SCASC

Southern Conservation Agricultural Systems Conference

Conservation Agriculture Impacts – Local and Global

Proceedings of the 32nd Southern Conservation Agricultural Systems Conference

20-22 July 2010

Jackson, Tennessee

Foreword

The theme for the 32nd Conference is *Conservation Agriculture Impacts - Local and Global*. The conference topic areas are varied, ranging from production issues in conservation tillage to conservation agriculture effects on bioenergy production and the use of new precision technologies and biotechnology for production efficiency. Technological advances have been a major part of the advancement of conservation agriculture in the US and worldwide. The conference presentations addressed a wide variety of topics dealing with crop and bioenergy production efficiency, precision agriculture, and biotechnology. The emphasis was on the local (southern US) impacts of these systems, but global impacts also result from adoption of conservation agricultural systems. The conference, July 20-21, was held in conjunction with the Milan No-till Field Day on July 22.

The primary mission of the *Southern Conservation Agricultural Systems Conference* (SCASC) is to provide a medium for exchanging information about conservation agricultural systems and related technology between and among researchers, Extension personnel, Natural Resources Conservation Service personnel, Soil and Water Conservation District personnel, crop consultants, agrochemical companies, farmers, and any other party interested in increasing use of sustainable agricultural practices. The primary goal of most conservation agricultural systems research is to develop improved technology to increase yields and/or profitability of agricultural crops and livestock while maintaining or improving the quality of soil and water resources available for agricultural, domestic, and recreational uses. The overall objective of the SCASC is to expand the conservation agricultural systems in the southern United States for the purpose of controlling erosion and reducing environmental degradation.

The conference papers deal directly or indirectly with the issues of conservation agriculture and the many economic and environmental aspects of these management systems. We hope this CD is useful in future referencing.

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Bioenergy

Production Issues for Conservation Tillage

Production Issues for Conservation Tillage (cont.)

Precision Agriculture Technology

Natural Resource Conservation

Natural Resource Conservation (cont.)

Miscellaneous

RYE COVER CROP AS A SOURCE OF BIOMASS FEEDSTOCK: AN ECONOMIC PERSPECTIVE

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ABSTRACT

As more emphasis is placed on biopower and biofuels, the availability of biomass feedstock is taking center stage. The growth of the biomass feedstock market is further strengthened by the implementation of new regulations and federal programs. One option for biomass feedstock is the removal of cover crops, such as cereal rye. An experiment was initiated to compare three rye residue management techniques (residue retained, residue harvested or removed, and no rye cover control) and four nitrogen fertilizer treatments (0, 45, 90, 125 lb ac^{-1}). Initial findings from this study show that the removal of rye cover crops for biomass feedstock is a viable option for producers, given the assumptions in the study. Further investigation is needed to determine the complete economic impact of removing rye cover crop for biomass feedstock.

INTRODUCTION

Biopower and biofuels are two areas where biomass feedstocks have the potential to provide renewable energy (English, et al, 2006). Recently, two regulations were published that established federal programs that may drive the expansion of the use of biomass feedstock in energy production: the Renewable Fuel Standard Program (RFS2) Final Rule and the Biomass Crop Assistance Program (BCAP).

The United States Environmental Protection Agency (EPA) published the RFS2 Final Rule on March 16, 2010. The final rule set the annual volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel as part of the National Renewable Fuel Standard (RFS) program. The RFS program was required as part of the Energy Independence and Security Act of 2007 (EISA). For 2010, the RFS volume standard is set at 12.95 billion gallons (bg). Each of the specific renewable fuel categories also has volume standards. The required renewable fuel volume increases each year between 2008 and 2022, reaching 36 bg in 2022 (EPA, 2010). Currently, cellulosic ethanol is being produced at facilities focusing on research and development. According to the RFS2 Final Rule, there are over 35 small pilot- and demonstration-level plants in North America (EPA, 2010). This revision to the RFS program strengthens the need for additional sources of biomass feedstock to meet the volume standards.

As part of the Food, Conservation, and Energy Act of 2008, the BCAP provides agricultural and forest land owners and operators with matching payments for collection, harvest, storage and transportation of biomass materials. The biomass materials must be sold to a qualified Biomass Conversion Facility (BCF), which is defined as a certified facility that produces head, power, biobased products, or advanced biofuels. The matching payment is limited to a maximum of $45 dry ton $(dt)^{-1}$ and a two-year payment duration (FSA, 2009). Nationwide, there are over 450 facilities certified as BCFs; however, the type of biomass utilized at each facility is not clearly identified. The BCAP provides a market for a variety of biomass feedstock and a guaranteed price for the short-run.

While there is significant research being conducted on corn stover, switchgrass and, more recently, miscanthus, as biomass feedstock (English et al., 2006; Brechbill and Tyner, 2008; James et al., 2010; Turhollow, 1994), there is limited research on the use of cover crops as biomass feedstock. In the Southeast, cereal rye is a popular winter cover crop and could be harvested for biomass. Therefore, the objective of this study was to estimate the net returns associated with the removal of rye cover crop for biomass in a continuous cotton operation.

MATERIALS AND METHODS

A field experiment was established in November 2005 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center – Field Crops Unit (32^o 25' 19" N, 85^o 53' 7" W), near Shorter, in central Alabama. The soil was a Marvyn loamy sand (fine-loamy, kaolinitic, thermic Typic Kanhapludult). This area is characterized by a humid subtropical climate, with an average annual precipitation of about 1100 mm (Schomberg et al., 2006).

Three rye residue management treatments were evaluated, which included residue retained, residue harvested or removed, and no rye cover control. The experiment also included four nitrogen fertilizer rates (0, 45, 90, and 125 lb ac^{-1}). Rye (cultivar "Elbon") was drilled at 90 lb ac^{-1} in early November each year using a no-till drill. In the retained treatment, rye was rolled down at the early milk (73) development stage (Zadoks et al., 1974) in late April each year, then sprayed with glyphosate (N-phosphonomethyl glycine) at a rate of 0.8 lb a.i. ac^{-1}. At the same time, rye biomass in the removed treatment was mechanically harvested to a height of 4 inches over the soil surface and removed from the plots. The no cover plots were kept weed free by using herbicide.

In early May each year, the experimental area was tilled in-row with a narrow-shank subsoiler to a depth of 14 inches. The in-row tillage was conducted using a tractor with a Trimble AgGPS Autopilot automatic steering system (Trimble, Sunnyvale, CA 94088), with sub-inch level precision, to avoid compaction of the cotton rows. Cotton was planted during the third week of May each year with a John Deere 1700 MaxEmerge Plus™ (Deere & Co., Moline, IL) air planter with a 40 inch spacing between rows. Cotton was harvested with a spindle-type picker. Other management operations were the same for all treatments.

Net return is driven by two main components: yield and production costs. A partial budgeting approach was used to estimate the change that occurred in farm profit or loss with the addition of a cover crop to the current rotation and varying rates of nitrogen application (Boehlje and Eidman, 1983). This approach allowed for the comparison of costs incurred with either retaining or removing the cover crop. Aside from ginning and hauling costs and nitrogen (N) fertilizer costs, all other cotton production costs were excluded from this study. Fixed costs were not considered and production costs and market prices were held constant at 2009 values (Table 1). Holding prices and costs constant removes variability due to changes in the market. Machinery costs, excluding fuel costs, were based on machinery cost data included in the Mississippi State Budget Generator Version 6.0 (Laughlin and Spurlock, 2008). Fuel and fertilizer costs were from USDA-NASS prices for 2009 (NASS, 2009b). Costs for planting the rye cover crop included the cost of fertilizer and fall application, no-till grain drill, and rye seed.

Herbicide costs, as part of termination, were not included in the study because all treatments, including the no cover crop treatment, received the same application of herbicide. Cover crops were terminated using a roller or a mower/conditioner. Custom application rates were used for fertilizer application, mowing and baling the cover crop, and moving, loading and hauling the biomass (NASS, 2009a; Halich, 2009). It was assumed that the biomass bales were 5 ft x 5 ft and weighed 1200 lbs. The cost of net wrapping was included in the custom rate for the baler. Due to varying production needs throughout the year by potential end users, the bales were assumed to be stored on farm until needed (6 months). The cost to move the bales to the field edge was \$2 ton^{-1}. The bales were loaded on trailers and hauled to the final location. Assuming a 40 mile trip, the cost for loading was \$1.15 ton^{-1} and the cost for hauling was \$6.80 $bale^{-1}$. The market value of cotton lint and cottonseed produced was included in net return as part of the revenue calculation. The price for cotton lint and cottonseed (\$0.64 lb^{-1} and \$129 ton^{-1}, respectively) were the Alabama marketing year average prices received by farmers in 2009 (NASS, 2009b). The biomass price assumed in this study was \$50 ton^{-1}. Reductions in fertilizer needs due to the cover crop or soil erosion resulting from the removal of the cover crop were not accounted for in this study.

The experiment was a randomized split-plot design with four replications. Cotton lint yields and net returns were analyzed using SAS PROC MIXED (SAS Institute, 2008). Replications were treated as a random effect, and cover crop management (RM) and nitrogen fertilizer rate (N) as fixed effects. There was a significant interaction between year and treatments; therefore, cotton lint yield and net returns were analyzed within each year. Significant differences and mean comparisons were based on Fisher's protected LSD at a 5% probability level (α=0.05).

RESULTS AND DISCUSSION

Table 1 lists the treatment effects of cover crop management and N fertilizer rates on cotton lint yields and net returns. For the purposes of this study, cotton lint yields are discussed only as they relate to potential changes (positive and negative) in net returns. Across all four years, cotton lint yields were numerically highest where the rye cover crop was retained in the field and where fertilizer rates were 90 lb ac^{-1} or above. In 2006, the cotton lint yields for all cover crop management treatments were not significant (P-value = 0.0768). For 2007, 2008, and 2009, the cotton lint yields for all cover crop management treatments were significant, with the retention of the rye cover crop being significantly higher than the removal of the rye cover crop in 2008 and 2009. With regard to N fertilizer rates, cotton lint yields at 90 lb ac^{-1} and 125 lb ac^{-1} were the highest, with 125 lb ac^{-1} being significantly higher in 2006 and 2009. Figure 1 displays the average biomass removed per year. There is variability in the biomass yield each year due to weather conditions in the fall and winter.

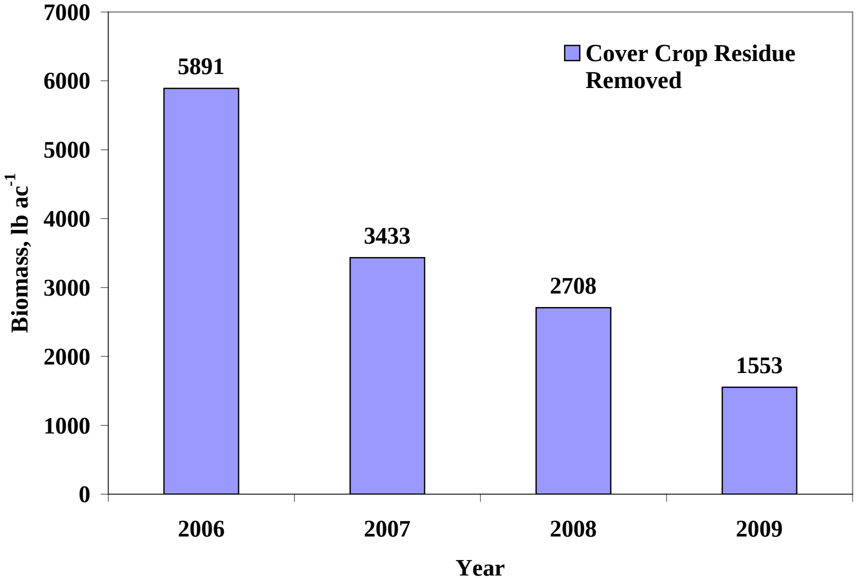

Figure 1. Rye biomass removed during the 2006, 2007, 2008, and 2009 growing seasons at the E.V. Smith Research Center in Shorter, Alabama.

For 2006, 2008, and 2009, net returns for cover crop management treatments were not significant (P-value = 0.1762, 0.0883, and 0.0647, respectively). In 2007, the net return for the removal of the rye cover crop was the highest (\$420.58 ac^{-1}), but was not significantly different from the net return for the retention of the rye cover crop (\$411.51 ac^{-1}). For N fertilizer rate treatments, net returns were significant for all years. In all four years, there was no significant difference between the net returns from 90 lb ac^{-1} and 125 lb ac^{-1}. In 2007 and 2008, there was no significant difference between the net returns from 45 lb ac^{-1}, 90 lb ac^{-1}, and 125 lb ac^{-1}.

As cotton yields increase, net returns increase, assuming constant production costs; however, increases and decreases in net returns were driven by changes in yields, both for cotton and biomass, and production costs associated with the cover crop and cotton. For cover crop management treatments, cover crop production costs were the highest for the removal of the rye cover crop and the lowest for no cover crop. The amount of biomass removed directly impacts the cover crop production costs. Cotton yields also influence production costs through the increase or decrease in ginning and hauling costs, which were calculated by the pound of cotton lint. Increasing N fertilizer rates also change the production costs and any additional revenue is dependent on the potential increase in revenue from yield being greater then the increase in fertilizer costs. Other cotton production costs may change with increases or decreases in yield, such as machinery efficiency; however, these costs were not included in this preliminary study.

In 2006, cotton lint yields and net returns responded significantly to cover crop management and N fertilizer rate treatments (Table 2). The removal of rye residue with zero lb ac^{-1} and 125 lb ac^{-1} of N fertilizer produced the lowest yield (576 lb ac^{-1}) and the highest yield (1345 lb ac^{-1}), respectively (Figure 2). When the rye cover crop was retained, the cotton lint yield differed by 20.9 lb ac^{-1} from the yield associated with the removal of the rye cover crop, and was not statistically different. Yields observed at the 90 lb ac^{-1} N fertilizer rate were not statically different across all cover crop management treatments. As expected, when no N fertilizer was applied, cotton lint yields were the lowest across all cover crop management treatments.

Even with higher cover crop production costs, the removal of the cover crop had the highest net return at 45, 90, and 125 lb ac^{-1} of N fertilizer (Figure 3). The net return associated with the removal of cover crop residue is dependent on the ability to sell the biomass at a price that covers increased production costs or to have a contract with an end user that covers production costs, including transportation costs. Production costs for the removal of the cover crop exceeds the cost of retaining the residue by \$24.89 ac^{-1}, excluding moving, loading and hauling biomass.

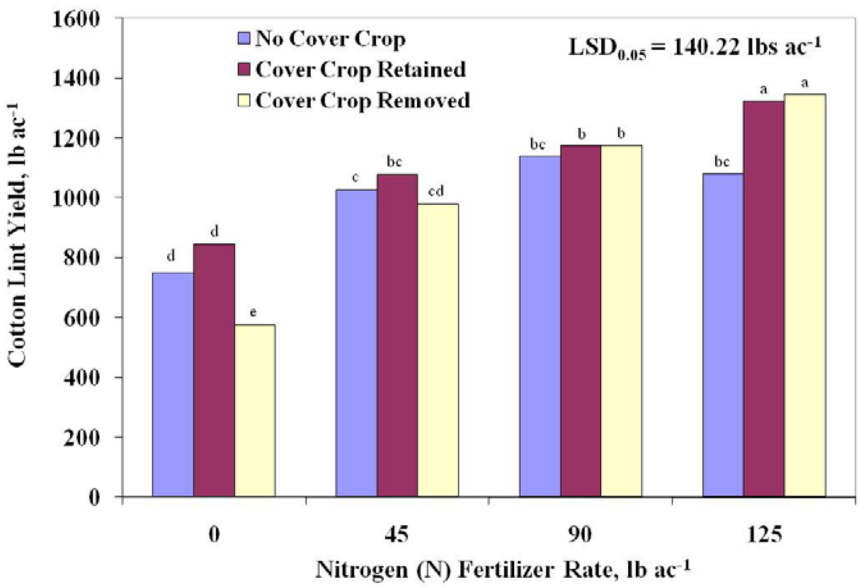

Figure 2. Cotton lint yields following a combination of cover crop management and nitrogen fertilizer rate treatments during the 2006 growing seasons at the E.V. Smith Research Center in Shorter, Alabama. Different letters denote statistical significance between treatments.

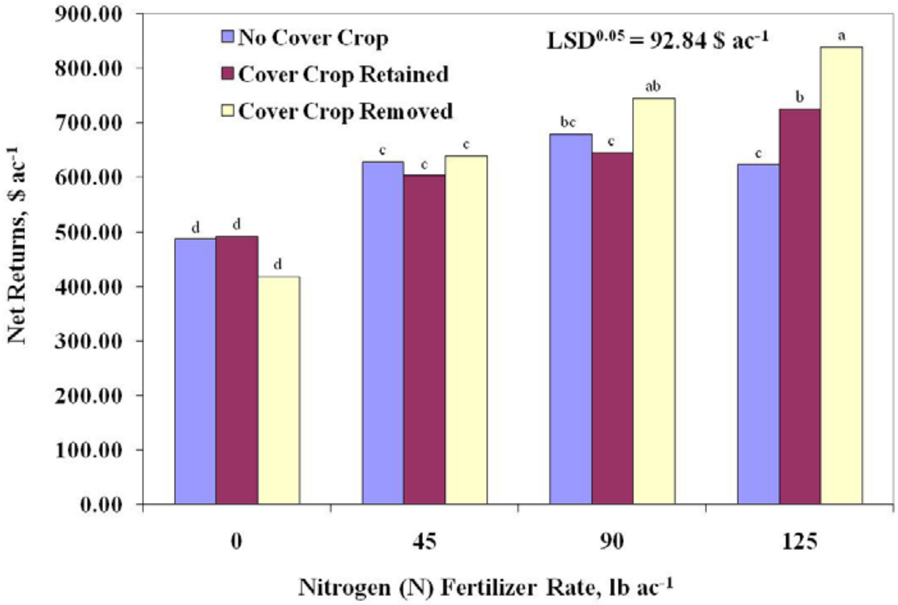

Figure 3. Net returns following a combination of cover crop management and nitrogen fertilizer rate treatments during the 2006 growing seasons at the E.V. Smith Research Center in Shorter, Alabama.

CONCLUSION

Cotton lint yields and net returns responded to cover crop management and N fertilizer rates. Depending on year, net returns were largest for the retention of rye cover crop or the removal of rye cover crop for biomass feedstock. Based on the assumptions in this study, harvesting rye cover crop for biomass feedstock is a viable option. Additional analysis will be performed to determine the magnitude of change in the results due to changes in the basic assumptions.

Disclaimer

Mention of a company name or trademark does not constitute endorsement by the United States Department of Agriculture or the Agricultural Research Service to the exclusion of others.

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TABLES

Table 1. Cost of cover crop management and fertilizer nitrogen (N) rate treatments.†

Production Item	**Cover Crop Retained**		**Cover Crop Removed**
	----------------------$ ac^{-1}----------------------		
Application of fertilizer for cover crop, including fertilizer	20.00		20.00
Cover crop establishment, including seed and no-till grain drill	34.72		34.72
Roller	2.91		NA‡
Custom mowing/conditioning	NA		12.10
Custom raking	NA		5.70
Custom baling large round bales with net wrap	NA		10.00
Custom moving and loading round bales, $ Ton^{-1}	NA		3.15
Custom hauling round bales, $ Bale^{-1}	NA		6.80
	Nitrogen (N) Fertilizer Rate		
	----------------------lb ac^{-1}----------------------		
	45	**90**	**125**
	----------------------$ ac^{-1}----------------------		
Application of N fertilizer for cotton, including fertilizer	40.15	62.20	79.35

† Costs include material costs and variable costs of application. Fixed costs of application are not included in the costs.
‡ Not applicable to the treatment option.

Table 2. Cotton Lint Yields and Net Returns for cover crop management and nitrogen (N) fertilizer rates for the 2006, 2007, 2008 and 2009 growing seasons at the E.V. Smith Research Station in Shorter, Alabama.† ‡

	Cotton Lint Yields				Net Returns			
	2006	2007	2008	2009	2006	2007	2008	2009
Cover Crop Management	------------lb ac^{-1}------------				------------$ ac^{-1}------------			
No Cover Crop	998.4	616.8	914.5	854.4	604.44	356.06	549.79	500.62
Rye Cover Crop Retained	1104.9	790.6	1115.7	1005.6	616.08	411.51	623.10	541.40
Rye Cover Crop Removed	1019.0	722.7	999.1	867.1	659.94	420.58	586.75	468.96
$LSD_{0.05}$	NS‡	74.5	106.1	85.8	NS	54.10	NS	NS
Fertilizer Nitrogen (N) Rate								
0 lb ac^{-1} N	723.1	521.9	741.4	848.6	465.48	318.99	457.31	479.63
45 lb ac^{-1} N	1027.2	715.7	1038.5	810.7	623.24	405.01	610.53	454.97
90 lb ac^{-1} N	1163.1	784.1	1155.7	957.1	689.65	427.48	664.76	528.18
125 lb ac^{-1} N	1249.8	818.5	1103.4	1019.8	728.92	432.73	613.58	551.86
$LSD_{0.05}$	76.3	61.0	93.3	58.1	49.67	39.68	60.74	37.84
Analysis of Variance (P>F)								
Cover Crop Management	0.0768	0.0036	0.0101	0.0089	0.1762	0.0439	0.0883	0.0647
Nitrogen Rate	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cover Crop Management X Nitrogen Rate	0.0018	0.8364	0.0708	0.3653	0.0018	0.8364	0.0708	0.3653

† Net Returns are calculated as total revenue from cotton lint, cottonseed, and biomass minus cover crop establishment and harvest costs, N fertilizer costs associated with cotton, and ginning and hauling costs.
‡ Not significant at the 0.05 level of probability.

WEED CONTROL EFFICACY AND LINT YIELD OF HERBICIDE RESISTANT COTTON TECHNOLOGIES UNDER DIFFERENT TILLAGE SYSTEMS AND ROW SPACING

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SUMMARY

A field study was conducted from 2004 through 2006 at the E.V. Smith Research Center, Field Crops Unit near Shorter, AL, to compare weed control efficacy and lint yield in a conventional variety, a glyphosate tolerant variety, and a glufosinate tolerant variety under conventional and the conservation tillage systems with standard row (100 cm) and narrow row (37.5 cm) spacing. In 2005, conventional cotton produced 12% greater yields, while glyphosate-tolerant cotton produced 13% greater yields compared to glufosinate-tolerant cotton. In 2006, glyphosate-tolerant cotton was superior to both conventional and glufosinate-tolerant cotton by 29%. There were no remarkable yield differences during 2004 among different weed control technologies. Similarly, the 37.5 cm lint yields were equivalent to 100 cm cotton lint yields. As regard weed control, both the Roundup ready and the Liberty link varieties were significantly better than conventional variety under the conventional tillage systems. Likewise, row spacing did not offer any significant enhancement in weed control in HR varieties but in conventional variety.

PEANUT RESPONSE TO STARTER FERTILIZER ACROSS TILLAGE SYSTEMS

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SUMMARY

The benefits of conservation systems have been documented across the Southeast, however, the widespread adoption of conservation systems for peanut (*Arachis hypogea* L.) lags behind other crops despite these benefits. Previous research has documented inconsistent peanut yields in conservation systems, especially for single rows, compared to conventional tillage peanuts. As a result, the possibility of reduced yields in conservation systems has concerned growers and limited the adoption of peanut production in conservation systems.

Starter fertilizers have been successfully adopted in conservation systems with other crops. A starter application supplies a small amount of soluble fertilizer near the root zone of young plants, which strengthens young root systems, enhances early season growth, protects the plants from unfavorable environmental conditions, and potentially decreases the susceptibility of plants to various pests throughout the growing season. The benefits associated with starter applications could also permit earlier planting dates with increased yields in conservation systems compared to conventional peanut production. However, limited research has investigated how peanut responds to starter fertilizer. Therefore, the objective of this research was to determine the interactive effects of various starter fertilizer combinations and placements for two planting dates across conventional and conservation tillage peanut production systems during the 2008 and 2009 growing seasons.

