VALUE OF PERENNIAL GRASSES IN CONSERVATION CROPPING SYSTEMS

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ABSTRACT

Soils in the southeast have low organic matter content, low native fertility, and low water holding capacity which has resulted in stagnant yields. Long term studies across the country (Morrow, Sanborn, Magruder, Old Rotation [Auburn]) have shown that land coming out of long term perennial grasses often has an organic matter content of over 4% and decreases as it stays in continuous annual cropping and levels off after 80-100 years once the level reaches about 1½% with use of conservation tillage, cover crops, proper rotation, and modern fertility practices. 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 this perennial grasses grown in rotation with crops has shown higher yields (50% more peanuts than under conventional annual cropping systems), increased infiltration rates (more than 5 times faster), 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.

INTRODUCTION

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 high yields of crops. 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 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 from the fields, widespread contamination of surface waters in the region, 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 areas fallow after production decreases, exposing 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 legume production 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 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 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 crops allowing farmers to maintain or enhance quality of the soil 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 that had been 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 1930s and 1940s, when Dr. Glen Burton and others began breeding and releasing new grass varieties. During the 1950s and 1960s 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 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 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. 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 being concerned about maximizing short term productivity at least cost instead of looking at long term 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). Data from the Magruder plots indicated that organic matter dropped at a very rapid rate during the first 50-60 years and has slowed since the 1950s. These 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 1940s and 1950s 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. Soil quality and especially SOM or carbon sequestration is of major concern to the farming community and 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 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 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. However, long term plots across the U.S. and in other countries are still showing a decline in SOM after 100 years or more though the decline appears to have slowed down from the first half of the last century. 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 1/10th the current water use for irrigation, alleviating some of the water problems for annual crops.

MATERIALS AND METHODS

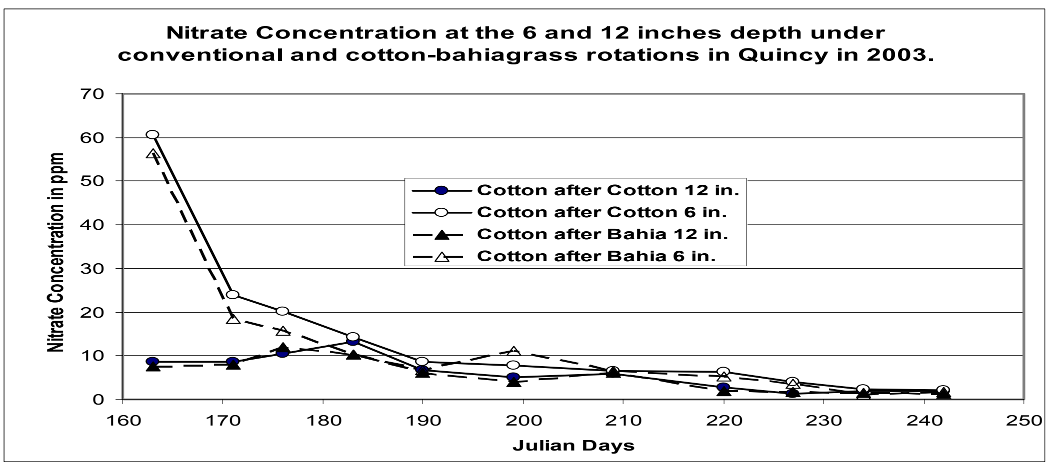
A multi-state project was started in Florida in 2000 and in Alabama and Georgia in 2001 to examine the influence of 2 years of bahiagrass on peanut and cotton in the rotation. The site at Marianna, FL was under a pivot and has a cow-calf operation in rotation with peanut and cotton and winter grazing after these 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:

	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 AND DISCUSSION

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. When we evaluated soil moisture in cotton, the bahiagrass rotation retained more soil moisture as compared to conventional cotton during the 2003 growing season. The increased moisture levels in the bahiagrass rotation was partially attributed to the increased infiltration rates observed in cotton after bahiagrass.

Soil water nitrates were determined at the 6 and 12 inch depth in the conventional and bahiagrass rotated cotton (see figure below). The cotton in the bahiagrass rotation had less soil water nitrate at both depths throughout the growing season. 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 is also responsible for algae blooms in fresh water bodies. Hence rotations which reduces 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 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.

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.

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.

Our results show that including bahiagrass in the traditional peanut/cotton cropping system results in a healthier soil.

Cotton grown after bahiagrass has improved yield component parameters including plant height, plant biomass and LAI. 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.

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 bahigrass rotated cotton also had reduced weed biomass compared to the bahigrass 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. This more 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.

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 (<u>we will test this this year when we look at peanut plant measurements</u>) There was no differences in infestation levels between the rotations for white mold.

We observed no differences in cotton yield between the conventional and bahiagrass rotated cotton at Quincy. The lack of yield differences was surprising, taking into consideration the differences in soil properties between the rotations. It is possible that the bahiagrass rotated cotton could have developed excessive vegetative growth at the expense of fruiting bodies. Literature reports several cases where excessive vegetative growth has resulted in reduced yield. In 2004, 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 not always consistent in peanuts as was the case with cotton. When combined over years, the 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 slightly higher yield compared to the peanuts grown immediately after bahiagrass. It's not clear why this happened. The field with peanuts after bahiagrass generally tended to have higher soil test nutrient levels and also better soil health properties. This however did not translate into higher peanut yield for the rotation.

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. Having large acreage of land under bahiagrass will also help provide more silage for the dairy industry. 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.

REFERENCES

Anonymous. 1997. Washington's five farms: crop rotation. www.Mount Vernon.org.

Atjay, G.L., P. Ketner, and P. Duvigneaud. 1979. Terrestrial primary production and phytomass. In B. Bolin, E.T. Degens, S. Kempe, and P. Ketner, Eds., The Global Carbon Cycles. John Wiley & Sons, New York. 129pp.

Boman, R.K., S.L. Taylor, W.R. Raun, G. V. Johnson, D.J. Bernardo, and L.L. Singleton. 1996. The Magruder Plots: A century of wheat research in Oklahoma. Div. Of Agri. Sci. and Natural Resources. Pp1- 1-69.

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

Dickson, D. W. and T. E. Hewlett. 1988. Effects of bahiagrass and nematicides on Meloidogne arenaria on peanut. Supplement of J. nematology 21 (4S):671-676.

Edwards, J. H., D. L. Thurlow, and J. T. Eason. 1988. Indluence of tillage and crop rotation on yields of corn, soybean, and wheat. Agron. J. 80:76-80.

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

Glover, J. 2003. Characteristics and impacts of annual vs. perennial systems. Proc. Sod Based Cropping System Conf. 20-21 Feb., 2003, Quincy, FL pp 1-6.

Frye, W. W., W. G. Smith, and R. J. Williams. 1985. Economics of winter cover crops as a source of nitrogen for no-till corn. J. Soil Water Conser. 40:246-249.

Hagan, A., W. Gazaway, and E. Sikora. 1995. Nematode suppressive crops. AL Coop. Ext. Ser. Cir. ANR-856.

Imhoff, J. C., R. F. Carsel, J. L. Kittle, Jr., and P. R. Hummel. 1990. Database analyzer and parameter estimator (DBAPE) interactive program user's manual. EPA/600/3-89/083, U.S. Environmental Protection Agency, Athens, GA.

Marois, J.J., D. L. Wright, and T. D. Hewitt. 2001. Economics of sod-based rotations. Proc. Beltwide Cotton Prod. Conf. Jan. 9-12, 2001. Anaheim, CA pp. 10-12.

McGuire, A.M., D.C. Bryant, and R. F. Denison. 1998. Wheat yields, nitrogen uptake, and soil moisture following winter legume cover crop vs. fallow. Agron. J. 90: 404-410.

McVickar, M. H., E.T. Batten, E. Shulkum, J. D. Pendelton, and J.J. Skinner. 1946. The effect of cover crops on certain physical and chemical properties of Onslow fine sandy loam. Soil Sci. Soc. of Amer. 10: 47-49.

Paustian, K., W. J. Parton, J. Persson. 1992. Modeling soil organic matter in organic-amended and nitrogen- fertilized long-term plots. Soil Sci. Soc. Am. J. 56:476.

Wright, D.L., P. J. Wiatrak, D. Herzog, and J.A. Pudelko. 1998. Comparison of Bt corn to non Bt using strip tillage at four planting dates. Proc. Southern Cons. Till Conf. For Sustainable Agr. July, 1998. Little Rock, AR. Pp. 95-98.