to enhance the rapid utilization of precision technologies.

QUALITY AND COST ADJUSTED ECONOMIC IMPACTS OF ALTERNATE TILLAGE AND PRODUCTION PRACTICES IN SOUTH CAROLINA COTTON

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ABSTRACT

This study identifies the partial net value contributions of alternate soil types, tillage, rotational and pesticide treatments on cotton. Output and practice data were utilized from USDA-ARS cropping studies conducted from 1997 through 2002 in Florence, SC. Data were then converted to gross revenues net of quality adjustments and additions to cost from a baseline reflecting continuous cotton produced on Bonneau soil with conventional (disk) tillage and no Temik application. A hedonic-type regression was conducted to elicit the significance of the explanatory practice variables and their partial net contribution.

ECONOMIC CONTRIBUTION OF VARYING TILLAGE, ROW SPACING AND WEED MANAGEMENT PRACTICES IN SOUTH CAROLINA SOYBEAN AND CORN PRODUCTION

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ABSTRACT

This study identifies the partial net value contributions of alternate spacings, tillage, and herbicide regimes on corn and soybean production in South Carolina. Output and practice data were utilized from cropping studies conducted from 2001 through 2004 at the Edisto REC in Blackville, SC. Data were then converted to gross revenues and additions to cost from a baseline reflecting corn and soybeans produced with conventional (disk) tillage and spacing and traditional seed (Non-GMO) with prescriptive conventional herbicide application. A hedonic-type regression was conducted to elicit the significance of the explanatory practice variables and their partial net contribution.

MEETING THE REQUIREMENTS OF THE CONSERVATION SECURITY PROGRAM: A SYSTEMS APPROACH TO CONSERVATION TILLAGE

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ABSTRACT

The USDA Conservation Security Program (CSP) was introduced in the 2002 Farm Bill to support conservation stewardship on agricultural lands. Monetary rewards will be made to farmers who meet the highest standards of conservation and environmental practices on their farms. For this reason, many farmers are looking at conservation tillage as a means to meet the requirements of the program. But through the tears, farmers haven't been very successful with conservation tillage. Farmers trying the practice have reported problems with weed control, fertilization, and equipment setup. To address these issues, a "systems approach" was developed. The system involves the use of cover crops, improved weed control and fertility practices, and tillage equipment that can run in heavy residue. In addition to meeting the requirement of the CSP, farmers implementing the "systems approach" benefit from improved soil quality, excellent yields, and lower input costs to make a crop.

PLANTING STRIP TILL PEANUTS

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ABSTRACT

Strip till peanut production is increasing in the southeastern US due to a need to conserve soil moisture, reduce inputs, and to save time. History has shown that reduced tillage systems for peanuts can be as successful as conventional tillage systems. Some troublesome areas should be noted. Good stand establishment and good early season management is a must. Weed control is a little tougher with reduced tillage. Some insects tend to be less of a problem in reduced tillage while others may increase. There appears to be no major shift in diseases with Tomato Spotted Wilt Virus actually improving with reduced tillage. Harvest efficiency can be a problem depending on the level of residue.

Our strip till peanuts were planted around May 15. The variety was NCV11. We used paraquat PRE, pentemethalin PRE, and imazapir POST for weed control. We used aldicarb and rhizobium inoculants at planting in seed furrow.

For tillage, peanuts were strip tilled with a small power tiller and then planted into tilled area. Results of a four year study for strip till yielded 3070 lbs/A, while conventional yielded 3206 lbs/A in a non-rotated peanut plot. Yield were not significantly different. In the fourth year of the study, when plots were rotated; strip till produced 3823 lbs/A vs. 4167 lbs/A for conventional till. In these plots, the greatest problem encountered was common bermudagrass encroachment.

INTEGRATING WILDLIFE HABITAT ENHANCEMENT WITH AGRICULTURAL PRACTICES

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ABSTRACT

In 2001, state residents and nonresidents spent $1.3 billion on wildlife recreation in South Carolina. Studies have also shown that wildlife and recreational hunting are major contributors to the economy in rural South Carolina. The majority of wildlife habitats in South Carolina occur on private lands. Consumptive (hunting, fishing) and non-consumptive (wildlife observation, birding) uses of wildlife resources can benefit farmers and other landowners seeking means of supplementing decreasing economic returns from agricultural and forestry operations. Wildlife management activities must complement existing operations so landowners can continue to receive revenue from timber and agricultural products. Cost-sharing and technical assistance for various wildlife habitat improvement practices are available through the U.S.D.A. Farm Bill. However, there is a need for information that demonstrates and evaluates these alternative management options in real life settings. For the purposes of demonstration and evaluation, we are establishing eight wildlife habitat practices under the U.S.D.A. Farm Bill Wildlife Habitat Incentives Program on agricultural and forestland at the Clemson University's Pee Dee Research and Education Center. These practices include: 1) prescribed burning, 2) field borders, 3) filter strips, 4) forest openings, 5) forest stand improvement, 6) hedgerow planting, 7) native warm season grass establishment, and 8) riparian forest buffers. Data collected post-establishment will document changes in vegetative structure and composition in areas where practices are implemented and use of those areas by herpetofauna, avifauna, and small mammals. Early observations indicate the need for better methods of control of non-target vegetative species.

INCREASING EFFECTIVENESS OF SOYBEAN HOST RESISTANCE USING AN IMPROVED NEMATODE IDENTIFICATION SYSTEM

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ABSTRACT

Three root-knot nematode species predominate in the southeastern USA, namely *M. incognita*, *M. arenaria* and *M. javanica*. Traditional nematode soil assays (soil elutriation and sugar floatation) do not distinguish between root-knot nematode species, are a poor indicator of root-knot nematode soil populations and, consequently, are not very accurate in determining where root-knot nematodes may cause yield loss. Recent efforts at Clemson University using polymerase chain reaction (PCR) techniques have been successful in identifying root-knot nematode species using single second stage larvae (J2's) or eggs. The next step is to incorporate these species-specific primers into a real time PCR system. Integrating the DNA-based technique into an integrated pest management system would provide a great advancement in rapid pest detection and when integrated with precision farming technologies such as global positioning, would result in the more efficient use of host resistances. Field experiments were established to evaluate real time PCR nematode identification and compare the results to standard nematode identification methods. Three fields ranging in size from 3 – 4 hectares each were divided into 15 m grids. A soil sample was collected from each grid. Nematodes were extracted from soil by elutriation and sugar flotation. A sub sample from within each sampling grid was bioassayed for root knot species by planting a tomato cv. Rutgers into the soil, maintaining the plant in a greenhouse for 60 days and evaluating the roots for root galling, and egg mass production. Representative root samples (10%) were digested in pectinase, and adult females removed and identified with esterase phenotyping. A GIS database has been constructed for each field detailing each sampling point with soil type, J2 population, root gall index, egg mass index, and crop yield preceding the study. Soil populations of J2's were poorly correlated with egg masses produced on the tomato bioassay (R^2 = 0.18, P = 0.001). This confirms the inaccuracy of soil J2's as a predictor of future nematode damage. *M. arenaria* and total *Meloidogyn*e spp. specific primers were developed for real time PCR. Adult female nematodes (collected from all sites) were identified to species using real time PCR and compared to identifications based on esterase phenotyping. Data suggests a real time PCR system can be used to identify *M. arenaria* populations when adult females or soil J2s are used. This rapid and accurate method should allow for site-specific planting of resistant cultivars.

Agronomic and Ecological Effects of Innovative and Traditional Cropping Systems

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ABSTRACT

Recently developed agricultural practices have each been shown to result in improvements in crop productivity, soil quality, and/or environmental conservation. However, few studies have examined the agronomic and ecological effects of these innovative production practices when used as part of a wholistic cropping system. In this long-term field experiment, we monitored site-specific changes in crop productivity, soil chemical and physical properties, and pest populations resulting from the use of a conservation-tillage (CT) and a traditional-tillage (TT) system. In addition, we measured the effects of these two cropping systems on sediment, nutrient, and surface water runoff. This study was conducted from 1998 through 2005 using a split-field comparison at the Clemson University Pee Dee Research and Education Center in Florence, SC. A 14-acre field was split in half, with one half of the field receiving traditional production practices (disking, in-row subsoiling, traditional herbicides, single rate application of P) and the other a conservation-tillage production system (no surface tillage, broadcast deep tillage, Roundup Ready herbicide program, precision application of P). Changes in soil nutrient levels and nematode populations in the top 6-in of soil were monitored by taking soil samples on a 50-ft grid basis on both sides of the field. Corn (*Zea mays* L.) was planted in the study in 1999, 2001, and 2003 and cotton (*Gossypium hirsutum* L.) in 2000, 2002, and 2004. Cotton lint and corn grain yields were measured using commercially available yield monitors and GPS. Red imported fire ant mounds were located and marked using GPS following both planting and harvest of each crop. Nutrient, sediment, and water runoff were measured at three locations on each side of the field. Agronomic, soil quality, environmental, and ecological results from this long-term study will be discussed.

PLANTING STRIP TILL TOBACCO

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ABSTRACT

Traditional flue-cured tobacco production systems on southeastern coastal plain soils of the US involve disking, bedding, and cultivation. Data showing the positive benefits of this production system are significant. Only limited research using proven conservation tillage systems on flue-cured tobacco exists. We conducted a four year study evaluating strip till as a method of producing flue-cured tobacco. Our data supported many of the conventional concepts. Reduced tillage resulted in lower yields which could be partially overcome with in-row cultivation. Planting flat with no cultivation resulted in increased lodging. Reduced tillage did result in lower bacterial wilt and tomato spotted wilt virus.

In strip till tobacco here, a strip till unit with a subsoiler and rolling basket was used. Tobacco was planted flat directly into strip till area. Tobacco variety was NC297. We planted April 20 and used starter fertilizer and imidocloprid. We treated with gramoxone, sulfentrazone, clomazone, chlorpyrifos, and metalaxyl prior to planting. Fertility was 75 lbs N, 40 lbs P_2O_5, and 120 lbs K_2O. We normally fumigate with 1,3 dichlorpropene + chloropicrin, but didn't here because of limited time.

Our research convinced us that more research is needed on reduced tillage flue-cured tobacco production.

DEMONSTRATION OF ADVANCED CONSERVATION-TILLAGE EQUIPMENT AND TECHNOLOGIES

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ABSTRACT

A number of new types of conservation-tillage equipment will be shown and field demonstrated. These will include:

Automatic guiding systems (Trimble & John Deere)**:** The automatic guidance or automatic steering of tractors will free the operator from the steering task to perform other tractor operations. With this system, a Real Time Kinematics (RTK) GPS-based navigation system automatically steers the tractor along a precise path with centimeter-level precision. An in-cab display/computer lets the driver quickly define implements, set up field patterns, and view operating parameters. The computer stores the information for each field which makes it possible to subsoil in the fall, return in the spring and plant precisely on the subsoil furrow, cultivate or apply pesticides, and harvest in the fall using the same traffic patterns from the previous years. This could eliminate the need for annual deep tillage, increase productivity, save energy and time, increase application accuracy, and enhance safety.

Rolling of cover crops (Dr. Randy Raper): The use of cover crops has contributed to the overall success of conservation tillage systems for many producers. Flattening and crimping cover crops using round drums with attached blunt blades offer multiple benefits. First, the roller is equally effective as chemical herbicides at terminating the cover crop. Second, the energy required for rolling is significantly reduced compared to that of mowing. Third, a flat mat of cover crop is created that lies in the direction of travel. Producers using seeders operating parallel or slightly off parallel to this direction have been very successful in obtaining proper plant establishment.

Veris Mobile Sensor Platform, EC and pH meter: The soil pH typically varies more than a sample taken every 330 ft. (2.5 acre grid) can capture. The Veris Mobile Sensor Platform (MSP) features an on-the-go automated pH sensing system that maps pH variability in a field for precision lime applications. The MSP produces between 5 and 10 pH samples per acre. The Veris MSP is equipped with both the EC meter and the Soil pH Manager which collects soil EC data for management zones and yield goals while mapping soil pH.

Wilkinsons (Rotocult) Horizontal Cultivator: The Horizontal Cultivator is used for soil preparation prior to and after planting. The Horizontal Cultivator uses a revolutionary cutting action to prepare agricultural and horticultural land using minimum tillage techniques. The cutting action is horizontal instead of the vertical action used by most existing agricultural field preparation implements. The result is a one-pass destruction and mulching of old plant material to a maximum depth of 20 in (long blades) leaving prepared ground ready for new plantings. The cultivator also mulches any ground cover, weed and deposits it 6 in below the surface, reducing weed growth during early plant growth.