The experimental design consisted of a strip-split-plot with planting date (mid to late April and mid to late May) as the vertical plot and tillage system [conventional and strip tillage with a rye (*Secale cereale* L.) cover crop] as the horizontal plots and a 3x2 factorial combination of starter fertilizer (no starter, N starter alone at a rate of 30 lb N ac^{-1}, and N and P together applied at a rate of 30 lb N ac^{-1} and 12.5 lb P ac^{-1}) and placement (2x2 and in the row behind the subsoil shank) as subplots. Individual subplot size was 12 X 40 feet. Each treatment was replicated four times for a total of 96 plots with one location in Headland, Alabama at the Wiregrass Research and Extension Center and another location in Tifton, Georgia at the Lang Farm. The results from the Alabama location will only be presented in this report. With the exception of starter fertilizer applications, normal agronomic and pest management practices were administered to maximize peanut production. Data collection included yield, percent total sound mature kernels, and whole plant biomass samples approximately 4 weeks after planting to measure biomass. All data were analyzed separately within year with all fixed effects and interactions considered different if Pr > F was equal to or less than 0.1.

In 2008, an interaction was observed between planting date and tillage systems for peanut yield. Strip tillage peanuts from the first planting date and conventional tillage peanuts from the second planting date averaged 14% greater yields compared to the other planting date and tillage combinations. Fertilizer sources and placement only slightly affected yields with N and N + P

applied in a 2x2 band superior to the other fertilizer and placement combinations. Total sound mature kernels, a measure of peanut quality, were maximized in the conventional tillage peanuts from the first planting date, however, as previously mentioned, this treatment did not correspond to the highest yields. Early season plant biomass samples from the conventional tillage plots were 58% greater than samples from the strip tillage plots, regardless of the planting date. The difference between tillage systems was greatest for the second planting date. As with yield, fertilizer source and placement had a slight effect on early season plant biomass. N+P applied in a 2x2 band produced the highest early season plant biomass.

In 2009, the interaction between planting date and tillage systems was again observed for peanut yields, but the results were drastically different. Conventional tillage peanut yields from the second planting date were 20% higher compared to all other combinations. A clear explanation does not exist why the conventional peanuts were superior, but the 2009 growing season was extremely wet, which could have been detrimental for peanuts grown in a strip tillage system that typically retains more soil moisture than conventional tillage systems. Total sound mature kernels were also highest in conventional tillage peanuts from the second planting date with a difference over 1.5% compared to the other tillage and planting date combinations. Fertilizer source and placement also affected total sound mature kernels, but it appeared that deep tillage associated with deep placement resulted in the highest total sound mature kernels. Unfortunately, plant samples from the second planting date were not collected in 2009. As a result, the analysis of early season plant biomass was limited to the first planting date. Early season plant biomass from the strip tillage system was 14% greater than biomass from the conventional tillage system. It appears that the additional plant biomass did not translate into increased peanut yields, however, a complete analysis is not possible. N+P in a 2x2 band produced superior early season plant biomass compared to all other combinations.

The peanut cultivar (Georgia 03L) chosen for this experiment represents many of the new cultivars available to growers, however, Georgia 03L will no longer be commercially available. These new cultivars possess highly resistant disease packages compared to cultivars utilized in the past. As a result, expected benefits associated with starter fertilizers with earlier planting dates could have been overshadowed by the hardiness of the new cultivar. These findings do not provide strong evidence for the use of starter fertilizers in peanut production, but this summary only represents the findings at one location over two years. The results from the Georgia location will be examined in the future to determine how well they agree with findings from Alabama, as well as, examining results from on-going experiments related to starter fertilizer use in peanuts.

CONSERVATION TILLAGE FOR BURLEY TOBACCO

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ABSTRACT

Work with conservation tillage for tobacco in Tennessee began in the mid 1980's, with investigation of no-till systems. Registration of new herbicides overcame original constraints due to poor weed control, but yield from no-till continued to be lower than from tilled tobacco. The yield reduction appeared be largely due to poor transplant placement and restricted early root growth. Work since 1999 with strip-till systems has shown that these systems are capable of producing equivalent yields to tilled systems. The primary key to success is proper transplant placement. The best results have been obtained with fall killed sod, cover crops killed a month before transplanting or previous year row crop residues. Careful attention to soil conditions after strip tillage and to proper transplanter depth is very important. One potential problem is that the low residues cover which results in the best strip-till performance may not leave adequate cover for erosion control.

SUMMARY

Work with conservation tillage tobacco in Tennessee began in the mid 1980's. The initial work was with no-till systems. Poor weed control was a major problem in these early tests and appeared to be the major constraint on successful no-till production. However, after the registration of new herbicides for tobacco solved the weed control problem, yields of no-till tobacco continued to be lower than those achieved in tilled systems. No-till tobacco grew much more slowly early in the season. This slow early season growth appeared to be related to restricted root growth and possible nitrogen deficiency. The transplanter used in these trials used a leading coulter and a double disk opener to allow penetration into the soil by the transplanter shoe. The sides of the slot in the soil formed by the double disk openers appeared to be sealed, and did not allow easy penetration of tobacco roots into the surrounding soil. Based on this preliminary work, it was decided to investigate strip-till systems with more soil disturbance in the row zone to permit more easy soil penetration by roots. In 1999, a study was initiated at the Highland Rim Experiment Station near Springfield, Tennessee. The study consisted of three tillage systems: 1) no-till with a single cutting coulter and double disk openers on the planter, 2)strip-till with an in-row subsoiler, and 3) conventional tillage with a chisel plow and disk. The study was conducted with dark fire-cured tobacco in 1999, 2000, and 2001, and with burley tobacco in 2000 and 2001. With both types, yield was highest in tilled systems and lowest in no-till, with strip-till being intermediate in yield. The three-year averages for dark tobacco were 2153, 1949 and 1651 pounds per acre for tilled, strip-till and no-till systems, respectively. Corresponding two-year averages for burley were 2536, 1938 and 1789 pounds per acre. A second experiment was conducted with burley in 2002 and 2003. This experiment compared three main tillage systems: tilled, strip-till and strip-till with starter fertilizer applied beneath the plant row. Each of the main tillage treatment plots was split into to N fertilization treatments: 1) all N preplant and 2) half the N preplant and half sidedressed about one month after transplanting. In the strip-till/ starter fertilizer treatment, 20 % of the N, P and K fertilizer was applied in a band beneath the row using the subsoiler shank, with all other preplant fertilizer broadcast. In the strip-till and tilled systems, all preplant fertilizer was broadcast. Over the two years, tilled tobacco averaged 2620 pounds per acre in yield, while the strip-tilled treatments averaged 2286 pounds per acre. Neither in row fertilization nor splitting the nitrogen fertilizer affected yield. Continued lower yield in the strip till system appeared to be related to shallow transplanting and inadequate placement of soil around the transplant root ball by the transplanter closing wheels.

Another series of experiments was begun in 2006 and 2007 at the Highland Rim Research and Education Center and at the Research and Education Center at Greeneville, Tennessee, to investigate no-till and strip-till practices with different ground cover management practices. The first study evaluated cover management in established sod. Conventional tillage tobacco was compared to tobacco transplanted either no-till or strip-till into the following sod treatments: (a) spring killed sod, (b) fall killed sod without a winter cover crop, (c) fall killed sod, spring killed wheat cover, and (d) fall killed sod, spring killed rye cover. The second study evaluated the management of annual cover crops in no-till and strip-till systems. Conventional tillage tobacco was compared to tobacco transplanted either no-till or strip-till into the following ground cover treatments: (a) wheat cover, (b) wheat grazed, (c) rye cover, (d) rye grazed, (e) rye straw, and (f) soybean residue. In these studies, a no-till transplanter with a narrow shank in front of the transplanter shoe was used rather than a double disk opener to loosen the soil for transplanter shoe penetration. This transplanter was used in the strip-till treatments as well. In the strip-till treatments, the strip till rig was run multiple times as needed over a period of weeks prior to transplanting to achieve better soil conditions for transplanter operation. Depending on the soil and season, strip tillage was performed from one to three times. In both no-till and strip-till systems, extra care was taken to adjust transplanters to achieve proper transplant placement. In 2006, conventional tillage produced higher tobacco yields than conservation tillage in three out of four tests. Conservation tillage yields in the sod test at Highland Rim were equal to conventional tillage. Generally no-till yields were lower than strip-till, and tilled yields were higher than strip-till. In 2007, a generally drier year, strip till yields equaled tilled yields in all four tests. No-till yields were lower than tilled and strip tilled at Springfield, but not at Greeneville. Overall, the best strip–till systems generally gave yields as high as tilled, while no-till yields were lower, especially at Highland Rim. The best strip-till systems were those that involved fall killed sod with no cover crop or removal of cover crop residue by simulated grazing or as straw. Improved performance of strip till and no-till systems in these tests compared to earlier studies was attributed to better performance of the modified no-till transplanter, better soil conditions for transplanting in the strip till systems, and more attention to proper transplant placement.

Based on the success of the strip till systems, a new series of experiments was initiated in 2009 at Highland Rim and Greeneville evaluating strip-till systems. Systems evaluated were wide strip-till with an inrow subsoiler, narrow strip till with a narrow shank, rototill strip, and inrow subsoiler plus rototill strip. All of these were compared to no-till with the narrow shank opener and to full tillage. In 2009 all the strip till treatments were equal to full tillage in yield. No-till was lower at Highland Rim.

Overall, it appears that strip-till systems using well adjusted equipment are essentially equivalent to full tillage as alternatives in tobacco production. One problem with these systems is that they perform best with relatively light residue cover, and in the more aggressive strip-till systems cover may not be adequate for erosion control.

SPRING FORAGE YIELDS AND QUALITY OF PLOTS FERTILIZED WITH BROILER LITTER, EXCEPTIONAL QUALITY BIOSOLIDS

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SUMMARY

High prices and volatility in the chemical fertilizer markets have increased agricultural producer interest in alternative fertilizers. Though the rate of biosolds beneficial reuse in the southeastern states lags well behind other parts of the country, utilities are increasingly producing more attractive "exceptional quality" biosolids with no land application restrictions. Research documenting the performance of these products is lacking. This study examines two years of Spring forage yield and quality using an "exceptional quality" biosolids that will be available in bulk granulated form through TN, KY and AR. Results are benchmarked to broiler litter, chemical fertilizers, and control plots.

EFFECTS OF ROLLING/CRIMPING RYE AND CLOVER WITH DIFFERENT HERBICIDE TYPES AND RATES ON THEIR TERMINATION RATE, COTTON POPULATION AND YIELD IN A NO TILL SYSTEM

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ABSTRACT

In 2008, a field experiment was initiated in central Alabama to study the effects of terminating rye and crimson clover utilizing rolling technology and three different types and application rates of herbicides on cover crops termination rates, cotton population and yield. A Two stage roller/crimper with and without supplemental application of glyphosate or two organic herbicides (Weed-Zap and vinegar 20% acidity) applied as a continuous spray, every second crimp and every third crimp controlled by a high speed solenoid valve nozzle system were used to terminate rye and crimson clover. Cover crop termination rates were assessed at rolling, one, two, and three weeks after rolling. In 2009, three weeks after rolling, complete termination rate was achieved with rolling/crimping and glyphosate treatments (96-99%). Organic herbicide treatments generated between 91-94% terminations. Rolling treatments and cover crop type had no effect on cotton population which averaged 40,987 plants ac^{-1}. However, significantly higher average seed cotton yield of 3110 lbs ac^{-1} was reported for rye cover crop compared to 2,545 lbs ac^{-1} for crimson clover.

INTRODUCTION

Cover crops are an integral component in conservation agriculture because they provide important benefits that enhance soil quality and plant growth. To maximize benefits of cover crops they must produce optimum biomass (Brady and Weil, 1999). Commonly used cover crops in the Southern United States are cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.). Rye produces up to 10000 lbs ac^{-1} of biomass (Bowen et al., 2000) and crimson clover, a legume which in addition to biomass production is an important alternative to fertilizers as a nitrogen source (Hargrove and Frye, 1987). Major benefits include soil protection from impact of rainfall energy, reduced runoff, decreased soil compaction and increased infiltration (Kern and Johnson, 1993; McGregor and Mutchler, 1992; Reeves, 1994; Raper et al., 2000a; Raper et al., 2000b). Cover crops also provide a physical barrier on the soil surface which inhibits weed emergence and growth (Creamer et al., 1996). In addition to providing a physical barrier, rye has alleopathic properties that provide control similar to applying a pre-emergence herbicide (Barnes and Putman, 1986; Hoffman et al., 1996). Legumes such as crimson clover produce nitrogen, a benefit that is important in terms of providing a nitrogen source instead of fertilizers (Hubbell and Sartain, 1980; Mansoer et al., 1997). Long term soil quality effects are associated with improving soil physical/chemical properties due to increasing soil organic carbon, resulting in better crop growth and sustainable agriculture.

Rolling/crimping technology has been used to manage tall cover crops by flattening and crimping cover crops such as rye in conservation systems. Crimping cover crop tissue causes plant injury and accelerates its termination rate. In the southern United States conservation systems, terminating cover crops should be carried out three weeks prior to planting the cash crop which is similar to normal burndown recommendations (Reeves, 2003). Typically, three weeks after rolling, the termination rate for rye is above 90% when rolling is performed at an optimal growth stage (Ashford and Reeves, 2003; Kornecki et al., 2006, Kornecki et al., 2009). Most agricultural extension services recommend terminating the cover crop at least two weeks prior to planting the cash crop to prevent the cover crop from competing for valuable spring soil moisture that could be used by the main cash crop after planting. Hargrove and Frye (1987) reported that a minimum time from cover crop termination should be at least 14 days before planting of the cash crop to enable soil water recharge prior to planting cash crop.

When late winter months and early spring months are unusually cold and wet or too dry, producers must wait longer for rye to obtain an optimum growth (in terms of appropriate growth stage and biomass), while planting the cash crop late which might compromise yield. Delays in termination of cover crop may decrease the time between rolling and planting the cash crop and might also create problems with managing cover crop residue during planting. This is especially critical in vegetable production when delays in planting cash crop could negatively affect growth of plants and yield. On the other hand, warm weather and plentiful rainfall in spring can increase weed pressure and insect population, and if small transplants are planted too late, insects and weeds could substantially damage yield of main crops.

If there is an insufficient time between cover crop termination and planting of a cash crop, the cover crop might not completely loose its elasticity, strength and moisture, making planting difficult due to the possibility of frequent wrapping and accumulation of cover crop residue on planting units, as well as increasing the possibility of hair-pinning. One effective way to reduce the time between terminating cover crops and planting the cash crop is to apply herbicide with rolling operation using a sprayer with nozzle boom mounted behind the roller. However, mechanical crimping and continuous herbicide application might exceed the amount of herbicide needed to effectively terminate cover crops. Applying herbicides in short spray intervals to the area of injured cover crop tissue may result in reduced herbicide use.

The objectives of this study were to determine the effectiveness of different application methods for three herbicides combined with rolling/crimping operation on termination of rye and crimson clover and rolling/herbicide treatment effects on cotton stand and yield in conservation system.

MATERIALS AND METHODS

The experiment was conducted at the E.V. Smith Research Station near Shorter, Alabama on a Compass loamy sand soil (thermic Plinthic Paleudults). Cereal rye (‘Elbon’, 90 lbs ac^{-1}) and crimson clover (‘Dixie’, 25 lbs ac^{-1}) were seeded as a winter cover crops in fall 2008 using no-till drill. All rolling/herbicide treatments were applied in mid-April 2009, when rye was in the early milk growth stage equal to Zadoks #73 (Zadoks et al, 1974), and crimson clover was in the flowering (full bloom) growth stage. Application rate for (Roundup^{TM} Weather Max)** glyphosate continuous spray was 22 oz ac^{-1}; rate for non-selective organic herbicide Weed-Zap (clove oil 45%, cinnamon oil 45%, lactose and water 10%) continuous application was 96 oz/ac; and for Natural Horticultural Vinegar (20% acidity) continuous spray was 15 gallons ac^{-1}. Roller operating speed was set to 3.0 MPH. Following treatments were assigned to each cover crop (sub-main plots). To supply an equal amount of herbicide and control the flow and pressure of the water solution, a plastic 53 L tank with a pressure compensated vane pump powered by a 12-Volt electric motor from FlowJet (model # 4300-504) and flow regulator were used. Operating system working pressure was set to 30 PSI. A split plot design for this experiment was employed with two main plots (for each cover crop) with four replications. To each main plot, 11 treatments were randomly assigned (individual sub-plots 50 ft long and 6 ft wide) which also included standing (non-treated) rye and clover as the controls. Treatments descriptions are listed below:

Treatment No.	Treatment Description applied to both cover crops
1	No roller (standing cover crops as control)
2	Roller only (two stage roller/crimper)
3	Roller + Weed-Zap as a continuous spray
4	Roller + Weed-Zap every 2nd crimp
5	Roller + Weed-Zap every 3rd crimp
6	Roller + Vinegar 20% as a continuous spray
7	Roller + Vinegar 20% every 2nd crimp
8	Roller + Vinegar 20% every 3rd crimp
9	Roller + Roundup as a continuous spray
10	Roller + Roundup every 2nd crimp
11	Roller + Roundup every 3rd crimp

Figure 1. Two-stage roller/crimper with mounted 53 L plastic tank and boom with 5 nozzles each controlled by fast acting solenoid valve to discharge herbicides on crimped cover crop residue.

Herbicide application method was a steel boom with five nozzles mounted to the roller to provide spray continuously, every 2nd crimp and every 3rd crimp (Fig 1). Each nozzle was spaced 14.5 in apart and mounted to the steel boom providing a 6 ft spraying width. Each nozzle assembly comprised of a fast acting solenoid valve and a narrow band nozzle (Fig 2).

Components of the control system were an electric micro-switch mounted to the roller's structural frame of the crimping drum (Fig 3) and custom engagement bars used to trigger the switch. The electrical switch was comprised of an adjustable engagement arm both in length and angle of engagement.

Three engagement bars (for every second crimp) and two bars (for every third crimp) as shown in Fig 2 were fastened to the end of crimping bars at equal intervals. When the engagement bar was in contact with the micro-switch arm, the arm was rotated and energized/de-energized the solenoid valves through the ON-OFF micro-switch (Fig. 3). When the solenoids were energized and activated the fast acting valves, herbicides were discharged through the nozzles for a very short period of time on the crimped cover crop residue.

Figure 2. High speed solenoid valves to control nozzle discharge (flat pattern) of herbicides.

Figure 3. Two-stage roller/crimper with the electric switch mounted on the pivoted roller's frame to be energized by the ½ inch DIA engagement bars mounted on the crimping bars of the crimping drum.

Rye termination, based on visual observation, was estimated on a scale of 0% (no injury symptoms) to 100% (complete death of all plants) (Frans et al., 1986) and was evaluated at rolling and then one, two, and three weeks after rolling treatments. Cotton (Stoneville 4427 variety) was planted May 21, 2009 using a no-till vacuum planter John Deere 1700 Emergence Plus and DAWN™ row cleaners. Cotton stand data were collected after seed emergence twice per week up to 5 weeks. Cotton was harvested on October 26, 2009 utilizing 2-row cotton picker John Deere 9920 model.

Data was subjected to analysis of variance and treatment means were separated using the ANOVA GLM procedure, Fisher's protected Least Significant Differences (LSD) test at the 10 % probability level (SAS, 2001). Because significant differences in termination rates and cotton yield occurred between rye and crimson clover data for each cover crop were analyzed separately.

RESULTS AND DISCUSSION

Cover crops height and biomass

There were significant differences in plant height between rye and crimson clover ($P<0.0001$) Average height for rye in 2009 was 66 inches whereas for crimson clover was 29 inches. Similarly, the dry biomass produced by rye was significantly higher (8,415 lbs ac^{-1}) compared to crimson clover which produced 5,852 lbs ac^{-1} ($P<0.0001$).

Rye and crimson clover termination

Because termination for rye and crimson clover was significantly different and each week after termination was significantly different ($P<0.0001$), data were analyzed separately for each cover crop and week separately. Results are presented in Table 1.

Results indicate that one week after rolling; treatments #9, #10, and #11 which utilized glyphosate application produced the highest termination rates for rye (96 - 97%). No significant differences observed among continuous (treatment #9), every second (treatment #10) and every third crimp (treatment #11) of application implying that spraying glyphosate every third crimp was as effective as the continuous spray (Table 1). Termination rates every third crimp (96%) one week after rolling exceeded recommended termination rate which is 90% to normally allow plant cash crop into rye residue cover three weeks after rolling (Ashford and Reeves, 2003). One week after rolling treatment roller alone and roller with supplemental application of vinegar and Weed-Zap produced between 90 and 93% termination for rye and there were no significant differences in rye termination among continuous spray, every second and third crimp applications for vinegar and Weed-Zap. Two and three weeks after rolling no differences in rye termination found among all treatments except for the non-treated control of standing rye.

Termination rates for crimson clover were significantly lower than for rye one week after rolling and for glyphosate were between 38% (every third crimp) and 41% (for continuous and every second crimp); for other treatments including roller alone termination rate were between 34% and 36%. No significant differences in clover termination rates reported among continuous, every second and every third crimp for Weed-Zap and vinegar organic herbicide applications.

Second week after rolling spraying glyphosate continuously resulted in the highest clover termination (95%), although no differences were found between continuous spray and every second crimp (88%). Applying glyphosate every third crimp produced 84% termination. Except for vinegar continuous spray which produced 70% clover termination, no differences among Weed-Zap, vinegar and roller alone observed and resulted between 73 and 80% (for roller alone) clover termination. Two weeks after rolling termination rate for control (untreated clover) was only 4%. Three weeks after rolling spraying glyphosate continuously produced 98% but no significant differences observed among continuous spray, every second (93%) and every third crimp (92%). There were no significant differences among roller alone (86%) Weed-Zap (#3, #4, #5) generating between 84 and 89% termination, and vinegar (#6, #7, #8) was generating from 81 to 84% of clover termination. It was expected that addition of herbicide to rolling would increase clover termination rates.

Cotton population

There were on significant differences of cotton stand due to different covers (P=0.168) nor due to treatments effects (P=0.745). Overall average cotton final stand was 40,897 plants ac^{-1}. Although, no significant difference observed, an average cotton stand planted into rye residue was slightly higher numerically (42,248 plants ac^{-1}) compared to cotton stand planted into crimson clover residue cover (39,545 plants ac^{-1}).

Cotton seed and lint yield

Significant differences in cotton yield observed between rye and crimson clover cover crops (P<0.0001) as well as due to treatment effects (P=0.066). An average cotton yield for rye cover crop was 3,110 lbs ac^{-1} compared to crimson clover (2,545 lbs ac^{-1}). There were no significant interactions between covers and treatments with respect to cotton yield (P=0.956). Cotton yield for different covers and treatments are presented in Table 2. No significant differences in cotton yield observed among all treatments for rye cover crop. Although no significant differences occurred, numerically the lower cotton yield of 2,715 lbs ac^{-1} observed with control (standing rye) compared to other treatments which exceeded 3,000 lbs ac^{-1} of cotton yield.

On the other hand, there were significant differences in cotton yield for crimson clover. The highest cotton yield observed with rolling and glyphosate sprayed continuously (Treatment #9) on crimson clover (2,749 lbs ac^{-1}). No significant differences in cotton yield recorded among all glyphosate treatments and by rolling clover by roller/crimper alone (treatment #2). Numerically they produced higher cotton yield: 2,651 and 2,655 Lbs ac^{-1} for applying glyphosate every second crimp (treatment #10) and every third crimp (Treatment #11), respectively. Cotton yield for roller/crimper alone was 2,689 lbs ac^{-1}. Standing (untreated crimson clover; treatment #1) generated significantly lower cotton yield of 2,334 lbs ac^{-1} along with treatment #7 (Vinegar every second crimp) which produced 2,331 lbs ac^{-1}. Surprisingly, crimson clover generated lower cotton yield compared to rye cover crop. It was expected that crimson clover as legume would produce nitrogen which could be utilized by cotton and consequently increase cotton yield. However, we noticed that in 2009 growing season, cotton plants for crimson clover were taller than with rye. The average cotton plant height for crimson clover was 49.2 inches whereas for rye the height was only 43.7 inches. It appears that nitrogen released from crimson influenced vegetative growth of the cotton plant but did not increased cotton yield, and in fact lowered cotton yield by 18% compared to rye cover. Growing and harvesting cotton in 2009 was the first year of the study and we need to observe during the next two years if the same trend will continue. If so, than using crimson clover as a cover crop in no-till cotton may not be advantageous. However, for no-till/organic vegetable utilizing crimson clover may benefit selected vegetables.

SUMMARY AND CONCLUSION

Three different herbicides: glyphosate (Roundup^{TM}) Weed-Zap, vinegar 20% and were applied continuously, every second, and every crimp on rolled/crimped rye and crimson clover. Data indicate that one week after rolling, the highest rye termination rates were recorded for glyphosate continuous spray (97%) for spray every 2nd crimp (96%) and every 3rd crimp (96%). Organic herbicides (Weed-Zap and vinegar) and roller/crimper alone generated between 90 and 93% rye termination which was at the recommended termination level to plant a cash crop into residue rye cover. Contrary to rye, termination rates for crimson clover was lower, and one week after rolling, glyphosate application generated only between 38 to 41% termination. By third week after rolling the highest termination for clover was observed with all glyphosate treatments (92 to 98%) which exceeded recommended termination to plant cash crop into this cover. Other treatments resulted between 81 and 86% clover termination. Cotton population was neither affected by cover type nor was treatment averaging 40,897 plants ac^{-1}. Cotton seed and lint yield significantly higher for rye residue producing 3,110 lbs ac^{-1} compared to 2,554 lbs ac^{-1} produced by crimson clover. This reduced yield may be associated with increased vegetative growth of cotton.

Disclaimer

**The use of trade names or company names does not imply endorsement by the USDA-Agricultural Research Service.

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Table 1. Rye and crimson clover termination rates in 2009 growing season.

Treatment number	Rye termination (%)				Crimson clover termination (%)			
	Week 0	Week 1	Week 2	Week 3	Week 0	Week 1	Week 2	Week 3
#1	8	49d	85b	97b	0	0d	4f	25e
#2	8	90c	100a	100a	0	35bc	80bcd	86bcd
#3	8	90c	99a	100a	0	36bc	78cde	84cd
#4	8	91bc	100a	100a	0	35bc	76cde	89bc
#5	8	91bc	99a	100a	0	35bc	76cde	84cd
#6	8	93b	100a	100a	0	35bc	70e	84cd
#7	8	92bc	100a	100a	0	35bc	80bcd	83cd
#8	6	90c	100a	100a	0	34c	73de	81d
#9	8	97a	100a	100a	0	41a	95a	98a
#10	8	96a	100a	100a	0	41a	88ab	93ab
#11	8	96a	100a	100a	0	38b	84bc	92ab
LSD (α=0.1)	N/S	2.54	1.56	0.00	0.00	2.72	9.34	7.32
P-value	0.46	<0.0001	<0.0001	<0.0001	NA	<0.0001	<0.0001	<0.0001

Table 2. Treatment effect on cotton yield for rye and crimson clover cover crops in 2009 growing season.

Treatment number	Cotton yield for rye (lbs ac^{-1})	Cotton yield for crimson clover (lbs ac^{-1})
#1	2,715	2,334d
#2	3,174	2,689ab
#3	3,205	2,614abc
#4	3,097	2,400cd
#5	3,043	2,494bcd
#6	3,185	2,574abcd
#7	3,038	2,331d
#8	3,225	2,503bcd
#9	3,197	2,749a
#10	3,158	2,655ab
#11	3,179	2,651ab
LSD (α=0.1)	N/S	244
P-value	0.521	0.069

ECONOMIC COMPARISON OF FOUR WINTER COVERS FOR NO-TILL COTTON CROPPING ROTATIONS UNDER RISK

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SUMMARY

Cotton producers are continually searching for ways to increase the profitability of their farm enterprise. Two potential strategies include adjustments to cropping rotations and the use of winter cover crops. Previous research indicates that alternating the sequence of crop rotations may increase cotton yields. Likewise, winter cover crops can substitute for nitrogen fertilizer and help conserve soil. While data on net returns is commonly reported among crop rotation research findings, few studies assess the relative risk exposure. Information on how winter cover systems may interact with different cotton crop rotations and also influence both net returns and economics risks is indeed even more limited. The objective of this research was to assess the relative profitability and risk exposure of five cotton crop rotations under four alternative winter cover systems.

The ranking of cotton crop rotations and winter cover systems by expected net return and risk depends on producers' risk preferences. Risk neutral producers will select the crop rotation and winter cover system that maximizes net returns relative to other options, even if a possibility for low or negative net return outcomes exists. By contrast, risk averse producers will select a crop rotation and winter cover system that provides a utility-maximizing tradeoff between net returns and risk of low or negative returns. Due to a lack of information about the risk preferences of Tennessee cotton producers, alternative crop rotations and winter cover systems were ranked using stochastic dominance efficiency criteria. First degree stochastic dominance (FSD) ranks alternatives by assuming producers are risk neutral. Second degree stochastic (SSD) ranks alternatives by assuming producers are risk averse.

Data are from a 2002 to 2009 no-till crop rotation and winter cover experiment in Milan, TN. Main plots consisted of thirteen 4-yr crop rotation sequences for cotton, corn, and soybeans. Subplots consisted of four winter cover systems including hairy vetch, winter wheat, poultry litter, and fallow. In this analysis, we consider only those rotations with cotton planted in two or more years of a single 4-yr rotation. The rotations considered included continuous cotton, cotton-soybeans-cotton-corn, cotton-corn-cotton-soybeans, cotton-soybeans-corn-cotton, and cotton-corn-cotton-corn. All plots were established according to The University of Tennessee Extension crop production guidelines. Budgets were constructed for crop production and the establishment and burndown of winter cover systems. Fertilizer credits were assigned to each winter cover system based on the amount of soil available N, P, and K provided. The economic value assigned to the fertilizer credits equaled the level of cost savings provided. Finally, yield and production cost data were combined to determine net returns for each row crop and winter cover combination in each year of the experiment.

Currently, findings are preliminary. Before firm recommendations can be made additional rotation data must be incorporated into the analysis and sensitivity analysis on market prices must be conducted. Ranking of the cotton crop rotations and winter cover systems by net returns and risk using stochastic dominance criteria resulted in two major observations. First, under a fallow cover, we found that continuous cotton tended to be risk inefficient under both FSD and SSD as compared to rotations that alternate cotton with soybeans or corn on an annual basis. By contrast, continuous cotton under fallow was risk efficient for both FSD and SSD as compared to the cotton-corn-cotton-corn and cotton-soy-corn-cotton rotations. These results imply that producers who alternate cotton production with corn and soybean on an annual basis may reduce their net return risk exposure. Second, among winter covers for continuous cotton, SSD results suggest that poultry litter and fallow were the most risk efficient. One implication of this result may be that legume winter cover crops are risk inefficient as compared to nitrogen from poultry litter or commercial sources.

DEMONSTRATING USE OF HIGH–RESIDUE COVER CROP CONSERVATION TILLAGE SYSTEMS TO CONTROL GLYPHOSATE–RESISTANT PALMER AMARANTH

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SUMMARY

Adoption rates of transgenic cotton have been on the incline since its introduction in 1997 to make up almost 90% of total cotton production in the United States (Shaw et al. 2009). Reduced-tillage practices, with their even lower production costs, have seen a concomitant increase across the southern region of the US. However, the limited number of herbicide options and the loss of weed control through tillage, paired with the effectiveness of glyphosate, have resulted in a heavy dependence of a single herbicide mode of action in these systems (Green et al. 2008; Givens et al. 2009; Kruger et al. 2009). At present, cases of glyphosate-resistant Palmer amaranth have been documented throughout the Southeast including: Georgia, Arkansas, Tennessee, Alabama, Mississippi, North Carolina, and South Carolina (see figure 1). With this development, the future of conservation tillage remains uncertain.

SUSTAINABLE NITROGEN FERTILIZER REGIMES FOR SNAP BEANS IN VIRGINIA

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ABSTRACT

Over 5,500 acres of snap beans (*Phaseolus vulgaris*) are grown in Virginia per year within the environmentally sensitive Chesapeake Bay watershed. The objective of this study was to pinpoint correct nitrogen (N) rates and fertilizer sources containing varying amounts of ammonium, nitrate, or other N forms. The experiment was arranged as a factorial arrangement of 3 N rates (40, 80, and 120 lbs N/acre) × 5 N sources [liquid urea-ammonium nitrate (UAN, 30% N), calcium nitrate (CN, 17% N), ammonium nitrate (AN, 34% N), ammonium sulfate nitrate (Sulf-N26, 26% N and 14% S), and urea + dicyandiamide (DCD) nitrification inhibitor (UDCD, 46% N)] plus a 0-N control on a Bojac sandy loam. Two additional treatments of AN and UAN had gypsum applied at the equivalent 43 lbs sulfur (S)/A along with 80 lbs N/A to allow sulfur treatment comparison (ANS and UANS, respectively). The study was repeated as a spring and fall planting. For the spring crop, we suspect that record rain events leached N fertilizer below the root zone as no source had significantly higher yields than the 0-N control, except UDCD (4477 vs. 5639 lbs/acre, respectively). Fall treatments suggested that all N sources had statistically similar yields and were higher than the 0-N control (6703 vs. 4296 lbs/acre, respectively). A quadratic relationship indicted that 80 lbs N/acre was optimum for maximum yields (7200 lbs/acre). Sulfur did not appear limiting in this study and did not offer a yield advantage to no-S treatments, but did reduce rust disease incidence.

INTRODUCTION

The Commonwealth of Virginia has substantial snap bean (*Phaseolus vulgaris*) acreage and currently ranks seventh out of the 12 commercial fresh market snap bean producing states in the nation (USDA-NASS, 2010). On average, Virginia produces 5,500 acres of fresh market snap beans annually that are worth 4.5 million dollars (USDA-NASS, 2010). Nearly all commercial Virginia fresh market snap bean production occurs in the Chesapeake Bay watershed with most occurring on the Eastern Shore of Virginia. Of all the snap beans produced, nearly all are produced using conventional tillage regimes due to trash concerns during harvest and disease problems (Reiter, 2009). Eastern Shore of Virginia production systems have similar soils, production, and environmental concerns as other large vegetable producing areas in the Mid-Atlantic and utilizing conservation agricultural systems would be beneficial. However, conservation tillage systems need more research for snap bean production; therefore, improving nitrogen fertility is a way to make these vegetable production systems more sustainable in the short term. Farmers utilizing intensive vegetable production systems in the Mid-Atlantic understand the sensitivity of the ecosystem in which they operate and are establishing sustainable farming practices to increase fertilizer use efficiency to reduce nutrient losses to the environment.

Overall, N fertilizer is the most difficult nutrient to manage in crop production systems because it can be lost from the effective root zone or immobilized into unavailable N forms via numerous environmental pathways. Plant uptake and utilization of N fertilizer is a major concern to farmers because it impacts fertilizer use efficiency. In 2008, nitrogen (N) fertilizer prices doubled in a year and were over 400% higher than baseline values 10 years earlier (USDA-NASS, 2009). Nitrogen prices have since decreased, but we are still experiencing fertilizer prices nearly double 10 years earlier and we expect prices to increase again in the future as the economy improves and energy prices rise again. Fertilizer costs have increased to the point where they are now a major crop input and farmers no longer have the luxury to over-apply as "insurance" for top yields and are looking for ways to increase their fertilizer use efficiency and add value.

Value-added fertilizer sources may contain other nutrients, such as sulfur (S), or additives that increase nitrogen fertilizer use efficiency. Sulfur may be added to fertilizer sources since S is used in large quantities by snap beans and readily leaches through the soil profile out of the effective root zone. Since sulfur reacts similar to nitrogen regarding movement from irrigation and rainfall, it is intuitive to mix these two nutrients and apply them similarly. Additives, such as dicyandiamide (DCD), can be included with fertilizer sources to effectively reduce nitrification following fertilizer application. Keeping fertilizer sources in the ammonium forms may retard leaching since the cation can fix to the soil's cation exchange complex. The objective of this study is to determine if sulfur containing fertilizers, fertilizers with varying amounts of ammonium or nitrate, or fertilizers with a nitrification inhibitor will increase yields in Mid-Atlantic snap bean production systems.

MATERIALS AND METHODS

Research plots were established at the Virginia Tech Eastern Shore Agricultural Research and Extension Center near Painter, Virginia in Spring and Fall 2009 on a Bojac sandy loam (Coarse-loamy, mixed, semiactive, thermic Typic Hapludults; surface horizon = 65% sand, 25% silt, 10% clay, and 0.75% organic matter) (USDA-NRCS, 2010). Painter, Virginia averages 43 inches of precipitation per year, has a mean annual temperature of 59°F and 210 frost free days per year (NOAA-NWS, 2010).

The experiment was arranged as a factorial arrangement of 3 N rates (40, 80, and 120 lbs N/acre) × 5 N sources [liquid urea-ammonium nitrate (UAN, 30% N), calcium nitrate (CN, 17% N), ammonium nitrate (AN, 34% N), ammonium sulfate nitrate (Sulf-N26, 26% N and 14% S), and urea + DCD nitrification inhibitor (UDCD, 46% N)], plus a 0-N control. Two additional treatments were applied and analyzed separately to test for sulfur response. Sulfur as gypsum was applied at Sulf-N26 equivalent rates for 80 lbs N/A (43 lbs S/A) to additional plots fertilized using UAN (UAN + S = UANS) and AN (AN + S = ANS). Sulf-N26, AN, ANS, UDCD, and gypsum were weighed and broadcast applied by hand to plots. Liquid UAN, UANS, and CN were applied with a calibrated backpack CO_2 sprayer. All N treatments were 50-50% split applied between at-planting (broadcast applied and incorporated) and early bloom (band applied to soil surface). Phosphorus, potassium, other macro and micronutrients, and production practices were based on Virginia Cooperative Extension Recommendations (Wilson et. al., 2010). Conventionally tilled 'Bronco' snap beans were planted in 4 row plots that were 30 ft long and set on a 36" row spacing. The second row of each plot was mechanically harvested and pods were graded according to size. During the fall experiment, common rust (*Uromyces* *appendiculatus*) naturally occurred and spread due to cool and wet conditions. Disease was assessed by rating the percentage of infected leaf area using a visual rating at early bloom (James, 1971). The experiment was arranged in a randomized complete block design and replicated four times in a factorial arrangement of 5 N sources × 3 N rates + 2 S comparisons + a 0-N/S control. Data were analyzed using the SAS system and means separated using Fisher's protected least significant difference test (LSD) at $p = 0.10$ that was established *a priori*.

RESULTS AND DISCUSSION

Spring snap bean yield data did not have a significant N source × N rate interaction and was not significant by N rate; therefore, only N source will be discussed and data is averaged across N rate treatments (Table 1). Overall, it appears that most of the N applied was lost via leaching or denitrification. The 2009 Spring growing season was extremely wet (Fig. 1) and it is evident that fertilizer N was not present during the growing season since nearly all N source applications were statistically similar to the 0-N control (Table 1). The urea treatment that included DCD did have higher yields (5639 lbs/A) than the no-fertilizer control, AN, and UAN (4477, 4341, and 4219 lbs/A, respectively) (Table 1). Comparing the subset of data that included UAN, AN, UANS, ANS, and Sulf-N26 at 80 lbs N/A, no treatment was statistically different than the 0-N control. Generally, snap bean size distributions mirrored total yield regarding N source effects.

Fall snap bean treatments varied significantly from the Spring fertilizer trial. Similar to the Spring trial, the N source × N rate interaction was not significant and only main effects will be discussed. For N source, all treatments were statistically similar but higher than the 0-N control (4296 lbs/A), averaged across N rates (Table 2). No differences were observed between N sources regarding yield for sieve sizes 1, 2, 3, and 4, but CN, Sulf-N26, and UAN trended towards larger pods (size 5) than other sources (Table 2). For N rate, 80 lbs N/A was necessary for highest yields (7200 lbs/A), averaged across N sources (Table 3). Sulfur treatments were compared by comparison of a sub-set of data that was applied at 80 lbs N/A and 43 lbs S/A (Table 4). Overall, sulfur did not appear to be deficient in these soils as treatments without sulfur application were statistically similar to treatments that had sulfur applications. However, the sulfur containing Sulf-N26 fertilizer (5.7%) had significantly less leaf area infected with rust disease then the control, UAN, UDCD, and AN (22.5, 13.8, 11.8, and 11.4%, respectively) (Table 5).

CONCLUSION

Overall, the preliminary data indicate that DCD may increase snap bean yields by increasing N fertilizer use efficiency. In wet years, keeping N fertilizer in the ammonium form may increase sorption on the cation exchange complex and reduce leaching due to nitrate formation. Reduction of nitrate losses will reduce N fertilizer loading into groundwater that ultimately ends up in sensitive waterways such as the Chesapeake Bay. Sulf-N26 and CN are acceptable fertilizers for snap bean producers in the Mid-Atlantic utilizing sandy loam soils; however, they may not offer increased yields or fertilizer use efficiency over more common N sources such as UAN or AN when applied using current fertilizer regimens. Sulfur additions did not appear to significantly increase yield, but did reduce overall disease incidence. More research needs to be conducted concerning N source, N rate, and S fertilization for snap bean production systems and the economic and environmental benefits of using fertilizer additives such as nitrification inhibitors.

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TABLES AND FIGURES

Table 1. Spring snap bean total yield and yield passing each grade sieve size for various nitrogen treatments on the Eastern Shore of Virginia on a Bojac sandy loam, averaged across N rates.

	Snap Beans Passing Sieve Size			
Nitrogen Source	1, 2, 3	4	5	Total Yield
	---------	---------lbs/A---------	---------	---------
Control	1041 b†	1476 ab	1960 b	4477 b
Ammonium nitrate	1008 b	1105 b	1976 b	4341 b
Calcium nitrate	1089 b	1230 ab	2291 ab	5278 ab
Sulf-N26	1004 b	1226 ab	2408 ab	4638 ab
Urea ammonium nitrate	988 b	1150 ab	2081 b	4219 b
Urea + nitrification inhibitor	1363 a	1545 a	2731 a	5639 a

†Within each column, means followed by different letters are significantly different at *p*=0.10 and were separated using Fisher's protected least significant difference tests.

Table 2. Fall snap bean total yield and yield passing each grade sieve size for various nitrogen treatments on the Eastern Shore of Virginia on a Bojac sandy loam, averaged across N rates.

	Snap Beans Passing Sieve Size			
Nitrogen Source	1, 2, 3	4	5	Total Yield
	---------	---------lbs/A---------	---------	---------
Control	1476 b†	2432 b	387 c	4296 b
Ammonium nitrate	1920 a	3400 a	960 b	6280 a
Calcium nitrate	2033 a	3804 a	1291 a	7127 a
Sulf-N26	1952 a	3352 a	1085 ab	6389 a
Urea ammonium nitrate	1964 a	3864 a	1347 a	7175 a
Urea + nitrification inhibitor	1896 a	3666 a	980 b	6542 a

†Within each column, means followed by different letters are significantly different at *p*=0.10 and were separated using Fisher's protected least significant difference tests.

Table 3. Fall snap bean total yield and yield passing each grade sieve size for various nitrogen rates on the Eastern Shore of Virginia on a Bojac sandy loam, averaged across N sources.

	Snap Beans Passing Sieve Size			
Nitrogen Rate	1, 2, 3	4	5	Total Yield
	--lbs/A--			
0	1476 b†	2432 c	387 c	4296 c
40	1752 b	3158 b	796 b	5706 b
80	2018 ab	3937 a	1244 a	7200 a
120	2089 a	3756 a	1358 a	7202 a

†Within each column, means followed by different letters are significantly different at *p*=0.10 and were separated using Fisher's protected least significant difference tests.

Table 4. Fall snap bean total yield and yield passing each grade sieve size for various nitrogen treatments applied at 80 lbs N/A plus 43 lbs. S/A. Plots were located on the Eastern Shore of Virginia on a Bojac sandy loam.

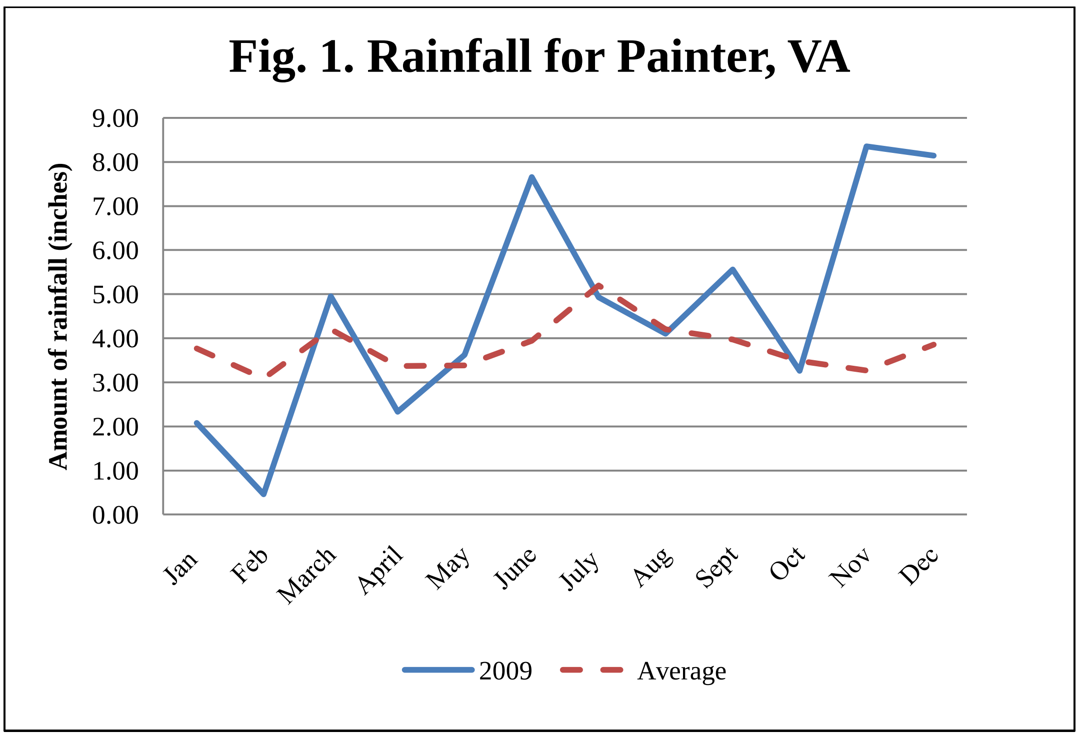
	Snap Beans Passing Sieve Size			
Nitrogen Source	1, 2, 3	4	5	Total Yield
	--lbs/A--			
Control	1476 b†	2432 b	387 a	4296 b
Ammonium nitrate	1960 b	3654 ab	1077 a	6691 ab
Ammonium nitrate + Sulfur	3468 a	4356 a	1307 a	8131 a
Sulf-N26	1670 b	3291 b	1029 a	5990 b
Urea ammonium nitrate	2118 ab	4392 a	1452 a	7962 a

†Within each column, means followed by different letters are significantly different at *p*=0.10 and were separated using Fisher's protected least significant difference tests.

Table 5. Fall snap bean disease incidence for various nitrogen sources on the Eastern Shore of Virginia on a Bojac sandy loam, averaged across N rates.

Treatment	Infected leaf area
	------%------
Control	22.5 a†
Ammonium nitrate	11.4 bc
Calcium nitrate	8.5 cd
Sulf-N26	5.7 d
Urea ammonium nitrate	13.8 b
Urea + nitrification inhibitor	11.8 bc

†Within each column, means followed by different letters are significantly different at p=0.10 and were separated using Fisher's protected least significant difference tests.



POTENTIAL USE OF *FGD* GYPSUM IN AGRICULTURE

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SUMMARY

The performance of conservation tillage management systems is, in large part, dependent upon practices that stabilize the soil surface, improve infiltration and soil water storage capacity, ameliorate soil acidity problems, and provide an adequate supply of essential plant nutrients. The application of lime and fertilizer amendments to the soil surface for this purpose in no-till systems can be less than adequate due to excess time required for slowly soluble agricultural lime to dissolve and improve soil surface properties to the extent that water and nutrients can more rapidly move into and down the soil profile. As an alternative amendment to agricultural lime, fluidized gas desulfurization (FGD) gypsum can be used due to its high calcium and sulfur contents, and its much greater solubility than agricultural lime.

ANNUAL NUTRIENT REMOVAL FROM HARVESTING VAUGHN'S HYBRID BERMUDAGRASS

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SUMMARY

Research was conducted on a Staser silt loam (Cumulic Hapludoll) on the Highland Rim approximately 30 miles north of Nashville (N 36° 28' and W 86° 50', elevation 217 m). Maintaining yield of hybrid bermudagrass (*Cynodon dactylon*) hay involves annual fertilization with a potassium containing fertilizer. Even though fertilization with potassium occurs at high rates, soil test levels declined because of luxury consumption and subsequent removal of forage from the field. Three years of data indicate that a different management strategy is needed for efficient use of potassium fertilizer. Forage potassium levels and thus removal increased with rates of fertilization but decreased at each level of fertilization as the season progressed. No increases in soil test levels of potassium were measured at any rate of fertilization in this experiment.

TILLAGE AND NUTRIENT SOURCE EFFECTS ON NITROGEN AVAILABILITY IN A SOUTHERN PIEDMONT SOIL

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ABSTRACT

Nitrogen availability in cropping systems using no-tillage (NT) and poultry litter (PL) may be different than in systems using conventional tillage (CT) and commercial fertilizer (CF). Water availability and organic matter contents can increase with NT and influence the rate of N mineralization and microbial demand for N. We evaluated the effects of tillage (NT and CT) and N source (CF and PL) on soil mineral N content and crop N uptake over two years for a corn (*Zea maze*) cropping system at the USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA. Nitrogen was applied at 150 lb ac^{-1} as NH_4NO_3 in the CF treatment and as 5 ton PL ac^{-1} in the PL treatment (to give the equivalent N rate assuming 50% mineralization). Mineral N in the top 4 inches was measured through the corn growing season using *in situ* undisturbed soil cores. Tillage treatment did not significantly influence the total amount of soil mineral N or its distribution during the growing season. The mean soil N content for the 120 day period was near 100 lb $acre^{-1}$ for both CF and PL treatments. Maximum mineral N content was greater for the CF treatment compared to the PL treatment (203 lb ac^{-1} vs. 153 lb ac^{-1}) but the peak amount occurred 5 days later for the PL treatment and the rate of decline following the peak was slower for PL. Tillage treatments did not significantly influence corn biomass accumulation but the amount of biomass produced was greater for the PL treatment compared to the CF treatment (13,669 vs. 10,600 lb $acre^{-1}$). Maximum biomass accumulation occurred at approximately 100 DAP in both treatments. The N content of the corn biomass was greater for the PL treatment compared to the CF treatment (159 vs. 120 lb $acre^{-1}$). Maximum accumulation of N occurred at 90 DAP in both treatments. Previous research from the site showed that NT and PL combined increased corn grain yield by 31% compared with CT and CF combined. Similarly, soil water was 18% greater in NT than CT in the 0- to 4-inch depth. From our data it appears that the distribution of N from PL is more favorable to corn N demand. The increased productivity from using NT and PL apparently comes from a synergistic effect of better growing season N availability from the PL and greater water availability with NT.

INTRODUCTION

Nitrogen management in cropping systems can be influenced by nutrient source and tillage management. Poultry litter is a valuable source of nutrients readily available in the Southeast due to the large poultry production industry. Using conservation tillage and cover crops with increased residue can increase soil water availability and increase soil organic matter over time due to increased soil quality. Both water availability and organic matter content can influence nutrient availability by influencing the rate of N mineralization and microbial demand for nitrogen during the residue decomposition process. We evaluated the effects of tillage (no-till and conventional) and nitrogen source (commercial fertilizer and poultry litter) on soil mineral N content and crop N uptake over two years for a corn cropping system at Watkinsville, GA in the Southern Piedmont.

MATERIALS AND METHODS

Experimental Site and Agronomics

The research was conducted in 2004 and 2005 on the instrumented water quality facility at the USDA-ARS J. Phil Campbell Sr. Natural Resource Conservation Center, Watkinsville, GA (83°24' W and 33°54' N). The facility has 12 large (30 x 100 ft) nearly level (<1.5% slope) plots with drainage tiles in a Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludults) (Bruce et al., 1983). Soil C is near 1.5 % at the surface (0 to 1 inch) but declines to 0.5 % below 2 inches. A majority of mineralized N therefore comes from the upper 0 to 4 inches. The research plots have been in a long term comparison of conventional tillage (CT) and no-tillage (NT) since the fall of 1991. Beginning in 1994 subplot treatments were changed from a comparison of fall planted cover crops to a comparison of spring applied commercial fertilizer (CF) and poultry litter (PL 3.3% N, 1.5% P, 2.7% K). This arrangement results in a factorial combination of treatments: CT-CF, CT-PL, NT-CF, and NT-PL arranged in a randomized complete block split-plot design with three replications, with tillage treatment as main and fertilizer treatment as sub plots. From 2001 to 2005 corn was grown and the fertilizer treatments were adjusted to meet the N demand of corn. A rye cover crop was planted in the fall and killed in the spring. Corn was planted April 12, 2004 and May 11, 2005 and harvested September 9, 2004 and October 20, 2005. Nitrogen was applied at a rate of 150 lb ac^{-1} as NH_4NO_3 in the CF treatment and as 5 ton PL ac^{-1} in the PL treatment to provide the equivalent N rate assuming 50% mineralization (Vest et al., 1994; CAES, 2007). Other agronomic activities followed routine regional practices.

Soil and Plant Sampling

Nitrogen mineralization during the corn growing season was determined using *in situ* undisturbed soil cores (4 inches height by 2 inches diameter) incubated for successive 3 week periods (Schomberg et al., 2006). Three cores were incubated at each of two locations in each plot for each three week period. The in situ cores are driven into the ground between crop rows. A mesh bag containing approximately 0.75 oz (vol) (15 g or 25 ml) of a 50:50 mixture of anion and cation exchange resins (Sybron Ionac ASB-1, C-249)[1] was placed in the lower 0.4 inches of the tube to capture NO_3^- and NH_4^+ that might leach from the soil. Six 1 inch by 4 inch (2.5 cm by 10 cm) soil samples were collected around the *in situ* cores to determine inorganic N content at the beginning of each incubation period. At the end of an incubation period, the core and resin bags were placed in separate zip lock plastic bags and transported to the laboratory. The soil and resin bags were extracted 1 M KCl and analyzed for NO3− and NH4+. New cores were established for the following incubation period. Soil bulk density, determined from core volume and soil mass, was adjusted for water content and used in converting data to an area basis. Aboveground biomass and N contents (including ears) were determined from 4 to 6 randomly selected plants per plot taken five times each in 2004 and 2005 at approximately 21 day intervals after planting. Biomass was dried for 3 to 5 days at 130 F, weighed, ground and analyzed for C and N using Near Infrared Spectroscopy.

Statistical Analysis

Statistical analysis was conducted SAS version 9.2 (SAS Inst. 2009). Mixed model analysis of variance was conducted with PROC MIXED. Replication, replication-by-tillage, and replication-by-tillage-by-fertilizer and year and its interactions with other fixed and random effects were treated as random effects in all analyses. Tillage, fertilizer source, and time (weeks or days after planting) were considered fixed effects. The BIC goodness of fit criterion was used to select the best fitting error model and structure for the analysis of variance. Unless otherwise indicated, all significant differences are given at $P \leq 0.10$. Nonlinear regression was used to estimate changes in soil and plant N contents over time using Proc Model. A logistic dose response peak function was fit to the data and differences among model parameters due to treatments were evaluated using a likelihood ratio test.

RESULTS AND DISCUSSION

Tillage treatment did not significantly influence the total amount or weekly amount of soil mineral N but there were differences between the two N sources (Fig 1). The amount of mineral N in the 0 to 4 inch soil depth increased during the first 30 days for both the CF and PL treatments. The mean soil N content for the 120 day period was similar for the CF and PL treatments (96 and 104 lb acre^{-1}, respectively). Maximum mineral N content in the CF treatments was estimated to be 203 lb ac^{-1} and occurred at 26 days after planting (DAP). Maximum mineral N content in the PL treatments was estimated to be 153 lb ac^{-1} and occurred at 32 DAP. The rate of decline of N appeared to be greater in the CF treatment compared to the PL treatment.

Corn biomass accumulation is shown in Fig 2. Similar to the results with the soil mineral N content tillage treatments did not significantly influence corn biomass accumulation. Nitrogen source did significantly influence the total amount of biomass produced during the cropping season. The amount of biomass produced was greater for the PL treatment compared to the CF treatment (13,669 vs. 10,600 lb acre^{-1}). Maximum biomass accumulation occurred at 98 DAP in the PL treatment and 102 DAP in the CF treatment but this was not different. Nitrogen concentration (%) was not influenced by any of the treatments and generally decreased over time (data not shown). The response for the N content of the corn biomass was similar to that of corn biomass (Fig 3). The amount of N in the corn biomass was greater for the PL treatment compared to the CF treatment (159 vs. 120 lb acre^{-1}). Maximum accumulation of N occurred at 90 DAP in both treatments.

Previously Endale et al. (2008) reported on yield and water relationships from this same study site for the years 2001 to 2005. They found that for the five years NT and PL increased grain yield by 11% and 18%, respectively, compared with CT and CF. Combined, NT and PL increased corn grain yield by 31% compared with CT and CF. Similarly, soil water was 18% greater in NT than CT in the 0- to 4-inch depth. Our results on mineral N in the upper soil profile provide further information about how PL is a more beneficial source of mineral N. From our data it appears that the distribution of N from PL is more favorable to corn N demand. It was surprising that we did not observe differences in soil mineral N content related to tillage even though Endale et al. (2008) showed greater water contents under NT compared to CT. The greater available water should increase N mineralization and N uptake but our data did not reflect greater amounts of mineral N in the NT treatment compared to the CT (based on the mean soil N content). One limitation to our approach is that we were only able to evaluate the upper 4 inches of soil. This is the depth of mixing of the N source in the CT treatment while in the NT treatments N sources were applied to the soil surface. This depth also is the area where most of the soil organic matter resides. In either situation (CT or NT) it appears that tillage had little impact on N availability and so the greater response of plant biomass in our study and yield reported by Endale et al. (2008) is probably a combined response due to better growing season N availability from the PL and greater water availability with NT which together produce a synergistic effect on corn production.

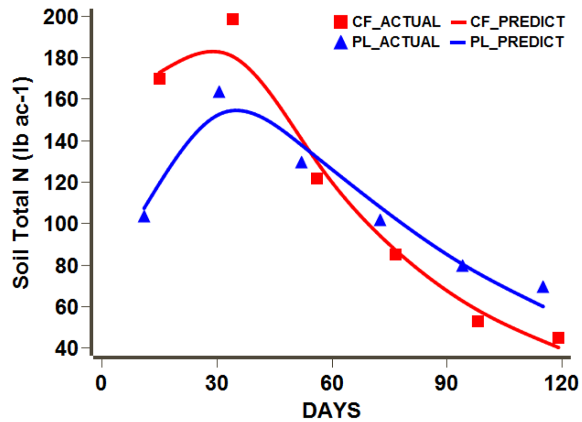

Figure 1. Influence of N source on soil total N content.

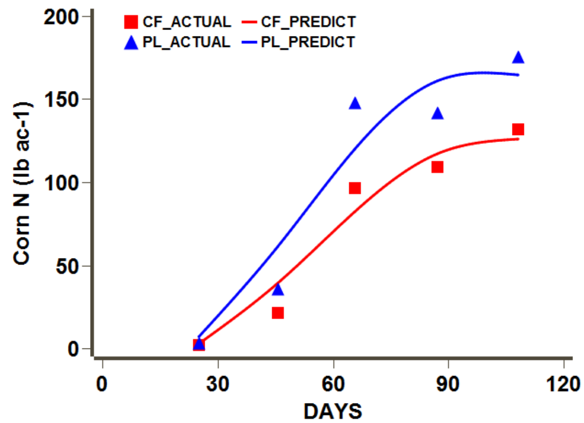

Figure 3. Influence of N source on corn N content.

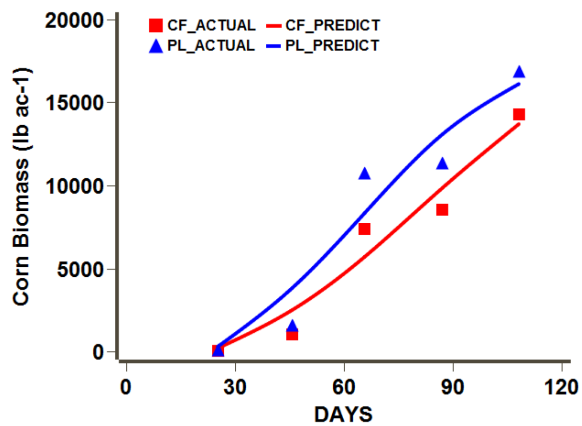

Figure 2. Influence of N source on corn biomass.

CONCLUSIONS

Our research indicates that a positive corn response to PL as a nitrogen source is related to a delay in peak N availability more so than a response to greater amount of N being applied. Availability of N from PL during the growing season apparently more closely meets the seasonal demand for N by corn in both CT and NT systems.

Acknowledgments

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IMPACT OF GLYPHOSATE–RESISTANT WEEDS ON NO-TILL ROW CROP PRODUCTION: SITUATION IN SOUTHERN US ROW CROPS

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SUMMARY

Six weed species have now been identified as glyphosate-resistant (GR) in the southern United States. *Conyza canadensis* (horseweed) is one of the six which was first confirmed in 2001 in a southern state and now is the most prevalent GR weed ranging from state of North Carolina to Arkansas. Two of the six are Ambrosia species: *A. trifida* (giant ragweed) and *A. artimisiifolia* (Common ragweed). Of these two *A. trifida* has proven to be the biggest problem in cotton and soybean production in fields adjacent to the Mississippi River in Arkansas and Tennessee. The most recently found GR weed species are *Sorghum halapense* (Johnsongrass) and *Lolium multiforum* (Italian ryegrass) which were confirmed in the southern U.S. states of Arkansas and Mississippi. The GR weed that is of most concern in the Southern U.S., due to it's competitive nature, is *Amaranthus palmeri* (Palmer amaranth).

In 2005, *A. palmeri* was found in Macon County, Georgia and two counties in North Carolina. In 2006 GR *A. palmeri* was found in three counties in Tennessee and one in Arkansas. Fast forward 4 and 3 years later respectively and GR *A. palmeri* has been identified in over 120 counties in 8 southern US states. The rapid spread of GR *A. palmeri* across the southern U.S. seems to have happened in a number of ways. First, field observations would indicate that spring floods moved GR *A. palmeri* seeds. Second, some GR *A. palmeri* could be found in fields where gin trash had been spread. Third, some GR *A. palmeri* field infestations appeared from their placement to have been mechanically moved by field equipment from field to field. However, no discernable pattern could be seen with some GR *A. palmeri* infestations. The recent research reported from Georgia that showed the GR trait in *A. palmeri* can be moved by pollen may help explain the spread to many of these fields.

The effect of the first GR weed, horseweed, was to reduce no-till cotton production by roughly 40% in 2005 and 2006. With the wide spread adoption of dicamba in a burndown program for horseweed help bring no-till cotton production back up to pre GR horseweed levels. History appears to be repeating itself with the recent outbreak of GR Palmer amaranth. Many cotton and soybean growers have reported increase in tillage to help manage GR Palmer amaranth. Some research has been conducted looking at cover crops as a tool to manage GR Palmer amaranth. Early results are encouraging and could help bring back some conservations tillage acres in fields with GR Palmer amaranth.

Early results are encouraging and could help bring back some conservations tillage acres in fields with GR Palmer amaranth.

EFFECTS OF CONSERVATION TILLAGE ON CROP YIELDS AS INFLUENCED BY CROP, REGION AND ENVIRONMENTAL FACTORS

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SUMMARY

Farmers are always looking for new ways to decrease costs and increase yields. No-tillage could be a viable option to help achieve this goal. No-tillage is a farm management practice where no tilling is done to the soil with seeds planted directly into the unprepared soil, and weeds and competing vegetation are controlled with herbicides (Phillips et al. 1980). No-tillage on many occasions has been found to have multi-faceted advantages. Some of those advantages include reduced fuel consumption, lowered maintenance and repair costs and lowered labor costs (Deen and Kataki 2003; Lankoski et al. 2004). No-tillage has also been found to reduce erosion, decrease moisture evaporation, sequester soil organic carbon and increased land use by being able to produce on highly erodible land (Lal 2004; Phillips et al. 1980).

Much research has been done as to how different methods of tillage affect crop yields. However, no clear consensus has been reached; many reports indicate higher yields with the use of no-tillage compared to conventional tillage (Endale et al. 2008; Smiley & Wilkins 1993; Wagger & Denton 1989). There are just as many reports stating the opposite (Graven & Carter 1991; Halvorson et al. 2006; Hammel 1995) as well as just as many stating there is no real significant difference in yields between conventional and conservation tillage (Archer & Reicosky 2009; Barnett 1990; Kapusta et al. 1996).

A review of literature indicates that an evaluation of the performance of conservation tillage yields relative to conventional tillage yields across the United States is needed to help better inform farmers if no-tillage is a good option for them. Therefore, the objective of this paper is to evaluate the impacts on mean crop yields of switching from conventional or reduced tillage practices to no-tillage as explained by factors such as time since conversion to no-tillage, crop, precipitation, soil texture and geographic region. This study evaluated the potential factors that influence differences in no-tillage and tillage crop yields. A dataset of paired tillage experiment from the *Soil & Tillage Research* journal was collected by Maithilee Kunda and Tristram West of the Oak Ridge National Laboratory (Kunda and West 2006). Of that data only the one's pertaining to the contiguous U.S. were used. Additional data was then collected from two other refereed journals, *Agronomy Journal* and *Journal of Production Agriculture*. These datasets allowed us to evaluate crop yield differences when comparing conventional and reduced tillage to no-tillage as explained by such factors as time since conversion from tillage to no-tillage, crop, precipitation, soil texture and geographic region. Data from corn, soybeans, cotton, oats, wheat and sorghum tillage experiments were incorporated in the analysis. The experiments were conducted across the United States, with data ranging from 1964 to 2005. Studies like this have been done before, for example DeFelice et al (2006), but their study only pertained to corn and soybeans with all experiments in the eastern United States. This study differs in that it

incorporates six different crops from all across the U.S. looking at many different variables like precipitation, soil texture, geographic region and time.

A meta-analytic approach was used to normalize the yields from each experiment which will make it possible to analyze more efficiently the paired experiments from the dataset (Miguez and Bollero 2005). This was obtained by creating a simple proportion of the strategy yield divided by the control yield. For example, the proportion was created by dividing the no-tillage yields by the conventional tillage yields.

The data were evaluated using PROC MIXED procedures. The results showed that when comparing conventional and reduced tillage yields to no-tillage yields, that no-tillage sorghum and wheat yielded more than conventional tillage sorghum and wheat, but no-tillage oats yielded less. One explanation for this could be the amount of residue left behind by each crop. Wheat and sorghum leave more residue on the ground than corn. Wheat averages 100 lbs. per bushel of grain of residue and sorghum averages 70-80 lbs. per bushel whereas corn only averages 60 lbs. per bushel (McCarthy et al. 1993; Smith 1986). Oats on the other hand leave a lesser amount of residue at only 50 lbs. per bushel; this could explain why its yields were less than corn (Hofman 1997). This result could imply to a certain extent that with no-tillage, the more residue left behind, the higher the yield since the more residue left behind would translate into less erosion and nutrient runoff, more water conservation and increased organic matter. This would fall in line with what Wilhelm et al. (1986) found. They found corn and soybean yields to be linearly related to the amount of residue on the surface. When residue was removed, yields decreased. Too little residue can result in stunted growth, stress and decreased yields caused from lack of soil water, poor canopy development and high surface temperatures (Doran et al. 1984).

The results also showed that soil texture plays a part in how well no-tillage performs, indicating no-tillage did not perform well under finely textured soils, such as silt, where no-tillage yields were 12% lower than conventional tillage. These results coincide with previous research that no-tillage performs better in coarse, well-drained soils, but does not produce as well under fine, poor-drained soils (DeFelice et al. 2006; Hairston et al. 1990). No-tillage crop yields were also found to perform better relative to conventional tillage yields in the Southern Seaboard ERS Farm Resource region which represents a good portion of the southeastern United States, but poorly in the Basin & Range region when both were compared to the Heartland region. All experiments that took place in the Basin & Range region were in the upper northwest corner of the United States. This coincides with previous studies that show no-tillage performs better than conventional tillage in the warm southern climates of the United States with conventional tillage performing better in northern climates (DeFelice et al. 2006). One possible reason for this is because of soil temperature. Colder temperatures coupled together with the crop residue left behind with no-tillage can delay crop emergence and development resulting in reduced yields (Halvorson et al. 2006). High amounts of precipitation resulted in lower no-tillage yields compared to conventional tillage. This corresponds with previous work that found no-tillage to perform better under dry conditions because of its moisture conservation ability, but did not perform as well as conventional tillage during cooler and wetter conditions (Eckert 1984; Herbek et al. 1986).

In conclusion, no-tillage could be a viable option to replace conventional tillage methods for a farmer. No-tillage yields relative to conventional tillage were higher in warmer, drier southern climates under a well drained coarse textured soil. A farmer’s decision to implement no-tillage should be on a case by case basis where factors such as precipitation, region, soil texture and crop are all considered.

DEVELOPING ORGANIC NO–TILL CROP PRODUCTION SYSTEMS FOR TENNESSEE

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SUMMARY

In organic row crop systems, weed management is a major challenge. Many organic growers continue to use tillage to control weeds. Tillage greatly increases soil erosion and other environmental impacts. Since 2008 a team from the University of Tennessee has been working on developing organic systems of no-till production for corn. This presentation will share some of the initial results on weed control and soil fertility management strategies being tested in the development of a suitable organic no-till system for Tennessee.

LONG-TERM TILLAGE AND POULTRY LITTER APPLICATION IMPACTS ON CROP PRODUCTION IN NORTHEASTERN ALABAMA

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ABSTRACT

Conservation tillage, manure application, and crop rotations are thought to increase yields compared to conventional monoculture (continuous cropping system without rotation) tillage systems. The objective of this study was to evaluate cropping sequences of corn with a wheat cover crop and corn with a wheat cover crop following a soybean rotation in conventional, strip, and no-tillage systems with poultry litter additions to the wheat cover crop. Thus, a field study was conducted at the Sand Mountain Substation in the Appalachian Plateau region of Northeast Alabama, USA, on a Hartselle fine sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults). In 1980, the corn cropping systems were initiated with three different tillage treatments (conventional, strip, and no-tillage). Poultry litter treatments were added in 1991. Poultry litter was applied in the fall of each year to the wheat cover crop at a rate of 50 lb N acre^{-1}. Wheat not receiving poultry litter received an equal amount of inorganic N. The corn crop was fertilized in the spring with 50 lbs N acre^{-1} at planting followed by 150 lbs N acre^{-1} applied approximately 3 weeks following emergence. Corn grain yields were influenced by tillage in 1991, 1992, 1993, 1994, 1996, 1997, 1998, and 2001 with conventional tillage producing the greatest yields except in 1993 (strip tillage) and 2001 (no-till). Increases in grain yield from poultry litter addition were observed in 1991, 1997, and 1998. Crop rotation increased corn grain yield in all years except 2001. Corn crops following soybean rotation provided the most consistent yield increase for the 9 yr study. Thus suggesting, crop rotations should be implemented into corn production systems in order to produce sustainable crop production.

INTRODUCTION

Adoption of conservation tillage systems has increased during the last two decades. These practices can increase surface organic matter (Edwards et al., 1988), which increases the level of macronutrients (Ca, P, K, and Mg) and micronutrients (Mn, Zn, and Cu) (Edwards et al., 1992, Watts et al., 2010) in soil. Also, less soil disturbance under conservation tillage systems improved soil physical properties, which increases water infiltration, water retention, soil aggregates, and decreases bulk density. Conservation tillage has been shown to improve soil structure and fertility while resulting in increases in crop yield (Triplett and Dick, 2008).

Poultry litter utilization has also been shown to increase SOM and yield (Nyakatawa et al., 2000a and Nyakatawa et al., 2000b). Alabama is one of the leading states in the US in broiler production (Reddy et al., 2008). The resulting broiler litter can serve as a relatively inexpensive source of nutrients for row crop production (Nyakatawa and Reddy, 2002).

Crop rotation can also increase yields. For instance, crop rotations can provide better weed control, interrupt insect and disease cycles, and improve crop nutrient use efficiency (Karlen et al., 1994). When grown in rotation, corn grain yields were 10 to 17% greater than under continuous corn (Higgs et al., 1990). Significant yield increases for corn grown in rotation have also been observed in experiments where N, P, and K soil test levels were high and pest populations were managed (Copeland and Crookston, 1992). Thus, crop rotations can have a positive influence on yield.

Few studies have investigated crop rotation and manure/litter application under conservation tillage systems in the southeastern United States. However these studies have typically been evaluated in 2–5-yr studies (Nyakatawa et al., 2001; Balkcom et al., 2005; Tewolde et al., 2008). Evaluation of long-term studies is vital for examining the sustainability of cropping or land management systems (Greenland, 1994). For instance, long-term studies allows for better evaluation of how year to year variability in environmental factors will impact crop yields (Grover et al., 2009). The objectives of this study were to determine the impact of tillage, poultry litter application, and crop rotation has on corn grain yield during 9 growing seasons.

MATERIALS AND METHODS

Site Description

The study was initiated in fall of 1979 at the Sand Mountain Research and Extension Center in the Appalachian Plateau region of northeast Alabama near Crossville, AL (34°18’N, 86°01’W). The soil was a Hartsells fine sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults). Climate in this region is subtropical with no dry season; mean annual rainfall is 52 inches, and mean annual temperature is 61ºF (Shaw, 1982). Prior to initiation of field study in 1980, the site had been under intensive row crop production for more than 50 years.

Experimental Design and Treatments

The experiment was a split-split plot design with a randomized complete block arrangement of three tillage treatments (initiated in 1980), two crop rotations (continuous corn and corn soybean rotation) and two fertilization treatments (initiated in 1991) for which there were four blocks. The main plots were tillage, the split plots were rotations, and the split-split plots were fertilization. The cropping system was a corn (*Zea mays* L.) system. Each plot consisted of four rows with 3ft spacings. The tillage treatments consisted of conventional tillage (CT; moldboard plow and disking followed by rototiller in the spring), no-tillage (NT; planting into crop residue with a double disk-opener planter), and strip tillage (Planting behind a strip till shank to a 1ft depth). Rotation treatments were continuous corn-wheat cover, corn-wheat cover-soybean-wheat cover, and soybean-wheat cover-corn-wheat cover. The rotational treatments alternated each year in order to evaluate the impact crop rotation had on corn yield each year. Corn was planted each year in mid April after the wheat cover and harvested in mid September for grain yield.

At planting in the fall, 50 lbs N acre^{-1} as NH_4NO_3 and poultry litter was applied to wheat. Corn received 50 lbs N acre^{-1} at planting and an additional 150 lbs N acre^{-1} as NH_4NO_3 (no poultry litter was applied to corn) 2 to 3 wk after emergence. No fertilizer was applied to the soybean plots. Both poultry litter and NH_4NO_3 were surface broadcasted by hand. Dolomitic lime and KCL (0-0-60) were applied in the fall according to Auburn University Soil Test recommendations. Lime and K application rates varied across years, but all plots received the same amount when applied. The middle two rows were harvested for grain yield using a combine and moisture adjusted to 150 g kg^{-1}.

Statistics

The experimental design was a split-split plot design with four replications. Tillage was the main plot, rotation was the split plot, and litter vs. no litter was the split-split plot. Corn grain yield analysis was performed using the Mixed procedure of SAS (Littell et al., 1996). A significance level of $P < 0.10$ was established.

RESULTS AND DISCUSSION

Corn grain yields were significantly increased by rotation in all years except 2001. Although, no significant differences we observed in 2001, rotating the crops increased grain yields compared to yields without a rotation. Significant corn grain yield increases in 8 out of the 9 years evaluated which suggests that crop rotations are needed in corn production systems to increase and maintain sustainable yields. Addition of poultry litter to the wheat cover crop significantly influenced corn yields in 1991, 1997, and 1998. Although not significant, poultry litter addition increased grain yields in 7 out of the eight years. Tillage significantly influenced corn yield in 1991, 1992, 1993, 1994, 1996, 1997, 1998, and 2001. In the eight years that tillage was significantly different, conventional tillage produced the highest yields 6 out of the eight and no-tillage and strip tillage both had the highest yield 1 year. There was a significant tillage x litter effect in 1992 and 1998, with conventional tillage with poultry litter producing the highest grain yields. Overall, crop rotation had the greatest impact on corn grain yields as evidenced by a more consist impact on yield compared to tillage and litter application.

CONCLUSIONS

Results from this study show that crop rotations are very important in corn production systems in the Southeast. Corn rotation with soybean had the most consistent increase in yield compared to continuous corn without a rotation. Corn grain yield response was greater with crop rotation compared to tillage and poultry litter application. Although less effective than crop rotation, poultry litter addition had a positive impact on corn grain yield.

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Table 1. Effects of tillage, poultry litter applicaton, and crop rotation on corn yields for 1991 through 2001.

						Yield of Corn					
Tillage system	fertilzer treatment	1991	1992	1993	1994	1995	1996	1997	1998	2001	9 yr mean
						Continuous corn					
No tillage	litter	6627.4	7780.15	3638.24	7528.47	4492.27	5250.91	6565.45	1968.05	12690.25	6282.354
	no litter	4974	9142.28	22997.23	7837.59	5090.97	5114.76	5038.33	2200.03	10894	8143.243
Strip tillage	litter	5039.63	9154.06	4582.75	5946.82	6078.27	6078.27	6519.03	2980.19	10004.76	6264.864
	no litter	4492.17	8308.68	4099.67	6433.32	5651.45	5618.18	5573.15	3071.77	9046.6	5810.554
Conventional tillage	litter	6847.42	9677.79	3354.24	8131.68	6038.03	8148.1	8383.38	6235.43	10749.86	7507.326
	no litter	5558.2	8370.98	3750.81	8104.13	5920.41	8472.99	6750.74	5741.17	11508.44	7130.874
						Corn-soybean rotation					
No tillage	litter	5971.86	6258.57	4701.07	7573.29	6675.01	7880.33	6748.05	6744.79	13152.32	7300.588
	no litter	5636	8833.8	4520.83	7956.37	6560.66	7390.11	6874.99	5877.01	11646.74	7255.168
Strip tillage	litter	6400.72	10894.39	6414.62	8400.26	6788.94	8179.66	8451.15	6867.21	12190.77	8287.524
	no litter	5661.97	11196.8	4884.1	7596.98	7158.51	7358	8511.61	5241.28	10687.86	7588.568
Conventional tillage	litter	7019.04	11082.01	4544.82	9194.6	6407.52	9509.98	8776.9	7594.77	10409.21	8282.094
	no litter	6474.46	10881.15	4240.54	8228.12	6116.94	9317.62	7512.95	7009.61	9393.89	7686.142
LSD (0.10) Tillage (T)		0.0651	0.0050	0.0745	0.0350	0.3518	<0.0001	0.0218	<0.0001	0.1085	
LSD (0.10) Rotation (R)		0.1007	0.0116	0.0082	0.0413	0.1090	<0.0001	0.0041	<0.0001	0.5380	
LSD (0.10) Fertilizer (F)		0.0255	0.4594	0.2719	0.7967	0.9938	0.2052	0.0560	0.1037	0.0156	
LSD (0.10) Cover x Tillage		0.3992	0.1779	0.6036	0.3721	0.9704	0.6892	0.2559	0.1995	0.6280	
LSD (0.10) Cover x Litter		0.3775	0.0060	0.8693	0.2041	0.3518	0.1890	0.2068	0.1000	0.1917	
LSD (0.10) Tillage x Litter		0.9186	0.0275	0.5795	0.6865	0.9001	0.4156	0.6253	0.8858	0.6542	
LSD (0.10) Rotationx Tillage x Litt		0.6988	0.9986	0.8693	0.7689	0.7388	0.8897	0.8360	0.6529	0.8303	

PROSPECTS FOR MONITORING COTTON CROP MATURITY WITH NDVI

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ABSTRACT

Cotton (*Gossypium hirsutum* L.) producers monitor crop maturity during the season to determine when to terminate crop inputs and to defoliate. We conducted a 4-year study in Tennessee to evaluate the suitability of the Normalized Difference Vegetation Index (NDVI) for monitoring cotton crop maturity. Maturity was varied by treatments that included nitrogen fertilization rates of 0 and 90 lb N/ac, and cover crops of winter wheat (*Triticum aestivum* L.) and hairy vetch (*Vicia villosa* L.). Crop maturity was estimated by heat-units accumulated from planting to open boll. Relative to zero N, boll opening was delayed by 90 lb N/ac in 3 yr. Cover crop effects on maturity were inconsistent. Canopy NDVI data were collected after mid-bloom with a hand-held GreenSeeker sensor. Significant date-by-treatment interactions indicated potential to detect maturity differences, but NDVI time courses obtained in different years were dissimilar. Late-season NDVI was positively correlated with degree-days to open boll in 3 yr. Relationships between changes in NDVI and maturity did not provide a simple basis for predicting maturity and readiness for defoliation. Improved NDVI sensors are needed for this purpose.

INTRODUCTION

Cotton producers monitor the maturity of their crops as the season progresses, in order to plan late-season defoliation and harvest operations. Prediction of crop readiness for defoliation and harvest facilitates the scheduling of operations in different fields. One management tool that monitors earliness and predicts crop readiness for defoliation is the COTMAN system (Oosterhuis et al., 1996). Data collection for COTMAN is relatively laborious and time consuming, however, and more efficient methods of crop monitoring are needed.

The advent of precision agriculture has increased interest in remote methods of crop monitoring. A common type of remote sensing data is the Normalized Difference Vegetation Index (NDVI), which indicates crop biomass and condition from the relative amounts of near-infrared (NIR) and visible light reflected from the canopy (Plant et al., 2001). It is calculated as the difference between NIR and visible light reflectance, divided by the sum of the two reflectances. Plant et al. (2001) concluded that remote NDVI sensing was useful for detecting spatial patterns in a field, but not as useful in measuring changes over time, due to changes in solar radiation and other environmental factors with time. This constraint was thought to be alleviated with the introduction of "active" sensors deployed in relatively close proximity (<4 ft) to the canopy. Because active sensors emitted pulses of NIR and visible light and detected their reflection from the canopy, they were considered to be insensitive to changes in background solar radiation (Schepers, 2008; NTech Industries, 2009).

Most research on use of active NDVI sensors in row crops has been directed towards site-specific detection and remediation of N deficiency early in the growing season (Samborski et al., 2009). Lower NDVI values of N-deficient cotton are associated with lower plant biomass and leaf area, relative to cotton with sufficient N (Li et al., 2001). Earlier studies had shown that flowering of N-deficient cotton cut out earlier than cotton with sufficient N, while higher N rates delayed maturity (McConnell et al., 1995). Hutchinson et al. (1995) reported that N rates that optimized yield resulted in slightly later maturity than lower N rates, but excessive N resulted in significant maturity delay with no additional yield.

Residue from a winter cover crop can modify cotton response to fertilizer N. Hutchinson et al. (1995) observed that N-deficient plants showed visible chlorosis by the first week of bloom, especially following wheat cover with no fertilizer N. Cotton with sufficient N following native vegetation or wheat, and cotton with zero N following vetch, began to show visible leaf chlorosis about 40-45 days after first bloom. Excessively fertilized plants remained dark green until defoliation. Larson et al. (2001) showed that cotton yield after vetch and no fertilizer N was as high as cotton after no cover and 74 lb N/ac, or cotton after wheat and 87 lb N/ac, with no tillage. However, Larson et al. (2001) did not investigate N or cover effects on crop maturity.

Temporal patterns of NDVI reflectance were studied over a cotton growing season with a passive sensor (Li et al., 2001). Maximum leaf area and NDVI occurred about 15 August and declined thereafter. As the crop matured in September, red reflectance increased but NIR reflectance decreased, reducing NDVI. Late-season leaf senescence also reduces leaf chlorophyll content, revealing accessory leaf pigments such as carotenes and xanthophylls (Pinter et al., 2003). The net effect is to decrease NDVI of leaves during senescence.

If changes in plant biomass and leaf senescence due to N status can be detected by proximal sensing of canopy NDVI, then crop progress towards maturity may be monitored by analyzing changes in NDVI with time. Objectives of this field study were to determine the effects of N fertilization and cover crop residue on crop maturation, and to evaluate the suitability of NDVI for monitoring crop maturity as influenced by N and cover crop residue.

MATERIALS AND METHODS

The suitability of NDVI for monitoring crop maturity was evaluated in a long-term field study of tillage regime, N fertilization, and cover crop effects on cotton at the West Tennessee Research & Education Center, Jackson TN. The underlying experiment was described by Larson et al. (2001). The soil was a non-irrigated Memphis silt loam (Typic Hapludalf). The field was planted to ‘DP451BR’ on 18 May 2005, to ‘DP455BG/RR’ on 17 May 2006, to ‘ST4554B2RF’ on 10 May 2007 and 21 May 2008 in 38-inch rows. Cotton was managed by following UT Extension guidelines. Treatments reported here were combinations of winter cover crop (wheat or hairy vetch) and N fertilization (0 or 90 lb/ac), applied annually to designated no-tillage plots. Nitrogen rates were main plot treatments and covers were subplot treatments in a RCB split-plot design with four replications. Nitrogen was broadcast to designated plots as ammonium nitrate between 12 and 28 days after planting (DAP) each year. Winter cover crops and native vegetation were killed prior to cotton planting, and re-seeded after cotton harvest each year.

Canopy NDVI data were collected from the center rows of each plot using a GreenSeeker hand-held red/NIR sensor (Model 505, NTech Industries, Ukiah CA). The sensor head was suspended by telescoping boom over the center of each row, oriented vertically at 30 to 36 in. above the top of the canopy. Light emitting diodes in the sensor generated red (656 nm) and NIR (774 nm) light (NTech Industries, 2009). The light generated was reflected from the crop and measured by a photodiode in the sensor head. NDVI data were collected weekly from mid-bloom (69 to 78 DAP) until early boll opening (112 to 118 DAP) each year. Additional details about NDVI data collection in this study were reported by Gwathmey et al. (in press).

About 20 white flowers blooming at a reference fruiting site (five nodes above white flower; NAWF=5) were flagged in each plot. Dates of boll opening at the flagged fruiting sites were recorded. Accumulation of ambient heat-units were measured as degree-days, base 60°F, calculated from daily maximum and minimum air temperature data from a nearby NOAA weather station. The number of heat-units accumulated between planting and boll opening estimated the total crop maturation period in each plot.

After defoliation each year, the two center rows of each plot were harvested with a JD9930 cotton picker. Seedcotton harvested from each plot was weighed at picking. Gin turnout was determined for each treatment sample using a 20-saw gin assembly. Lint yields were calculated from seedcotton weights, gin turnouts, and plot areas harvested.

The NDVI data collected each year were analyzed with the Mixed procedure of SAS 9.2, with observation date as a repeated measure on subplots of N fertilization and cover crops. Other data were analyzed with the GLM procedure of SAS with fixed effects for each year of the study. Where F-tests indicated significant differences, least square means were separated at p=0.05 by independent pairwise comparisons (pdiff).

RESULTS AND DISCUSSION

Heat-unit accumulation was fairly similar in the four years of the study, but rainfall accumulation differed markedly between years. Several large storms in 2005 contributed to higher seasonal rainfall accumulation than in other years. Two drought episodes occurred between 65 and 115 DAP in 2007, accompanied by relatively high average air temperatures.

Year-to-year differences in cultivar, rainfall, and plant growth regulation resulted in differences between years in cotton plant height. Effects of N fertilizer and cover crop residue on plant height were fairly consistent (Table 1). Across cover crops, 90 lb N/ac increased plant height by 17 to 33%, relative to zero N (p<0.06). Across N rates, vetch residue increased plant height by 8 to 19%, relative to wheat (Table 1). Lint yields responded to treatment in most years, but not in 2007 because of heat and drought effects. Across cover crops, 90 lb N/ac increased yields by 22 to 31%, relative to zero N in 2005, 2006, and 2008 (p<0.08). Across N rates, vetch residue increased lint yields by 15 to 38% in those three years, relative to wheat (p<0.07) (Table 1).

Heat-unit accumulation from planting to open boll at the NAWF=5 fruiting site showed N and cover effects on crop maturity (Table 1). In three of four years, N fertilization delayed cotton maturity by 12 to 102 DD60, relative to zero N (p<0.05). Cover crop had relatively small influence on earliness of maturity. Nitrogen and cover effects on crop maturity were generally consistent with Hutchinson et al. (1995) and McConnell et al. (1995).

Date of observation was the predominant source of variance for NDVI in each year (data not shown). Main effects of N were significant in all except 2006, but cover effects were significant in all years. There were significant date-by-N interactions in three years, and date-by-cover interactions two years. Date-by-treatment interactions indicate that treatments differed in NDVI change with time, which may be useful in detecting treatment effects on maturity.

In a general sense, time courses of NDVI in 2005 and 2006 showed similar patterns consisting of a mid-season plateau followed by a late-season decline as the crop matured (Fig. 1). The late-season decline started ~180 DD later in 2006 than 2005, but once started, NDVI continued to decline until ~2000 to 2050 degree-days after planting (DDAP) each year. Time courses of NDVI in 2007 and 2008 (Fig. 1) showed different patterns than in 2005 and 2006. The main dissimilarity was an unexpected rise in NDVI values in late season. In 2007, NDVI values rose significantly at 2128 DDAP, before decreasing to the lowest levels observed in 2007, at 2284 DDAP. The peak at 2029 DDAP in 2008 represented the highest NDVI values observed for each treatment in that year. By the following week, however, NDVI values decreased for all treatments to levels similar to those observed 1810 and 1928 DDAP (Fig. 1). Mean separation of data points shown in Figure 1 were reported by Gwathmey et al. (in press).

The late-season NDVI peaks recorded in 2007 and 2008 occurred in all treatments, and they did not persist. Thus it seems less likely that they were caused by changes in crop condition or biomass than by variation in NDVI sensor performance or environmental conditions, relative to other dates of observation. Regarding stability of sensor performance, the manufacturer estimated NDVI variation to be ±0.02 for >500 h of sensor operation at optimal height (28 to 44 in) above canopy (NTech Industries, 2009). Differences between the late-season peaks observed in 2007 and 2008, and NDVI data collected one week before and after these peaks, were two to six times larger than this specification. There was no indication of instrument malfunction on these dates. Regarding environmental influence, Oliveira (2008) found that the GreenSeeker sensor was sensitive to solar time, air temperature, and solar irradiance. Allen et al. (2009) also reported strong negative linear relationship between GreenSeeker NDVI and ambient radiation intensity. Variation in NDVI observed in the present study is consistent with Oliveira (2008) and Allen et al. (2009).

Significant linear correlations were found between mean of NDVI values collected >1800 DDAP in each plot, and heat-units accumulated between planting and boll opening (Fig. 2). In these years, maturity was delayed by about 60 to 120 DD60 for each 0.1 unit increase in mean NDVI. The exception occurred in 2006, when the relatively short stature of the crop resulted in early cutout of flowering and relatively small differences in crop maturity (Table 1). In 2007, delayed flowering at NAWF=5, along with high temperatures in late season, elevated cumulative DD60 to boll opening. Despite these relationships between NDVI and crop maturity, the NDVI data do not provide a simple basis for predicting maturity and readiness for defoliation. For practical value, maturity prediction should occur sufficiently early in the season to influence defoliation and harvest management. Treatment differences in NDVI corresponding to maturity differences appeared between 99 and 112 DAP in 2005-07, just 3 to 32 d before bolls opened at the NAWF=5 fruiting site, and 15 to 39 d before harvest aids were applied each year.

These results also underscore the need for a new generation of multispectral sensors specifically designed for monitoring row crops. Ideally, sensors designed for monitoring of crop maturity would estimate the plant senescence reflectance index, based on difference in reflectance at 678 and 500 nm (Merzlyak et al., 1999). A sensor system that measures reflectance from lower leaves, from an oblique angle would be more likely to detect leaf senescence earlier than a nadir-oriented sensor over the row, and thus monitor crop maturity more effectively.

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Table 1. Cotton plant height, lint yield, and cumulative degree-days (DD60) from planting to open boll at the NAWF=5 fruiting site, as affected by N fertilizer and cover crop residue at Jackson, TN, 2005-2008, and *p*-values of F-tests.

Year	N rate	Cover crop	Plant height[†]		Lint yield		Degree-Days, planting to open boll	
	lb/ac		in.		lb/ac		DD60	
2005	0	Wheat	29	c[‡]	670	b	2211	b
	0	Vetch	36	b	1024	a	2216	b
	90	Wheat	42	a	1035	a	2296	a
	90	Vetch	44	a	1028	a	2335	a
	p (N-rate)		0.009		0.075		0.003	
	p (Cover)		0.013		0.006		0.337	
	p (N-by-cover)		0.119		0.005		0.448	
2006	0	Wheat	20	c	672	b	2042	b
	0	Vetch	25	b	1226	a	2039	b
	90	Wheat	27	b	1165	a	2049	ab
	90	Vetch	30	a	1316	a	2055	a
	p (N-rate)		0.057		0.059		0.019	
	p (Cover)		0.003		0.001		0.670	
	p (N-by-cover)		0.255		0.008		0.180	
2007	0	Wheat	28	c	513	a	2354	c
	0	Vetch	34	b	524	a	2378	bc
	90	Wheat	34	b	460	a	2460	a
	90	Vetch	37	a	484	a	2420	ab
	p (N-rate)		0.059		0.565		0.008	
	p (Cover)		<0.001		0.595		0.562	
	p (N-by-cover)		0.016		0.842		0.049	
2008	0	Wheat	32	c	892	b	2219	a
	0	Vetch	36	b	1178	a	2243	a
	90	Wheat	42	a	1262	a	2274	a
	90	Vetch	44	a	1303	a	2286	a
	p (N-rate)		0.003		0.049		0.119	
	p (Cover)		0.021		0.012		0.067	
	p (N-by-cover)		0.443		0.037		0.504	

[†] Measured at 97 DAP in 2005, 76 DAP in 2006, 92 DAP in 2007, and 77 DAP in 2008.
[‡] Letters separate means within groups at p=0.05 by independent, paired comparisons (pdiff) in SAS Proc GLM.

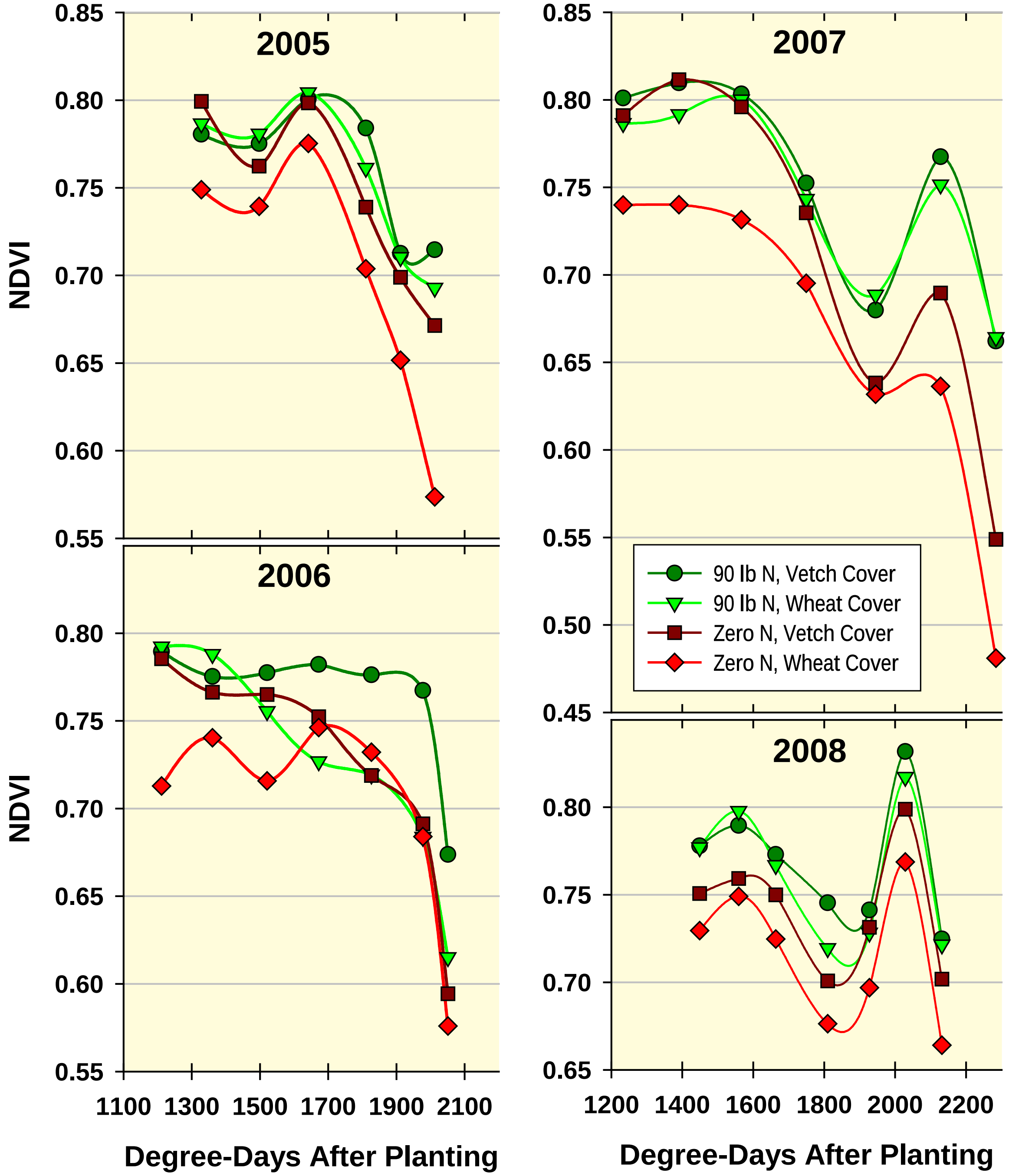

Figure 1. Changes in Normalized Difference Vegetation Index (NDVI) of the cotton canopy with heat-unit (DD60) accumulation, as influenced by two levels of N fertilization and two cover crop residues, Jackson, TN, 2005-2008.

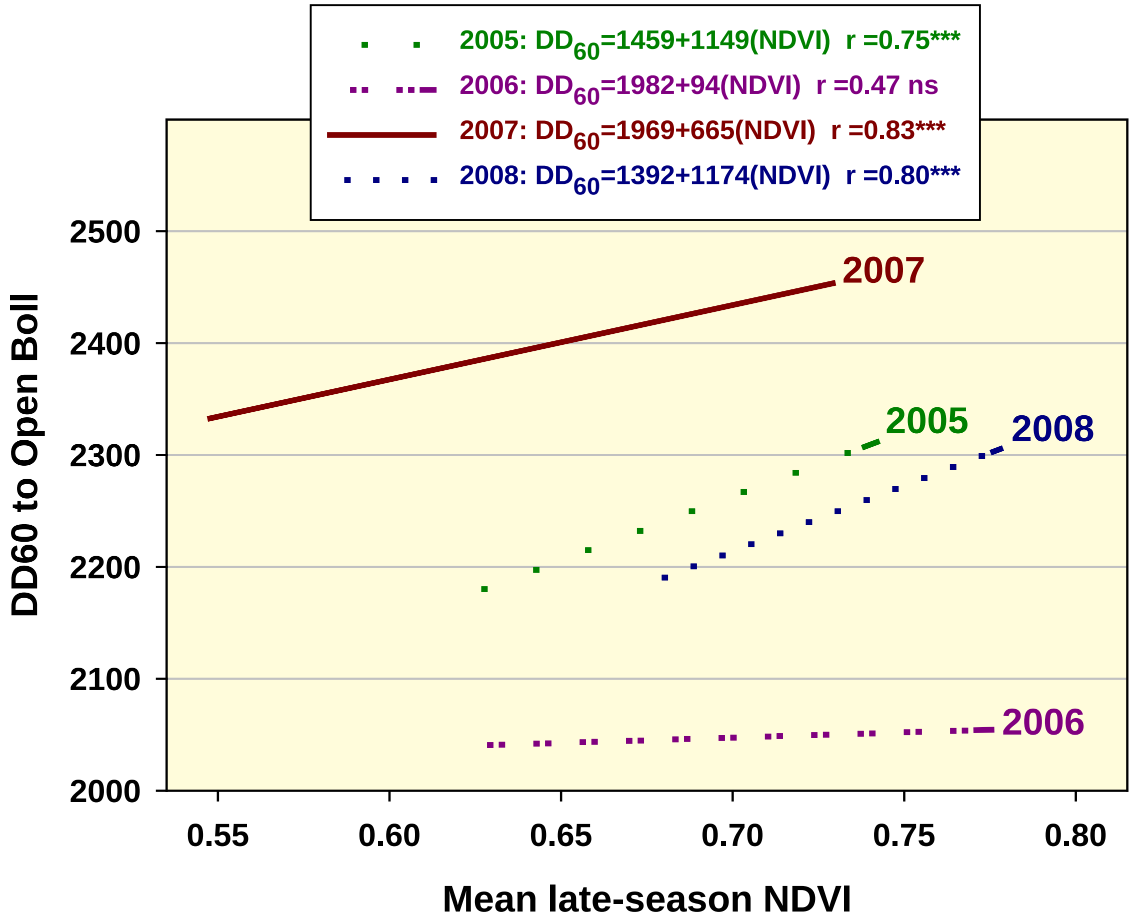

Figure 2. Linear relationships between late-season Normalized Difference Vegetation Index (NDVI) and degree-days (DD60) from planting to open boll at the NAWF=5 fruiting site, Jackson, TN, 2005-2008. NDVI data were collected >1800 DD60 after planting. For each regression, n=16.

USING NDVI AS A PREDICTOR OF COTTON PLANT HEIGHT FOR REAL–TIME SENSOR–BASED VARIABLE RATE APPLICATION OF GROWTH REGULATORS

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SUMMARY

Variable rate application of growth regulators could be a cost cutting means for cotton producers. One proposed method for variable rate application is using crop sensors to estimate cotton height and excessive growth. Small plots in Oklahoma and Tennessee were used to determine the relationship between the normalized difference vegetative index (NDVI) measured with sensors and plant height. The relationship between NDVI measured with optical sensors and plant height was evident early in the growing season. However NDVI and plant height lose correlation as the plant matures and the crop canopy begins to close.

CHANGES IN TOTAL SOIL ORGANIC CARBON AS AFFECTED BY CROPPING SEQUENCE AND BIO-COVER UNDER NO-TILL PRODUCTION

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ABSTRACT

The rate of soil carbon storage in no-till farmland is uncertain due to still unknown environmental and crop production effects. The objective of this experiment is to compare changes in total soil organic carbon (SOC) due to different cropping systems under no-tillage production. A split-block treatment design with four replications was used at the Research and Education Centers at Milan (RECM) and Spring Hill (MTREC). The whole-block treatment consisted of cropping sequences of corn, soybeans, and cotton. *The split-block was* bio-covers using winter wheat, hairy vetch, poultry litter, and fallow. Cropping sequences are conducted in 4 yr phases (Phase 1, 2002-2005; 2, 2006-2009; 3, 2010-2013). SOC was measured at the surface (0 - 5 cm) and subsurface (5 - 15 cm) in 2002 and after two and four years of experimentation for Phase 1. Overall, both sites showed small but consistent loss in SOC over all treatments during the first two years. After four years, SOC began to recover. Sequences with high frequencies of cotton lost significantly more SOC than others in the surface and subsurface regions. Plots under the poultry litter bio-cover lost less surface SOC (0.58 Mg ha^{-1}) than those under vetch (1.33 Mg ha^{-1}) or fallow 1.8 Mg ha^{-1}). Vetch under sequences high in soybean tended to lose less carbon than in sequences frequently planted with cotton or corn. Soil samples were collected after eight years of cropping sequences/bio-covers (2010); however data analyses have not yet been completed.

CONSERVATION TILLAGE IMPROVES SOIL PHYSICAL PROPERTIES ON DIFFERENT LANDSCAPE POSITIONS OF A COASTAL PLAIN SOIL

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ABSTRACT

Improved crop management is necessary due to raising production costs and environmental concerns. Spatial variability of soil physical properties can significantly affect management approaches. A study was established in 2007 to determine the effect of management practices and landscape variability on selected soil quality parameters (infiltration, aggregate stability and total C) of a 22 acre field located in the central Alabama Coastal Plain. The field was divided into three zones - summit, backslope and accumulation, using elevation, electrical conductivity and traditional soil survey data. Four management systems - conventional system with (CT+M) or without (CT) dairy manure, and conservation system, consisting of strip-tillage and a winter cover crop, with (ST+M) or without (ST) dairy manure – were established on a corn (*Zea mays* L.)-cotton (*Gossypium hirsutum* L.) rotation in 2001. Infiltration, aggregate stability and C content were generally lower in CT. Manure significantly increased the C content ($P \leq 0.001$), with an overall 62% increase in soil C content when manure was applied to CT, and 39% greater when applied to ST. Infiltration was greatest on the summit (5.7 in/h), followed by backslope and accumulation zones (3.4 and 2.8 in/h, respectively). No significant differences ($P = 0.69$ and 0.39, respectively) were found for aggregate stability and carbon between zones. Conservation tillage improved water infiltration and increased soil C content, whereas manure has only increased soil C content.

INTRODUCTION

Soil physical properties affect water and chemical movement in the soil and can have a significant impact on crop productivity and the environment. Certain landscapes can have significant differences in soil physical properties due to spatial variability and can be the major cause of spatial variability in crop yields (Terra et al., 2005). Topography is a significant factor for soil differentiation (Jenny, 1941). Conventional tillage practices in areas with steep slopes can lead to erosion and soil degradation. Additionally, nutrient distribution within a soil profile can change with landscape position (Balkcom et al., 2005). Another important factor is the spatial distribution of soil C, since soil C can significantly affect soil chemical and physical properties. Landscape position plays an important role in C sequestration (Terra et al., 2005). Conservation tillage practices, such as non-inversion tillage (strip-tilling), can benefit production systems of southeastern United States. Conservation systems that include strip-till and winter cover crops can increase the soil organic C content and provide protective crop residue on the soil surface. Therefore, the objective of this work was to determine the effect of management practice and landscape variability on selected soil quality parameters of a Coastal Plain soil in Alabama.

MATERIALS AND METHODS

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

Four zones were established at the site by other researchers using a digital elevation map, electrical conductivity survey and traditional soil mapping techniques (Terra et al., 2004). Three of these zones were selected (summit, backslope and accumulation) for this study. Two cells per management and zone were selected to conduct soil physical properties characterization (Fig. 1).

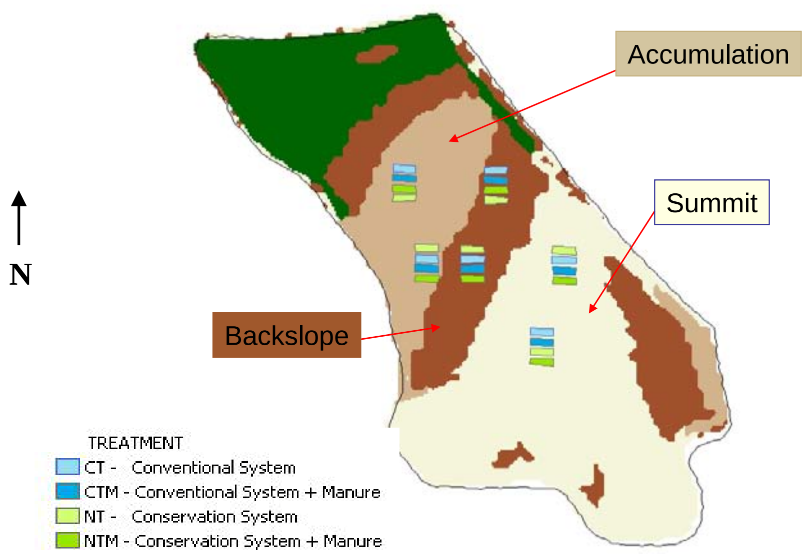

Figure 1. Map of the zones in the research site and the sampling cells used in this study. The green zone in the northern section of the field is an intermediate transitional zone not included in this research.

Soil properties studied included total soil C by dry combustion at three depths, water infiltration with a mini-disk infiltrometer, and water stable aggregates (Nimmo and Perkings, 2002). Other

data were collected, including soil bulk density and water retention, but will not be presented here.
Data were analyzed with the MIXED model procedure in SAS (SAS Institute Inc., Cary, NC). Management system, landscape position, depth, and their interactions were considered as fixed effects.

RESULTS AND DISCUSSION

Total C was greatest in the ST+M followed by CT+M, ST, and CT from 0-2 in of depth (Table 1). Soil C content was only affected by tillage at the 0-2 in depth, where total C was 56% greater with ST compared to CT. There were no differences in soil C in the lower two depths. Overall, soil C sequestration was greater with ST since soil respiration was probably lower than in the CT. There was a significant interaction ($P \leq 0.01$) between all management systems and depth, except CT. Conventional tillage operations tend to incorporate plant materials, increasing soil C breakdown and mixing it to lower soil depths creating a dilution effect (Table 1).

Total soil C content increased significantly with manure application for both tillages on the top 2 inches of soil (Table 1). However, soil C only increased significantly with manure application at the 2-4 in depth with CT. This can be attributed to the incorporation of the manure deeper into the soil profile by the mixing action of the CT practices. A similar trend was observed at 4-6 in of depth. Soil C content was not affected by landscape position ($P = 0.39$).

Table 1. Total soil C content for conventional, conventional with manure, strip-till, and strip-till with manure management systems in the research site near Shorter, AL.

	Total Soil Carbon			
	Conventional Tillage		Strip Tillage	
	No manure	Manure	No manure	Manure
Depth, in	------------------------------ %		------------------------------	
0 – 2	0.54	0.99	0.84	1.44
2 – 4	0.50	0.83	0.51	0.54
4 – 6	0.43	0.54	0.42	0.43

	Pr > F		
Depth	Tillage	Manure	Tillage x Manure
0 – 2	0.041	< 0.001	0.419
2 – 4	0.918	0.655	< 0.001
4 – 6	0.856	0.774	0.285

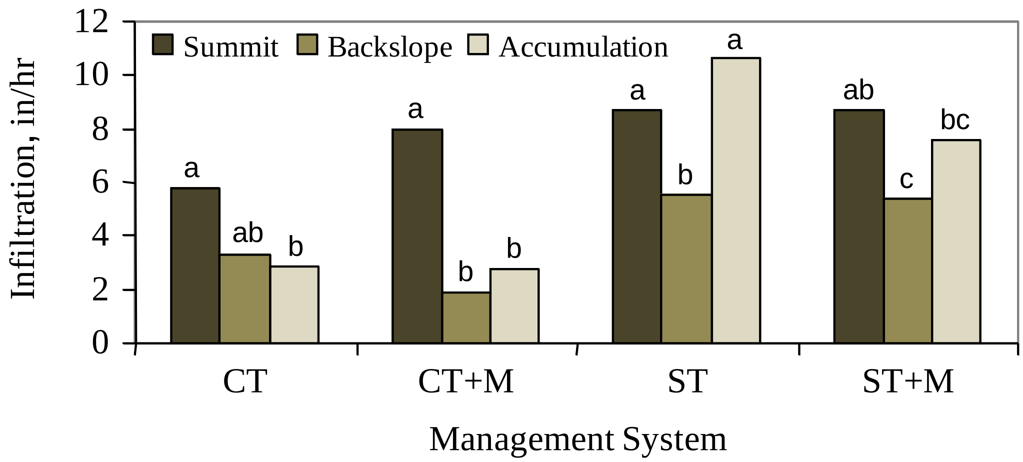

Figure 2. Infiltration rate as affected by landscape position for conventional tillage with and without manure (CT+M and CT), and strip tillage with and without manure (ST+M and ST) in the research site near Shorter, AL. Different letters indicate statistical significance between landscape positions within the same management system.

In general, water infiltration was increased by non-inversion tillage practices in all landscape positions (Fig. 2). Water infiltration was greater in the summit and accumulation positions than in the backslope of the ST management system. Similarly, infiltration was lowest in the backslope of the ST+M management, but it wasn't significantly different to the infiltration rate of the accumulation zone. A similar pattern was observed with CT+M. This reduced water infiltration rate in the backslope position can be attributed to lower C accumulation in the backslope position. Infiltration in the summit and backslope for the CT treatment was greater than in the accumulation zone. Water infiltration was not affected by manure application within tillage system. Water stable soil aggregates were not affected by management system ($P = 0.51$) or zone ($P = 0.27$). This may be due to the large variability in aggregate stability measurements.

CONCLUSION

Manure significantly increased the soil C content of the topsoil in CT and ST treatments. Soil C content was increased with manure application deeper in the profile for the CT treatment only. However, manure application did not appear to improve water infiltration or water stable aggregates. Similarly, there were no significant differences in water stable soil aggregates between treatments or zones. Water infiltration tended to be greater in the summit position for all the treatments, with the exception of ST. In general, it seems that conservation systems had a greater impact on improving measured soil quality parameters on this landscape than manure application.

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THE IMPACT OF LONGTERM CONVENTIONAL AND NO – TILLAGE MANAGEMENT ON FIELD HYDROLOGY AND GROUNDWATER RECHARGE

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ABSTRACT

No-tillage increases water conservation and crop yields, but the long-term (25 year) impact on semiarid field hydrology is not understood. Our objective was to estimate effects of SM or NT during the WSF rotation on field hydrology and potential groundwater recharge of a Pullman clay loam. Wheat (*Triticum aestivum* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench] were grown in a dryland 3-year wheat-sorghum-fallow (WSF) rotation in the U.S. Southern High Plains using stubblemulch tillage, SM, or no-tillage, NT, residue management. We measured crop yield, rainfall, runoff, and chloride (Cl) concentration in borehole cores taken to a depth of ~ 50 ft. Mean wheat yield did not vary with tillage, but sorghum grain yield (3020 lbs ac^{-1}) with NT increased significantly ($P<0.05$) compared to SM tillage (2720 lbs ac^{-1}) due to greater sorghum water use with NT. The 25 year mean plant available soil water for the 6 ft. soil profile ranged from 6.6 in. for SM to 7.7 in. for NT. Rainfall runoff was significantly higher for NT compared with SM, but we observed more available soil water at planting with NT compared with SM. Dryland SM and NT crop management displaced Cl downward compared with native rangeland, but Cl displacement exceeded the rooting depth only with NT. Calculated soil water drainage with NT averaged 0.45 in. annually or almost double the .25 in. yr^{-1} flux rate estimated for the region. These downward water flux rates translate to expected groundwater recharge; however, time lags range up to centuries.

INTRODUCTION

The Texas High Plains climate features limited and erratic precipitation coupled with high potential evapotranspiration; therefore, irrigation is often used to supplement precipitation for crop production. According to the "2007 Water for Texas Plan," (Pittman et al., 2007) the saturated thickness and irrigation capacity of the Ogallala Aquifer will decline. This decline may result in deficit irrigation of crops or an increase in dryland crop production as stabilized through water conserving residue management practices. Stubblemulch tillage (SM) and no-tillage (NT) conservation tillage practices that were initially practiced to conserve soil by retaining residues on the soil surface to reduce evaporation and increase storage of precipitation as soil water for subsequent crop use (Baumhardt and Jones, 2002). Increased soil water storage resulting from use of conservation tillage has the potential to increase soil water drainage and movement of nutrients through the soil profile to depths below the root zone (Eck and Jones, 1992). One impact of water conservation in excess of the soil storage capacity would result in drainage below the crop root zone. Texas groundwater recharge is not well quantified and this unknown contributor to the Ogallala Aquifer may help offset water used for irrigation. For example, groundwater recharge through a playa lake near Tokio, TX during ~20+ years raised the water table sufficiently that one land owner saw the return of irrigated cotton production by 1997. Crop production methods such as improved residue management, which conserve precipitation as soil water may promote profile drainage that enhances groundwater recharge to maintain or extend productivity of irrigated crops.

In a study quantifying conservation tillage effects on soil water drainage, Eck and Jones (1992) measured nitrate concentrations to ~ 12 ft. They reported that no tillage residue management practices not only increased conservation of water in the Pullman clay loam soil but also enhanced movement of nitrate to depths > 10 ft in the lower profile. Increased drainage and leaching of nitrate suggests that groundwater recharge is, potentially, possible with no tillage (NT) residue management. Aronovici and Schnieder (1972) determined potential groundwater recharge beneath the Pullman clay loam soil using basins excavated into the underlying caliche layer. Their data showed that water draining from the excavated basin would reach the water table in approximately three days. Because the hydraulic properties of this caliche layer are, regionally, uniform (Baumhardt and Lascano, 1993), groundwater recharge may be regionally possible.

Groundwater recharge in the Texas High Plains was evaluated by determining the displacement of a chloride (Cl) concentration peak with depth (Scanlon et al., 2007). That is, under rangeland vegetation the lack of ongoing leaching or recharge is shown by salts accumulated in the soil profiles resulting in a Cl concentration peak in the near surface root zone. In contrast, under crop management, downward displacement of the bulge shaped Cl peak through the soil profile is attributed to increased drainage below the shallow root zone that should ultimately recharge the aquifer, (Scanlon et al., 2005, 2007). Previous studies have shown that conversion from natural rangeland to cropland in the Southern High Plains has greatly increased recharge from zero under rangeland conditions to a median value of 1 in yr^{-1} under irrigated or dryland cropland (McMahon et al., 2006; Scanlon et al., 2007). For groundwater management and conservation, the impact of conservation tillage practices on groundwater drainage below the root zone and how long it might take to recharge the aquifer can be determined with the Cl mass balance approach. The objective of this study was to quantify the long-term effects of conventional stubblemulch tillage, SM, or no-tillage, NT, during a wheat-sorghum-fallow (WSF) rotation on crop yields, storm water runoff, soil water storage, drainage below the root zone, and potential groundwater recharge through a Pullman clay loam soil.

MATERIALS AND METHODS

Six large (4.5 – 10 ac) contour-farmed graded terraces (0.5% slope) at the USDA-ARS Conservation and Production Research Laboratory, Bushland, TX (35° 11’ N, 102° 5’ W) have been cropped according to the Wheat-Sorghum-Fallow rotation since 1958 with each phase of the sequence present (Jones et al., 1985; Jones and Popham, 1997). Winter wheat was sown at 35 lbs ac^{-1} with a high-clearance 12 in. row spacing grain drill during early September to late October. Seasonal broadleaf weeds were controlled in wheat using 0.5 lb a.i. ac^{-1} 2,4-D [(2,4-dichlorophenoxy) acetic acid]. Wheat was harvested in July and plot areas remained idle for approximately 11-months until mid-June when grain sorghum was seeded in 30 in. rows at the 22,000 seeds ac^{-1}, using unit planters. Atrazine [6-chloro-N-ethyl-N’-(1-methylethyl)-1,3,5-triazine-2,4-diamine] was usually applied preplant at 3.5 lbs ac^{-1} for seasonal weed control. Grain sorghum was harvested at maturity during November and plots were fallowed approximately 10-months when wheat was planted and the rotation repeated. No supplemental N fertilizer was required to meet expected dryland yields of wheat or grain sorghum because the needed N is mineralized between crops in this rotation (Eck and Jones, 1992; Jones et al., 1997). Because the clay mineralogy of a Pullman clay loam supplies sufficient K to meet crop demand (Johnson et al., 1983) and dryland crop response to broadcast applied P fertilizer has been limited (Eck, 1969, 1988), no P or K fertilizers were applied. Beginning in 1983, these three paired-terraces received either SM (stubblemulch) or NT (no-tillage) residue management of the Pullman clay loam (fine, mixed, superactive, thermic Torrertic Paleustoll). The SM weed control (3 - 4 tillage operations) was performed using a 15 ft.-wide sweep-plow operated at a depth of 4 in. For NT, weed control used both contact and soil active herbicides as governed by chemical residual and subsequent crop sensitivity (Baumhardt and Jones, 2002). Measurements during the 25-year study included a record of precipitation, storm-water runoff through 2.5 and 3 ft. H-flumes, and gravimetric soil water content for the beginning and end of each phase from each of the paired tillage treatments.

Infiltration into and drainage through the soil will, over-time, transport anions within the soil profile. Using Cl concentration in the soil as a marker, drainage below the root zone can be estimated from 30 to 60 ft (10-20 m) deep soil cores. A Geoprobe ™ push drill (Model 6620DT, Salina, KS) was used to collect a series of 4 ft (1.2 m) long core samples contained within plastic sleeves for subsequent analyses. These soil core analyses included: soil water content, matric potential, and the concentrations of Cl, sulfate, and nitrate as described by Scanlon et al. (2007). A Cl concentration peak displacement, relative to uncultivated rangeland vegetation, was used to define the depth of ion flushing and, subsequently, the rate drainage that should ultimately recharge the aquifer. We correlated soil water drainage to the long-term tillage treatments as corroborated with measured precipitation (standard gauges), surface water runoff, and soil water content at planting for the period of record, i.e., since 1983. Tillage effects on all parameters were compared according to a simple paired t-test (Baumhardt and Jones, 2002).

RESULTS AND DISCUSSION

Dryland residue management has the potential of increasing available soil water storage to a maximum of approximately 8 in. for a 6 ft Pullman soil profile. Under dryland conditions, this soil water is critical for crop production. The modest increase in soil water storage at wheat planting to a total of 7.7 in. with NT averaged about 1 inch more than the 6.6 in. observed for SM tillage. This was reflected in the subsequent crop water use estimated for wheat at 14.4 and 13.5 in. for NT and SM treatments, respectively. Similarly, available soil water storage at sorghum planting totaled 7.5 and 6.7 in. with NT and SM tillage, and resulted in the estimated sorghum water use of 12.8 and 12.2 in. Wheat grain yield averaged 2270 lbs ac^{-1} with NT was not significantly different from 2310 lbs ac^{-1} observed with SM tillage. In contrast, grain sorghum yield averaged 3380 lbs ac^{-1} with NT and was significantly greater than the grain yield of 3050 lbs ac^{-1} observed with SM tillage.

We estimated small but significantly (P = 0.05) different runoff amounts from both NT and SM treatments during wheat and sorghum growing season; however, during wheat growth runoff averaged only 2 % of the mean 11 in. growing season precipitation or 0.26 and 0.22 in. for NT and SM treatments, respectively. During sorghum growth, runoff from NT treatments averaged 0.47 in. compared with 0.61 in. for SM or 4.7 % and 6.1 % of precipitation for NT and SM, respectively. Measured runoff during fallow after wheat was 1.1 in. for NT and 0.8 in. for SM (6.2 % and 4.4 % of the 17.8 in. precipitation). Similarly, measured runoff of the mean 18.4 in.

precipitation during fallow after sorghum was 1.63 in. (8.9 %) and 0.82 in. (4.5 %) for NT and SM tillage, respectively. Total runoff during the WSF rotation averaged 4.6 in. for NT compared with 3.7 in. for SM. The greater runoff observed from NT than from SM plots would suggest less soil water would be available at planting; however, both available soil water at planting and summer crop yields averaged more with NT residue management. One likely explanation is that soil water evaporation for NT is sufficiently reduced compared with SM residue management to offset any differences in runoff and promote greater growth and yield.

Chloride accumulates naturally from atmospheric deposition, 0.234 ppm (mg kg^{-1}), in the long-term mean 19 in. annual precipitation. The Cl distribution for rangeland is shown in Fig. 1 for a site nearby the graded terraces. Data show Cl concentration begins transitioning at 1.1 ft. (0.35 m) with a peak bulge at approximately 3 ft. (~1.0 m) depth. The Cl concentration near the soil surface was 0 ppm (mg kg^{-1}), but increased rapidly beginning at 1.5 ft. (~0.5 m) depth. That is, the observed Cl displacement appears within the root zone; thus, indicating no water flux (drainage) through the profile. Our results show that the native range vegetation has consumed practically all the infiltrating precipitation, which resulted in no downward displacement of the Cl concentrations measured in the Pullman soil profile.

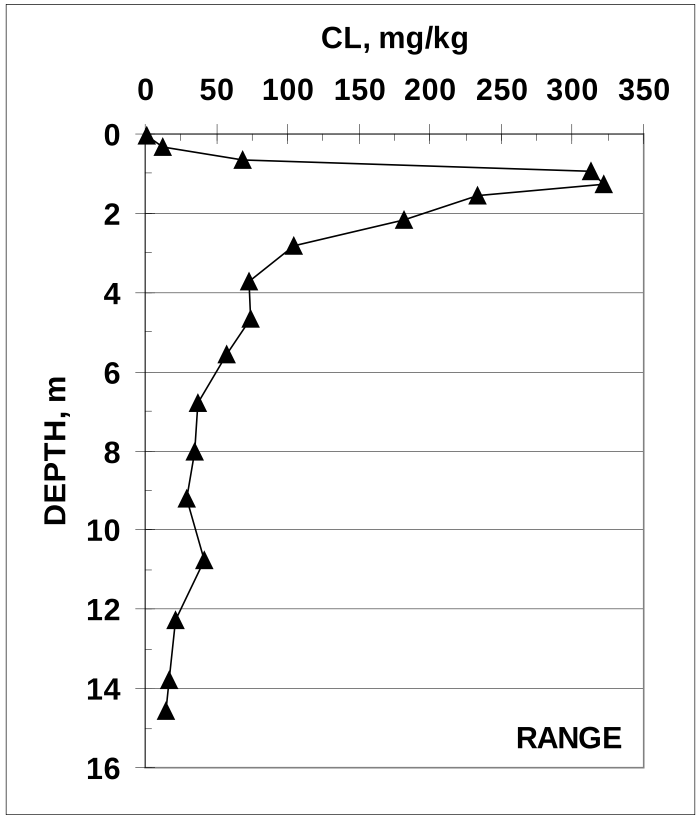

Figure 1. Chloride concentration, parts per million (mg/kg), plotted with depth, 1 m ~ 3.3 ft, for a nearby native range site.

The Cl concentration with depth is shown in Fig. 2 for SM and NT residue management of our wheat-sorghum-fallow rotation experiment that has been conducted for 25-yr. Compared with the rangeland site, the cultivated soils generally had deeper Cl peaks. The concentration of Cl was negligible for the upper 6.5 ft (2.2 m) in NT plots (Fig. 2 L) and 3 ft (0.95 m) in SM plots (Fig. 2 R). The depths where measured Cl concentrations transitioned from the negligible leached surface soil, generally, exceeded the estimated rooting depth only for the NT residue management treatment. For NT residue management, the concentration of Cl increases for an additional 6 ft (2 m) to peak at about 16 ft (5 m). In contrast, the Cl concentration displacement was approximately 10 ft (3.0 m) with SM tillage before decreasing to a common 25 ppm (mg kg^{-1}) Cl concentration in the lower profile. The calculated soil water drainage in NT plots averaged 0.45 in. (11.5 mm) annually or almost double the 0.25 in. (6.3 mm) annual drainage rate estimated for the region; however, the estimated time required to reach the water table is ~1400 years.

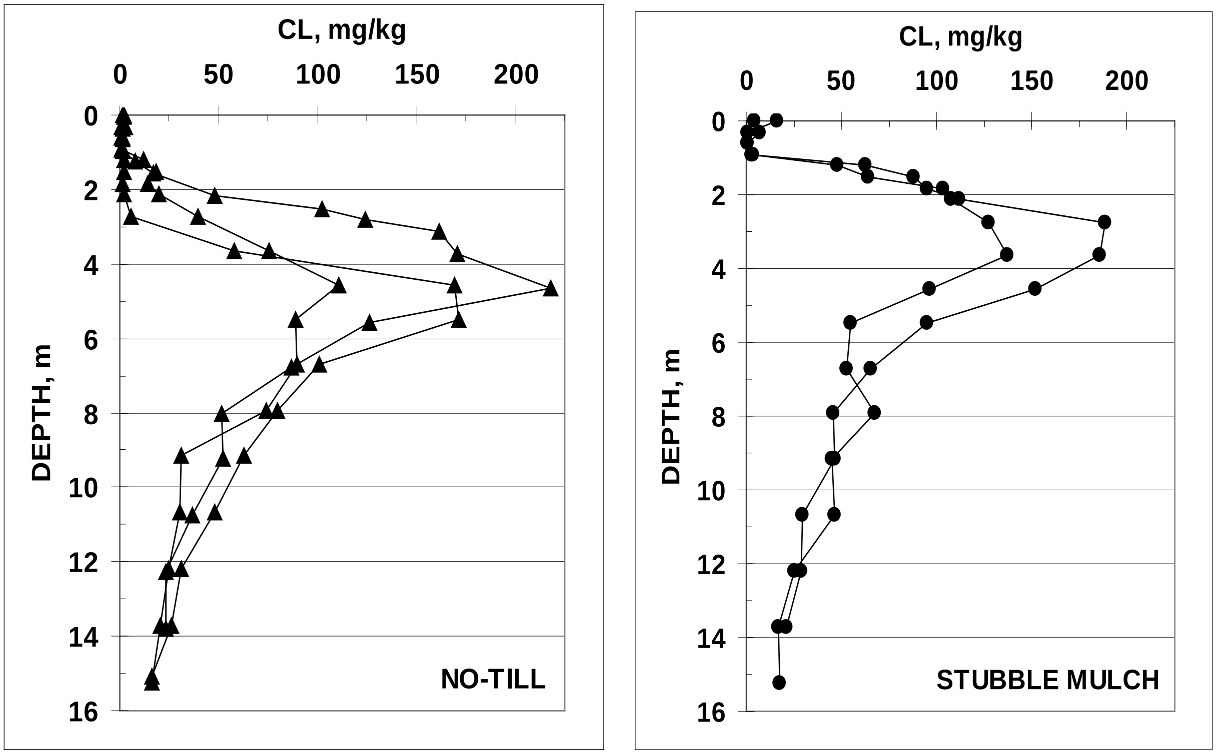

Figure 2. Chloride concentration, parts per million (mg/kg), plotted with depth, 1 m ~ 3.3 ft, for dryland Wheat-Sorghum-Fallow rotation no-till and stubblemulch tillage plots.

CONCLUSION

We measured, at planting, a consistent increase in plant available soil water of approximately 1 in. when using NT compared with conventional SM tillage. This greater soil water content did not increase grain yield of wheat that averaged 2290 lbs ac^{-1} for both tillage practices, but did result in approximately 300 lbs ac^{-1} more sorghum grain yield for NT compared with SM. Although NT tended to increase both available soil water stored during fallow and sorghum grain yield, we measured greater runoff for NT (4.6 in.) compared with SM (3.7 in.). Our data also show that Cl flushing under native rangeland was within the shallow root zone, and peaked at ~ 3 ft (1.0 m) depth. Cultivated dryland plots had Cl flushing to ~3 ft. (1.0 m) for SM tillage compared with ~ 6.5 ft (2.2 m) for NT. Because NT residue management increases precipitation stored as soil water, the Cl concentration was displaced ~ 4 ft (1.2 m) deeper than with SM during this 25-yr experiment. Calculated drainage rates in SM plots was negligible because the Cl displacement did not extend beyond the estimated rooting depth. With NT, the estimated mean annual drainage rates through the soil profile was 0.45 in. (11.5 mm) or almost double the 0.25 in. (6.3 mm) regional drainage rate. The estimated time required for no-till increased downward water flux to reach the groundwater table, however, is ~1400 years under conditions similar to those of our test.

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CURVE NUMBERS FROM A LONG-TERM NO-TILL CROP FIELD IN THE GEORGIA PIEDMONT

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ABSTRACT

Since its inception in the 1950s, acceptance, use and adaptation of the Curve Number (CN) method for estimating direct runoff from a rainfall event has increased worldwide. Some inconsistencies, limitations and problems have been identified as a result. There have been calls for development of locally defined CN values to address concerns with regional and seasonal variations. Researchers at the USDA-ARS near Watkinsville, GA, derived CN values from 33 years of rainfall-runoff data gathered from a 6.7 ac instrumented catchment (P1) managed under no-till. Summer crops included soybean, sorghum, millet, cotton and corn, with barley, wheat, crimson clover and rye as cover crops. Derived mean and median CN values were 36 and 31, respectively, compared to 60 to 70 expected from standard tables for the conditions at P1, implying that there was less runoff than would have been expected from standard CN-based estimates. Such low CN values suggest that, under long-term no-till management, hydrologic performance of P1 has become similar to those of pastures or meadows in good hydrologic condition which have low runoff potential. In half of the 126 storm events evaluated, <1% of the rainfall was portioned to runoff. On average, only 6.5% of the rainfall was partitioned to runoff. The derived median value of the initial abstraction ratio (λ) was 0.04, compared to the standard value of 0.2, which is very close to 0.05, a value proposed by researchers to improve the CN method. Such long-term data from field operations are essential for improving models.

INTRODUCTION

The CN methodology was developed in the 1950s, by hydrologists at the then USDA Soil Conservation Service (SCS). Empirical analysis of large amounts of rainfall and runoff data from small catchments and hill-slope plots, led to the development of the methodology for estimating event runoff from event rainfall with a minimal data set (Hawkins et al., 2009).

The derived equation is:

$$Q = (P - Ia)^2 / (P - Ia + S) \qquad \text{for } P>Ia;\ Q=0 \text{ for } P\leq Ia; \tag{1}$$

$$CN = 1000 / [10+S] \tag{2}$$

Where Q is runoff (in.), P is rainfall (in.), Ia is the initial abstraction (in.) and equals λS. The ratio λ is set at 0.2, and S is the potential maximum retention (in.).

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To solve for Q, one would need to know P and S in Eq. 1. To obtain S from Eq.2 requires selection of CN values from available standard tables based on land use, conservation practice, hydrologic condition of soil cover, hydrologic soil group, and antecedent moisture conditions (AMC- now called antecedent runoff condition ARC). Graphical charts are also available to obtain Q from known P and CN values.

Years of use and adaptation has led to critical review of the CN methodology. Garen and Moore (2005) vigorously argued that, while the CN method was appropriate for flood hydrograph engineering applications, its use in many nonpoint source water quality models was problematic. Hawkins et al. (2009) have summarized the origin, development, role, application and current status of the CN method, and cite studies by several researchers and task forces working to improve the method by incorporating knowledge developed since the original formulation. Some inconsistencies, limitations and problems have been identified. For example, research data across regions suggests that for the initial abstraction ratio λ, the original value of 0.2 is high and that a much smaller values of 0.05 appears to be more accurate. The CN method shows variance with infiltration-based analysis of runoff and the role of prior rain is not clear. Sometimes, additional data have shown the equation to be at variance with patterns of observed rainfall-runoff data. The equation is also more sensitive to CN than rainfall depth. In addition, there might have been bias in the original development of the equation from working with larger storms, since the model appears not to work well for small storm events, which make up the majority of storm events. The soil hydrologic classes can be expanded to include data bases that have been developed since the original formulation. Local and regional measurement and analysis of rainfall and its characteristics are common. However, ground truth data for CN are lacking. Concerns with regional and seasonal variation in CN have led to calls for the development of locally defined CN.

To derive CN values from measured data, one approach would be to solve Eq. 1 for S knowing P and Q (Hjelmfelt et al., 1982), or knowing P, Q and Ia, in which Ia equals the amount of rainfall prior to the start of runoff. With S determined, Eq. 2 can be used to solve for CN. Our objective in this study was to derive and analyze CN values from rainfall-runoff data gathered from 1976 to 2009 on a 6.7 ac catchment (P1) at the USDA-ARS in Watkinsville, GA, in the Georgia Piedmont. During this period P1 has continuously been under no-till management. A summary of the cropping history is given in Table 1, and Figure 1 shows the soil and topographic layout.

MATERIALS AND METHODS

Experimental Site

The research catchment P1 was established during the spring and summer of 1972 on 6.7 ac at the USDA-ARS J. Phil Campbell Senior, Natural Resource Conservation Center, in Watkinsville, GA. Slopes range from 2 to 7 percent. The catchment consists of three soil types: a gravely Cecil sandy loam (clayey, kaolinitic thermic Typic Kanhapludults) where 2 to 6 percent slopes dominate; a similar soil but with thinner solum, a gravelly Pacolet sandy loam, occurs on a smaller area on 5 to 7 percent slopes; and a Starr sandy loam occupies the lower portion of the catchment on 2 to 4 percent slopes.

Table 1. Summary of cropping history at P1.

		Spring-Summer		Fall-Winter	
Year	Tillage	Crop	Years	Crop	Years
1972-1974	Conventional	Soybean	3	Fallow	2
				Barley	1
1975-2009	No-till	Soybean	12	Barley	6
		Grain Sorghum	12	Wheat	8
		Forage sorghum	3	Clover	11
		Cotton	5	Rye	9
		Corn	2		
		Pearl millet	1		
Total years	Conventional		3		3
	No-till		35		34

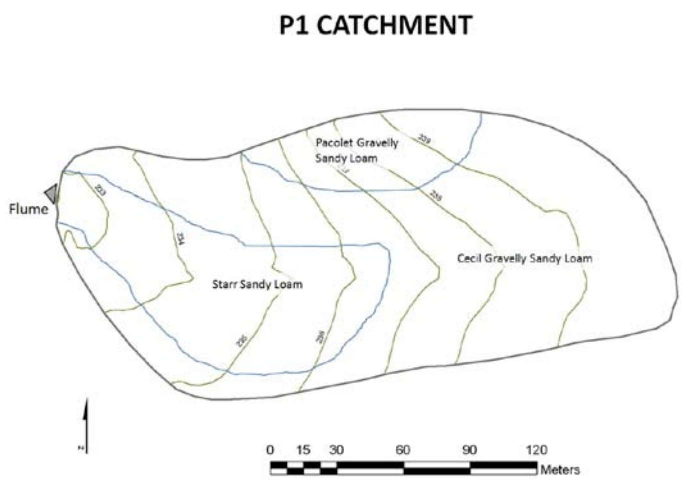

Figure 1. P1 Catchment showing soil distribution and elevation contours.

Research was started at P1 in 1972 to evaluate sediment and herbicide transport in runoff from a Piedmont watershed. The study was conducted cooperatively between the USDA-Agricultural Research Service and the US Environmental Protection Agency (Smith et al., 1978). As shown in Table 1, after 3 conventionally-tilled soybean crops, management converted to conservation cropping systems consisting of double-crop conservation tillage (no-till) rotations which have been maintained since (Langdale and Leonard, 1983; Endale et al., 2000). A gully formed during the conventional tillage phase on the lower part of the catchment which was renovated by establishing a 36-ft wide (0.79 ac) fescue (*Festuca arundinacea* Schreb.) grassed waterway in October 1974 (Langdale et al., 1979). The grassed waterway was converted back to the crop rotation during the summer of 1997 due to negligible soil losses from the catchment arising over the long history of conservation tillage.

Hydrology data

From 1972 to 1998, rainfall was gauged with a chart-based Fergusson-type weighing and recording rain gauge while flow was measured with a 2.5 ft stainless steel H-flume based on USDA specifications (Brakensiek et al., 1979) fitted with a chart-based Friez-type Fw-1 water-level recorder. Charts were manually processed to quantify and archive rainfall and runoff amounts. Beginning in 1998 the rainfall-runoff monitoring system was upgraded and automated using a tipping bucket rain gauge and submersible pressure transducer wired into a data logger. The data logger was programmed to convert the transducer flow depth values into runoff rates using the standard flume calibration curve. In March 2006 the transducer-based water flow sensing was changed to a water flow sensor based on a Shaft Encoder because of occasional instability of the transducer.

Endale et al. (2000) have summarized 26-years (1972-1998) of runoff and sediment data from P1 that show impacts of the contrasting cropping systems on long-term runoff and sediment losses and residue production. The major conclusions after 26 years were:

- Double cropped conservation cropping system following conventional tillage cropping immediately reduced runoff and soil erosion.
- Conservation cropping was essential to successfully combat accelerated erosive effects of high-energy storms following conventional tillage.
- Residue of 4.6 ton ac^{-1} yr^{-1} was produced over 20 years under conservation cropping systems. The residue modified the surface soil properties and allowed more infiltration and therefore less runoff. Residue production did not exceed 0.9 ton ac^{-1} yr^{-1} under the conventional tillage system.

Curve Number Investigations

Rainfall and runoff data were compiled for CN analysis beginning in 1976, one year into conservation tillage management. The 1976-1990 data were already available in a spreadsheet after the charts had been digitized. The 1991-1998 data were digitized by current staff from intact charts. From 1999 on the data were obtained from the data logger of the automated system. From a review of the rainfall-runoff graphs, 126 events were identified for analyses. Runoff varied from as little as 2.5 ft^3 to as large as 47993 ft^3. All runoff data except those that could not be quantified or could not be matched with the corresponding rainfall due to instrument, recording, processing, or some other error were included in the analysis. The initial step was to chronologically tabulate by columns the selected events and enter details such as rainfall amount, start and end rain times, runoff start, peak and end times, and runoff amount in cubic feet. Runoff expressed as depth was then tabulated by dividing volumetric runoff by the catchment area. For each event the total rainfall amount until runoff began was then determined representing the initial abstraction (Ia; Eq. 1). At that point, Q, P and Ia of Eq. 1 were known leaving S as the only unknown. The equation was solved for S and the results tabulated. Curve Numbers were then calculated using Eq. 2, and finally descriptive statistics were determined and corresponding graphs developed.

RESULTS AND DISCUSSIONS

Descriptive statistics for the parameters are given in Table 2. As expected, the standard deviations for all parameters were high indicating large variability. Values in Table 2 indicate a highly skewed distribution for runoff, percent runoff, the retention parameter S and the initial abstraction ratio λ. As previously reported (Endale et al., 2000), no-till management of P1 continues to significantly limit runoff compared to the period when the catchment was managed under conventional tillage.

Table 2. Descriptive statistics for parameters in Curve Number analyses.

Statistics	Rainfall P in.	Runoff Q in.	Q/P %	Initial abstraction Ia in.	Retention S in.	Initial abstraction ratio λ; (Ia/S)	Curve Number CN
Mean	2.18	0.19	6.45	1.09	378.11	0.15	36.32
Standard Error	0.11	0.03	0.98	0.07	107.95	0.02	2.76
Median	1.85	0.01	0.55	0.95	22.71	0.04	30.58
Standard Deviation	1.21	0.37	11.00	0.78	1211.75	0.23	30.97
Minimum	0.41	0.00	0.01	0.00	0.60	0.00	0.11
Maximum	6.56	2.06	46.02	3.58	9387.26	0.97	94.31
n (sample #)	126	126	126	126	126	126	126
Confidence Level(95.0%)	0.21	0.07	1.94	0.14	213.65	0.04	5.46

Despite a mean percent runoff of 6.5, partitioning of the rainfall into runoff was <1% in 50% of the events. Few of the large runoff events skewed the mean. There was a 5% probability of exceeding a 35% Q/P ratio, and a 20% probability of exceeding a 10% ratio. The runoff partitioning on an annual rainfall basis was much smaller. Piedmont landscapes are prone to serious runoff problems when disturbed by tillage and left without proper cover. In a 1940-1959 study of conventionally tilled continuous cotton on plots nearby, Hendrickson et al. (1963) found that about 21% of the 49.2 in. yr^{-1} rainfall was partitioned into runoff. Endale et al. (2000) reported that runoff at P1 during the initial 2.5 years of conventional tillage practice averaged 7.1 in. yr^{-1} compared to 0.9 in. yr^{-1} during 24 subsequent years of conservation tillage-based management. Endale et al. (2006) also reported that in an adjacent 19-ac field, the percent annual rainfall partitioned into annual runoff from 1940 to 1984 had a median of 5.1 and mean of 6.7. This field has been in pasture for the latter 40 of the 45 years.

The calculated mean and median CN values at P1 were < 40, which support the observed low runoff generating potential of no-till management at P1. In contrast, the CN values from standard Tables (NRCS National Engineering Handbook, Section 4, Hydrology) for conditions at P1 would be in the 60 to 70 range at antecedent rainfall condition II. That is: for hydrologic soil group A (least runoff-prone; sand, loamy sand, sandy loam); row crops on straight row and with good hydrologic condition; and small grains on straight row and good hydrologic condition. The effect of the grass waterway was to reduce the table-obtained CN values by approximately 3. According to the standard CN tables, CN values in the 30 to 40 range are assigned to pastures or meadows in good hydrologic condition. Hence P1 is responding as such under long-term no-till management. Nevertheless, there was a 30% probability of exceeding a CN value of 60. A plot of CN versus Q/P (not shown) indicates that CN values were > 60 for Q/P ≥ 15% approximately. Below a Q/P value of 15% the CN values are scattered in a band with an upper bound line at CN = 80, and a lower bound line from CN=0 to CN = 60 at Q/P of

15% though a few values were outside of these bounds.

There was agricultural drought in 13 of the 33 years whereby, in addition to reduced rainfall during crop growing season, annual rainfall was 29.4 to 46.0 in. compared to the long-term average of 49.2 in. These years usually occurred in clusters: 1985-1988 (34.5-39.6 in.); 1999-2002 (36.1-46.0 in.); and 2006-2008 (29.4-40.9 in.). Generally the mean number of annual runoff events was somewhat lower during these relatively 'dry' years than during the other 'normal-wet' years. However, the correlation for a regression of the number of the yearly runoff events against the annual rainfall was low (r^2 0.19), but the slope (0.005) was significant while the intercept (-2.93) was not. As previously indicated, some but not many runoff events had not been considered because we could not accurately quantify the runoff due to measurement errors.

A major thrust in recent times towards improving the CN method is the idea of replacing the initial abstraction ratio (λ) value of 0.2 with 0.05 (Hawkins et al., 2009). It is interesting that the mean λ value found in this study was 0.15, however, the median was 0.04. Hawkins et al. (2009) and others have pointed out that in the original selection of λ, 0.2 was in fact the slope of the median line for a regression of the initial abstraction Ia against the maximum storage potential S. Our data support changing λ to 0.05.

CONCLUSIONS

Long-term (33-yr) continuous row crop management of a small Georgia Piedmont catchment under no-till resulted in low mean and median CN values (30-40). Runoff partitioning was <1% of rainfall in 50% of the storms. The CN values from standard tables for the conditions at the catchment are approximately double those found in our study. Curve Numbers exceeded a value of 60 for Q/P ≥ 15%. Below a Q/P value of 15% the CN values are scattered in a band that has an approximate upper bound line at CN = 80, and a lower bound line from CN=0 to CN = 60 and a Q/P of 15% with a few values falling outside these bounds on either side. The initial abstraction ratio λ had a median value of 0.04 in contrast to the standard value of 0.2, supporting recent calls for changing this standard value to 0.05. Agricultural drought, where annual rainfall was approximately 3 to 20 in. below long-term average, slightly reduced runoff events but the correlation of annual rainfall with the annual number of runoff events was weak.

Approximately 41% of approximately 277 million acres of cropland in the US is in conservation tillage, and 57% of the conservation tillage is no-till. In land development planning, and TMDL and other water quality-related investigations, use of the established CN method is likely to lead to overestimation of runoff from no-till fields. Long-term data such are those in this study are essential for improving accuracy of predictive models that might have been developed from limited data that do not take into account the possible variability in weather and management variables.

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INFLUENCE OF ELEVATED ATMOSPHERIC CO_2 AND TILLAGE PRACTICE ON RAINFALL SIMULATION

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ABSTRACT

No work has investigated whether increasing atmospheric CO_2 concentration will impact sediment loss in agricultural systems. Rainfall simulation was conducted following a 10-year study investigating the effects of atmospheric CO_2 level (ambient and twice ambient) in two cropping systems (conventional tillage and no-tillage) on a Decatur silt loam (clayey, kaolinitic, thermic Rhodic Paleudults). The conventional system consisted of a sorghum [*Sorghum bicolor* (L.) Moench.] and soybean [*Glycine max* (L.) Merr.] rotation using spring tillage and winter fallow. The no-tillage system used this rotation along with three rotated cover crops [crimson clover (*Trifolium incarnatum* L.), sunn hemp (*Crotalaria juncea* L.), and wheat (*Triticum aestivum* L.)] without tillage. Elevated CO_2 increased residue in both tillage treatments, with the effect being greater under no-tillage. This resulted in increased water infiltration only under no-tillage. Overall, sediment loss was low under no-tillage regardless of CO_2 level; therefore, elevated CO_2 decreased sediment loss only under conventional tillage. Our results showed that both high CO_2 and no-tillage increased surface residues; this can improve water infiltration and reduce soil loss.

Keywords: global change, sediment loss, soil water infiltration, CO_2 enrichment

INTRODUCTION

The global atmosphere is changing as evidenced by the well documented rise in atmospheric CO_2 concentration, which is expected to continue (Keeling and Whorf, 2001). Since CO_2 is a primary input to crop growth, there is interest in how this rise in CO_2 will impact highly managed agricultural systems. Over the last decade, numerous studies have demonstrated that elevated atmospheric CO_2 can result in greater biomass production (Amthor, 1995). The effect of elevated CO_2 on crop residue production can influence soil carbon dynamics in agroecosystems (Rogers et al., 1999; Torbert et al., 2000). Furthermore, soil carbon dynamics can be altered by management practices (e.g., fertility practices, tillage methods, and cropping systems including cover crops) (Kern and Johnson, 1993). There is, however, a lack of information on how elevated CO_2 will interact with management practices.

No work has investigated whether increasing atmospheric CO_2 concentration will impact sediment loss in agricultural systems. In the current study, crops were grown under different atmospheric CO_2 environments (ambient and twice ambient) and management conditions (conventional tillage and no tillage) for 10 years. Our objective was to conduct a rainfall simulation following this 10-year study to investigate treatment effect on soil sediment loss.

MATERIALS AND METHODS

The experiment was conducted at the outdoor soil bin facility located at the USDA-ARS National Soil Dynamics Laboratory in Auburn, AL (Batchelor, 1984). This study was established in the fall of 1997 along the length of a bin (7m x 76m x 2m deep) filled with a Decatur silt loam soil (clayey, kaolinitic, thermic Rhodic Paleudults). Crops were grown from seed to maturity in open top chambers (Rogers et al., 1983) under ambient and twice-ambient atmospheric CO_2 levels in two crop management systems (conventional and no tillage). Carbon dioxide was supplied from a 12.7 Mg liquid receiver through a high volume dispensing manifold and the CO_2 level was elevated by continuous injection of CO_2 into plenum boxes as detailed in Mitchell et al. (1995).

This report covers a rainfall simulation following a 10-year elevated CO_2 study (1997-2007) comparing two crop management systems (conventional and no tillage). These crop management and crop rotation sequences have been previously described in detail (Prior et al., 2005). Briefly, the conventional system used a grain sorghum [*Sorghum bicolor* (L.) Moench. 'Pioneer 8282'] and soybean [*Glycine max* (L.) Merr. 'Asgrow 6101'] rotation with spring tillage and winter fallow. In the no-till system, grain sorghum and soybean were also rotated with three cover crops in the order of crimson clover (*Trifolium incarnatum* L. 'AU Robin'), sorghum, sunn hemp (*Crotalaria juncea* L. 'Tropic Sunn'), wheat (*Triticum aestivum* L. 'Pioneer 2684'), and soybean. The conservation system used "no-tillage" practices with no fallow periods. Fertility management practices followed local extension recommendations.

Prior to rainfall simulations, infiltration rates were estimated at three randomly selected locations in each plot using a mini-disk tension infiltrometer. Readings were made until a constant infiltration rate was achieved at 0.5 cm of tension.

A rainfall simulator was used to generate surface water runoff. Rainfall was created using a TeeJet ½ HH-SS50WSQ nozzle (Spraying System Co., Wheaton IL) approximately 2.5 m above the soil surface to achieve terminal velocity of water droplets (Sharpley and Kleinman, 2003). The rainfall simulator dimensions were 2.5 m long by 2.5 m wide. Prior to initiation, the simulator was calibrated to ensure a rate of ~100 mm h^{-1} to generate runoff for 40 minutes. Once runoff was initiated, water samples were collected at 10 min intervals (0, 10, 20, 30, and 40 min). Flow rate was determined by recording the time to fill a 250 ml sample bottle at each sampling time. Runoff was pumped from the collection basin into a plastic tank. Upon simulation completion, tank volume was measured and cumulative water samples were collected. Background water source samples were also collected during each simulation event.

Runoff plots were established within the open-top chamber plots. Each runoff plot was 0.25 m by 0.25 m. Metal (3.2 mm thick) plot borders of the same dimensions were used to define the runoff plots. Three sides of each border extended above the soil surface to keep runoff water within the plot (border heights were 10.2 cm and were inserted to a depth of 7.6 cm), while the forth side was flush with the soil surface to allow flow of runoff water to a trough located on the downslope side of each plot. Immediately after collection, water samples were acidified with concentrated HCl and frozen until analyzed. Water samples were filtered through a 0.45-μm membrane to separate sediment. The soil sediment was then dried at 40°C prior to dry mass determinations. Soil samples were analyzed for C on a LECO TruSpec CN analyzer (LECO Corp., Saint Joseph, MI). All plant residue was collected from each rainfall plot at the end of the study and dried (55°C) prior to dry mass determination.

The experiment was conducted using a split-plot design with three replicate blocks. Whole-plot treatments (cropping system) were randomly assigned to half of each block. Split-plot treatments (CO_2 levels) were randomly assigned to one chamber each within each whole plot. Statistical analyses of data were performed using the Mixed Procedure of the Statistical Analysis System (Littell et al.,1996). A significance level of $P < 0.10$ was established *a priori*.

RESULTS

Crop residue (lb ac^{-1}) was increased by both elevated CO_2 ($P < 0.001$) and no-till management ($P < 0.001$). There was a significant interaction between these two main effects treatments ($P = 0.006$) and was one of magnitude rather than direction. Residue was increased by elevated CO_2 in both no-till ($P < 0.001$) and conventional tillage ($P = 0.002$), but the increase was greater under no-till. Also, residue was increased by no-till in both ambient ($P < 0.001$) and elevated ($P < 0.001$) CO_2.

Water infiltration (in h^{-1}) was also increased by both elevated CO_2 ($P = 0.028$) and no-till management ($P = 0.070$). There was a significant interaction between these two main effects treatments ($P = 0.032$). Infiltration was increased by elevated CO_2 in the no-till treatment ($P = 0.010$) but not under conventional tillage ($P = 0.920$). Similarly, infiltration was higher under no-till than conventional tillage for plots exposed to elevated ($P = 0.006$) but not ambient ($P = 0.616$) CO_2.

Total sediment loss (lb ac^{-1}) was decreased by both elevated CO_2 ($P = 0.056$) and no-till management ($P = 0.030$). Again, there was a significant interaction between these two main effects treatments ($P = 0.057$). Sediment loss was decreased by elevated CO_2 under conventional tillage ($P = 0.020$) but not under no-till ($P = 0.989$), where these values were very low. Sediment loss was lower under no-till than conventional tillage for plots exposed to both elevated ($P = 0.076$) and ambient ($P = 0.011$) CO_2.

Total sediment C loss (lb C ac^{-1}) was lower under no-till, compared to conventional, tillage ($P < 0.001$). There a trend ($P = 0.133$) for sediment C loss to be lower under elevated, compared to ambient, CO_2. There was no significant interaction between these two main effects treatments ($P = 0.204$).

CONCLUSIONS

1) Elevated CO_2 increased crop residue and water infiltration, decreased total sediment loss and tended to decrease sediment C loss.

2) No-till management increased crop residue, water infiltration, and decreased both total sediment and sediment C loss.

3) Interactions showed that elevated CO_2: increased residue in both tillage treatments, with the effect being greater under no-till; increased water infiltration only in the no-till treatment; and decreased sediment loss only under conventional tillage.

4) Interactions showed that no-till management: increased residue in both CO_2 treatments; increased water infiltration only in the elevated CO_2 treatment; and decreased sediment loss in both CO_2 treatments.

5) Overall, our findings indicate that both high CO_2 and no-tillage increased surface residues which could improve water infiltration and reduce soil loss.

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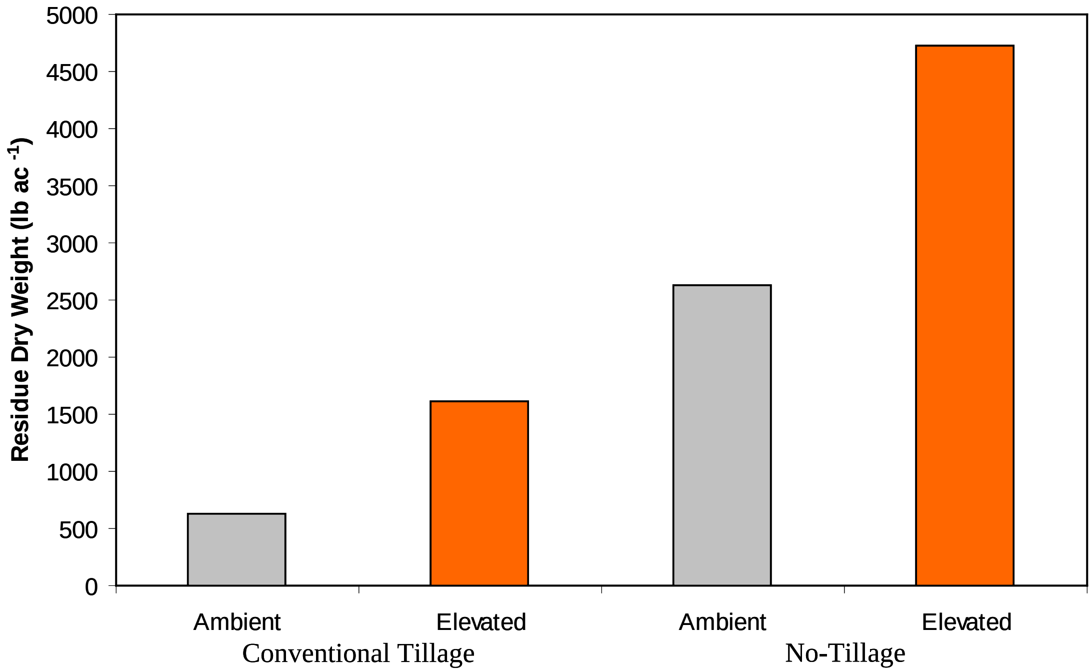

Figure 1. Residue dry weight under ambient and elevated atmospheric CO_2 conditions and two management systems (conventional tillage and no-tillage).

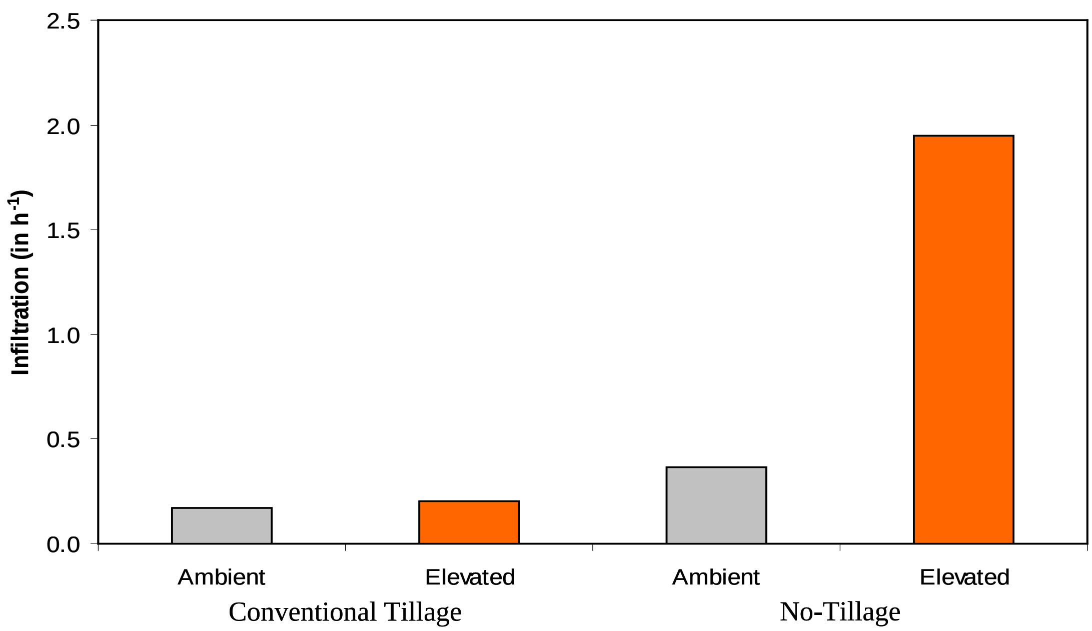

Figure 2. Water infiltration rate under ambient and elevated atmospheric CO_2 conditions and two management systems (conventional tillage and no-tillage).

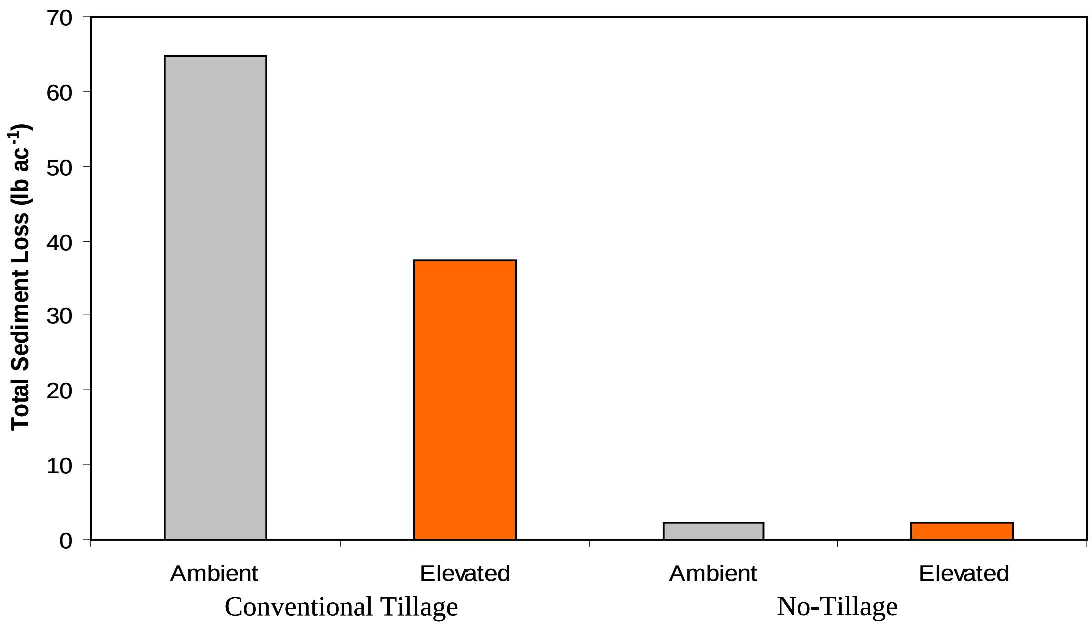

Figure 3. Total sediment loss under ambient and elevated atmospheric CO_2 conditions and two management systems (conventional tillage and no-tillage).

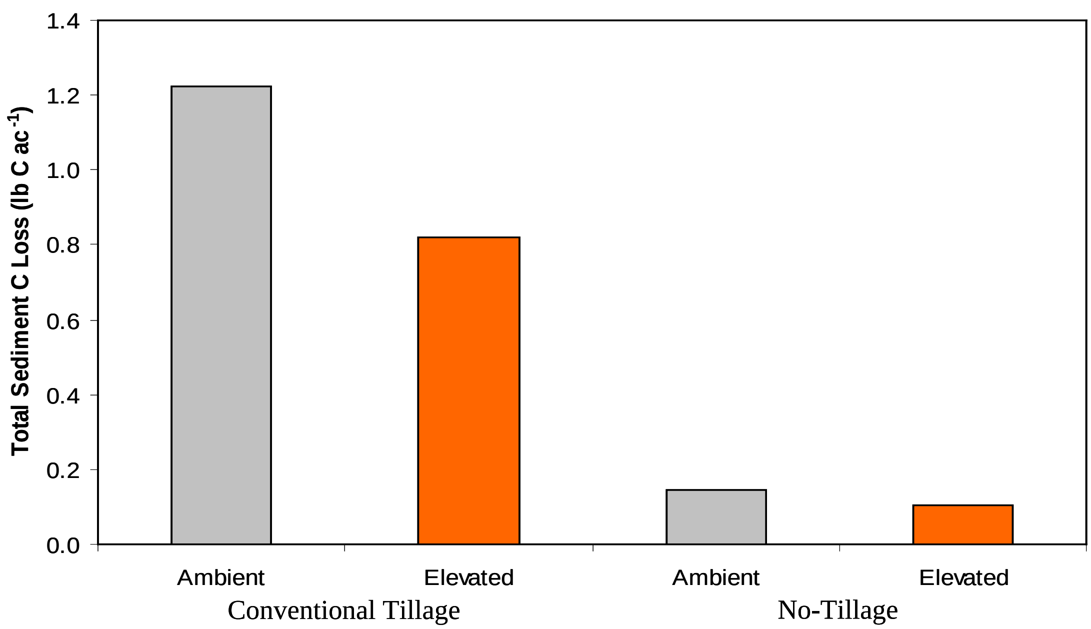

Figure 4. Total sediment C loss under ambient and elevated atmospheric CO_2 conditions and two management systems (conventional tillage and no-tillage).

FGD GYPSUM USE AS A SOIL AMENDMENT TO REDUCE SOLUBLE P IN SOIL

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ABSTRACT

Phosphorus loss from land-applied manure can be a major threat to water quality. Use of gypsum as a soil amendment could potentially minimize the water quality threat by reducing P loss from manured soils. Thus, a field study was conducted to evaluate if gypsum and lime amendment would reduce the extractability of P in soil. The study was located at the Sand Mountain Substation in the Appalachian Plateau region of Northeast Alabama, USA, on a Hartselle fine sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults). Poultry litter was applied at a rate of 4 tons acre^{-1}in an established bermudagrass pasture (*Cynodon dactylon* L.). Treatments consisted of commercial gypsum (1, 5, and 10 tons acre^{-1}), flue-gas desulfurization (FGD) gypsum (1, 5, and 10 tons acre^{-1}), FGD gypsum + fly ash (1, 5, and 10 tons acre^{-1}), lime (5 tons acre^{-1}), gypsum + lime (5 ton acre^{-1} gypsum and lime at an equivalent Ca content), and a control. Soil samples were collected at two depths (0-2 and 2-6 inches) and evaluated for water extractable P, Mehlich 3 extractable P, and Total P concentrations. Phosphorus concentrations in soil were the greatest in the first soil samples collected after poultry litter application. Also the greatest concentration of P was observed in the surface 0-2 inches of soil. Overall, the addition of all of the gypsum and lime treatments significantly reduced water extractable P concentrations in soil. No significant differences were observed between gypsum sources at the same rate. Averaged across gypsum sources (commercial gypsum, FGD gypsum, and FGD gypsum + fly ash), increases in application rates resulted in a greater reduction of soluble P. