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SODBASED ROTATIONS FOR COTTON/PEANUT IN THE SOUTHEAST U.S

David L. Wright, James J. Marois, P. J. Wiatrak and T. W. Katsvairo
University of Florida
Quincy, FL

Abstract

Cropping systems for the Southeast U.S. have been marginal in economic viability due to soils that are generally infertile, with poor water holding capacity, and low organic matter content along with stress factors of drought and pests. Even though conservation tillage has been accepted by row crop farmers, there are still broad environmental concerns due to lack of adequate soil cover from cover crops. This sodbased rotation system with cotton and peanuts has shown 50% higher yields with peanuts and almost a 100% increase in root size of cotton than when grown under annual cropping systems with conservation tillage. Water infiltration rates have been shown to increase in crops behind bahiagrass (more than 5 times faster), also higher earthworm numbers (thousands per acre vs. none in many cases), and a more economically viable (potential for 3-5 times more profit) cropping system. Diversification into livestock can add another dimension to the farming system making it more intensive and provide a readily available use for perennial grasses and crop residues while further reducing cash risks by growing cash crops. Winter grazing utilizes the land and resources in the time of year when the climate is more moderate with little impact from droughts, hurricanes, and insects and weeds. This results in reducing financial risks and diversification of enterprises with full utilization of land resources for a much more profitable farming system.

Introduction

Growers have long used management strategies to overcome many of the limiting factors to crop production and have less control over market opportunities and crop prices which have remained low with traditional crops competing in world markets. History of long term plots (Morrow, Sanborn, Magruder, Old Rotation [Auburn]) have shown us that land coming out of long term perennial grasses often has an organic matter content of over 4% and that tillage and annual crops causes this to decrease to about 1 ½ %. Good production practices such as conservation tillage, cover crops, proper rotation, and modern fertility practices help maintain that level. Many individual studies with crops in the southeast have shown that perennial grasses (bahiagrass) can help improve soil structure and reduce pests and increase rooting depth for subsequent crops resulting in increased crop yields.

It is commonly accepted in the agriculture community that organic matter in soils is one of the keys to productive soils in that it aids soil structure, increases fertility and water holding capacity, enhances growth of plants and results in higher crop yields. The history of world agriculture has been of “wearing out land” through growing annual crops for food production and moving to new sites that nature made fertile through many years of native forests and grassland. The region of the U.S. formerly in tall-grass prairie, under which the world’s most fertile soils were formed, was largely converted to annual cropping systems in less than 150 years (Glover, 2003). The result has been irrecoverable soil loss, widespread contamination of surface waters, and nutrient contamination in the Gulf of Mexico thousands of miles downstream.

Conversion of annually cropped land back to perennial cover provides great potential to mitigate these problems. These native perennials protected the soil from erosion while increasing soil organic matter (SOM). However, primitive farming methods used in many newly settled areas or in undeveloped regions of the world result in degradation of SOM until population growth in the area demands and can pay for farming practices that result in consistent quantity and quality of food which tends to slow the loss of SOM and farming becomes more sustainable. Many of these farming methods are still being used in the few virgin areas left in the world. Cutting forests, burning, cultivation, lack of cover crops, monoculture of annual crops, and leaving fallow after production decreases, exposes soils to erosion and further loss of SOM and productivity. Research efforts have shown several practices that lead to increased (SOM) formation or at least slower degradation. These practices include: including perennial grass and legumes in rotation or as permanent pasture, 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, 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 natural resources (especially soil and water) 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 crops allowing farmers to maintain or enhance quality of the soil and water resulting in long term sustainability of SOM and economic viability.

The Southeast is one of the most diverse crop production areas in the U.S. All of the major crops as well as pasture grasses can be grown. Native vegetation included hardwood and pine forest and small areas cleared by Indians where some grass encroached. 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. Improved pastures for beef and dairy production did not begin in the South until the 1930's and 40's, when Dr. Glen Burton and others began breeding and releasing new grass varieties. During the 50's and 60's there were reports that higher crop yields could be attained after perennial grasses and that soil tilth had indeed improved. It is known that rotation with perennial grasses will increase soil carbon, water infiltration, improve soil structure, and decrease erosion to a higher level than the winter annual cover crops which are better than summer annuals. Winter annual cover crops do not do as 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 looked at cover crops as green manure crops to be turned under for nitrogen benefit or nematode suppression. Recent advances with herbicides and herbicide tolerant crops have allowed crops to be planted directly into standing cover crops. Perennial grasses in all regions of the U.S. and in other countries have been shown to have a major impact on yield (Rogers and Giddens, 1957), including testimony from growers in the South who plant after bahiagrass. Since soil carbon is increased along with other quality components after permanent grass crops, best crop yields are obtained immediately behind these grass sod crops. 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. Farmers are often financially strapped to the point of being concerned about maximizing short term productivity at least cost instead of looking at long term productivity. At times this is a result of lack of knowledge about agricultural practices or a lack of proper resources to maintain productivity. There are often other factors such as environment or cropping marginal areas or marginal crops that result in minimum income and growers do only 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 CO_2 levels as well as resulting in abandonment of large areas due to erosion. Crop yields during the first 50 years of cultivation are relatively high without fertilizer as SOM released nutrients, held water, and maintained some aggregation of soil particles. Little fertilizer was available during the 19th century and early 20th century or was of low analysis resulting in a downward spiral of SOM and other soil quality factors. Prairie grasses were plowed under as pioneers moved across the country and settled. Cultivation and cropping resulted in losing ¼ to ¾ of the SOM that was present 100 years ago as seen from some of the long term plots (Magruder, Sanborn, and Morrow plots). The Magruder plots had about 4% O.M. in 1890 after the prairie grass was plowed under. After 110 years of continuous cultivation, O.M. is around 1.25%. It took more than 50 years to produce a nitrogen deficiency and almost 100 years to note a response to potassium on wheat. Manure slowed the decay of the SOM but still showed the same trend as the unfertilized 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 fairly rapidly when put back into perennial crops but can be degraded more rapidly. This slowed the degradation of SOM and in some cases has resulted in increases. A model (Imhoff et. al, 1990) currently in use for SOM by EPA and Natural Resource Conservation Service's Natural Resources Inventory shows a well documented decline between 1910 and 1950 to about one half the original level of SOM and a period of some stability until about 1970 and predicts an increase in the next 30 years due to a higher cropping intensity, use of commercial fertilizer, government programs that promote grass set aside of crop land, and 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 penetrate to water and nutrients. In crop production guides and many research papers, rotation is listed as an important component of producing crops profitably (Edwards et. al., 1988). George Washington, in his crop rotation plan of 1782, included 3 years of a permanent grass in rotation prior to planting corn (Anonymous, 1997). He believed that soils would not become "exhausted" or depleted of nourishment if crops were rotated and fertilizer was used. Research shows that legumes will add nitrogen to the soil and improve soil health (McGuire et.al.1998). 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 in native grasslands is cultivated. The reason for this is that most of these soils were highly productive and high in SOC when initially cultivated and many of these remain highly productive with ½ as much SOM as they started out with. Nitrogen fertilization is the fertilizer nutrient that has kept production of crops up to levels of virgin soil conditions. Temperate grasslands have been estimated to contain 18% of the global SOC 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 nematodes and other 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 so 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. In area with long growing seasons, two to three crops can be 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. Uhland, 1949 showed that corn yield was directly related to SOM in Indiana. 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 the "clean up" of soils that have become unprofitable for row crops due to low yield and expense of pesticides needed for pest control. These challenges along with infertile soils, low organic matter, and a natural soil compaction layer have to be over come in any cropping system. However**,** using a sod based rotation of bahia, bermuda, or guinea grass reduces nematode populations and other pests in this cropping system, adds organic matter to infertile soils for better nutrient and water holding capacity, and roots penetrate the natural compaction layer allowing subsequent crop roots to move through it to have access to more water and nutrients. All of these benefits of sod prior to row crop production 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, bermuda, or guinea grass as in conventional cropping systems, reducing irrigation needs from normal applications of about 30cm 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

A multi-state project was started in Florida in 2000 and in Alabama and Georgia in 2001 to examine the influence of 2 years of bahiagrass on peanut and cotton in the 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. Various data has been collected from each of these sites including 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 full cycle of this system will be completed in small plots at Quincy with data being summarized over years and locations. The basic design of the study is shown below:

Results

	Year 1		Year 2		Year 3		Year 4	
Field	Spring	Winter	Spring	Winter	Spring	Winter	Spring	Winter
1	Peanut	Oats	Cotton	Oats	Cotton	Oats	Bahia	Bahia
2	Bahia	Bahia	Bahia	Bahia	Peanut	Oats	Cotton	Oats
3	Peanut	Oats	Cotton	Oats	Bahia	Bahia	Bahia	Bahia
4	Cotton	Oats	Bahia	Bahia	Bahia	Bahia	Peanut	Oats

The results obtained from the study have been positive and encouraging. We found that 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 (Table 1). When we evaluated soil moisture in cotton, the bahiagrass rotation retained more soil moisture as compared to conventional cotton during the 2003 and 2004 growing season. The increased moisture levels in the soil of the bahiagrass rotation were attributed to the increased infiltration rates observed in cotton after bahiagrass.

Cotton in the bahiagrass rotation had less soil water nitrate at both 20 and 36 inch depths throughout the growing season (Katsvairo et. Al., 2004). Bahiagrass has deep roots which penetrate deeper soil layers. When the grass dies, the roots decay, leaving root channels. Cotton could have exploited the channels and developed a more extensive rooting system, which utilize more N across a wider soil profile. We observed higher root biomass, root area and root length 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. The levels are higher in states with sandier soils including the Tri-State region. High levels of N in ground water are also responsible for algae blooms in fresh water bodies. Hence rotations that reduce N levels can be a good way to protect the environment.

When we evaluated residual soil nutrients at the end of the season, the cotton in the bahiagrass rotation had less residual nutrients including P, Mg and B. 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 of the larger amount of biomass. A solution to this would be to keep the land under crop cover, so that the residual soil N would be utilized.

Earthworms are a good indicator of a health soil. They increase infiltration rates, aeration, soil nutrient cycling and help achieve good soil crumb structure. Including bahiagrass in the rotation increased earthworm densities, by as much as 7 fold. The higher organic matter and associated high soil moisture in the bahiagrass rotation may have caused the increase in earthworm densities (Table 2).

The Bahiagrass rotated cotton showed less soil mechanical resistance compared to both cotton and peanuts. 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 loss either through evaporation or as runoff.

Cotton in the Bahiagrass rotation had lower bulk density compared to 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 (Figure 1 and Table 3). The cotton in the bahiagrass rotation was taller than cotton in the conventional system. In addition, the bahiagrass rotated cotton 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. The larger root systems took up more total N and had a slightly higher N concentration (Table 4).

Cotton in the bahiagrass rotation had higher LAI compared to the conventional cotton. The high LAI is indicative of more efficient utilization of light. The more developed plant canopy was able to effectively shade the weeds rendering them less competitive to the cotton. The bahiagrass rotated cotton also had reduced weed biomass compared to the bahiagrass rotated 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. Better developed cotton plants in the bahiagrass rotation are indicative of better resource utilization including soil moisture, soil nutrients and light. Bahiagrass contributed to the positive aspects of a health soil which in turn resulted in healthier and more vigorously growing plants which were able to withstand weeds and pest attack, and should yield better under drought conditions. Yields during 2003 and 2004 were not different due to good rainfall during bloom period (Table 4).

We monitored disease in peanuts after bahiagrass and conventional peanuts for the major peanut diseases in the Tri-State region. These diseases included, tomato spotted wilt virus (TSWV), cercospora leaf (*Cercosporidium personatum*) spot, peanut rust (*Puccinia arachidis*) and white mold (*Sclerotium rolfsii*). The bahiagrass rotation had less infestation of tomato spotted wilt virus, leaf cercospora and spotted wilt virus. The bahiagrass rotation spaces out the peanut crop in time more than the traditional peanut/cotton rotation. This helps break disease cycles, resulting reduced disease outbreak. Also, the healthier soil after bahiagrass could have supported healthier peanuts which were more tolerant to disease pressure. There were no differences in infestation levels between the rotations for white mold.

Table1. Water infiltration rates in crop rotations

Rotation	Minutes for Infiltration of .4 inch of water	
Cotton after peanut	8.7	a
1st year Bahiagrass	8.3	a
Peanut after cotton	5.5	a
Peanut after bahiagrass	0.8	b

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Table 2. Earthworm population densities at Headland, AL, and Quincy, FL in crop rotations 2004

Rotation	Number of Earthworms #/A	
	Headland	Quincy
Cotton after peanut after bahia	-	96088
Peanut after bahia	64,059	-
Cotton after peanut	0	12812
Peanut after cotton	0	-
1st year bahiagrass	0	-

Table 3. Yield for peanuts grown under the conventional rotational system and the sod rotation at Quincy, FL. During 2002 and 2003 growing season

Rotation	Yield lbs/A
	---------2003---------
Cotton in bahia/bahia/peanut/cotton rotation	2485
2nd year cotton in peanut/cotton rotation	1750
LSD (0.05)	175
	----------2002--------
Cotton after cotton	2948
Cotton after peanuts	2820
LSD (0.05)	**NS**

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Table 4. Cotton yield for crop rotations at Quincy, FL during 2002-2004

Rotation	Year	Lint lbs/A
BBPC	2004	1029
CCPC	2004	955
CPCC	2004	961
LSD (0.05)		NS
BBPC	2003	851
CPCC	2003	877
LSD (0.05)		NS
CC	2002	837
PC	2002	625
LSD (0.05)		143

B= bahiagrass, C= cotton, P= Peanut

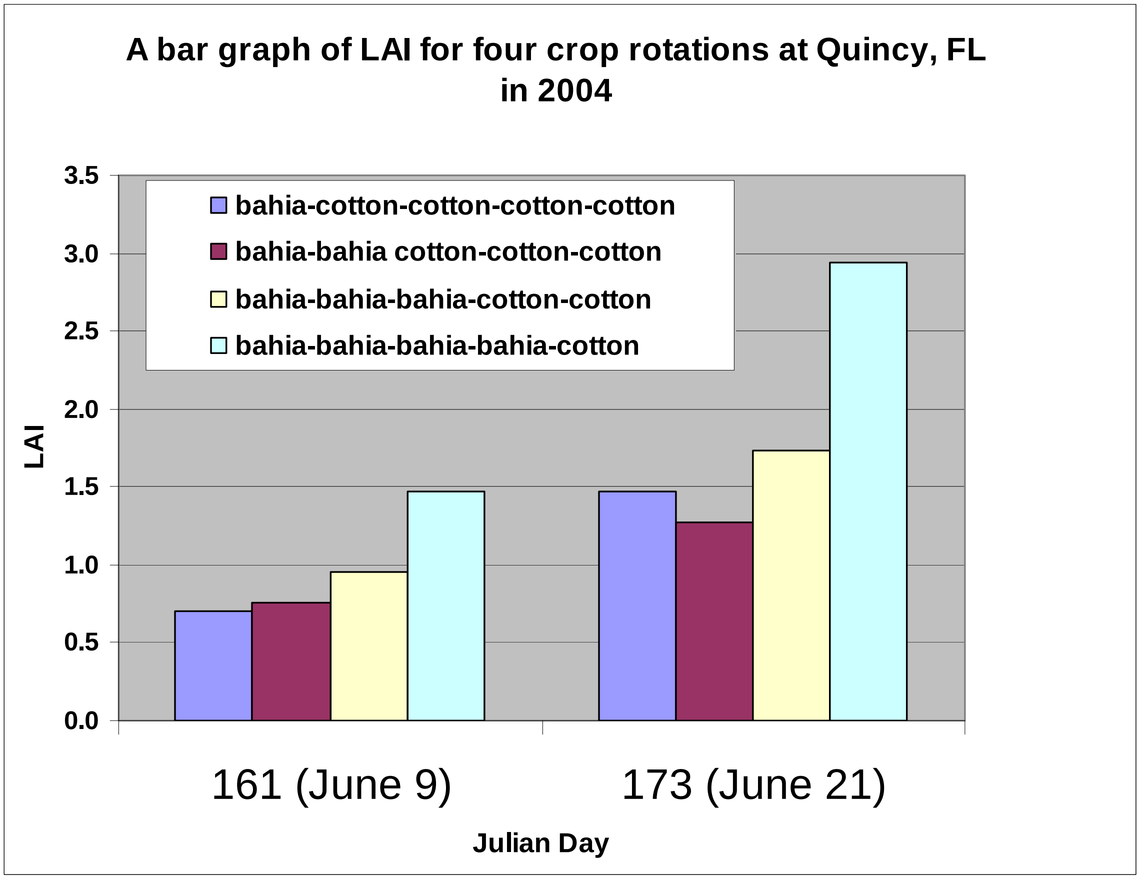

Figure 1. LAI at two dates of cotton grown after 1, 2, 3, or 4 years of bahiagrass at Quincy, FL in 2004.

Summary

We observed no differences in cotton yield between the conventional and bahiagrass rotated cotton at Quincy in 2003 and 2004. The lack of yield differences may have been due to adequate rainfall during bloom both years. However, crop growth factors were 50-100% higher in the bahiagrass rotated cotton. This may have resulted in higher yields if drought conditions had occurred. In 2005, we will reduce N application in the bahiagrass rotated cotton so as to reduce vegetative growth. Reducing N application rates will further reduce N leaching to ground water and also reduce N costs for the growers.

Differences in yield between the rotations were 50% higher in 2003 and 2004 in peanuts in the bahiagrass rotation as compared to the conventional strip tilled 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. There is a growing demand by the livestock industry for forage. Including bahiagrass in the traditional peanut/cotton cropping peanut increases the overall acreage under bahiagrass (forage). Perennial grasses including bahiagrass can be produced at lower production costs compared to other forages. Including bahiagrass in the traditional peanut/cotton cropping system will not only ensure more silage, but will also ensure that large acreage of land in the Tri-state regions would be conserved and protected from potential land degradation. Perennial grasses protect land from erosion and help build up organic matter levels. The average bahiagrass yields were approximately 7239lbs/acre at Quincy in 2003.The yield and quality of the forage was comparable to the other perennial forages including bermudagrass, digitgrass, stargrass and limpograss.

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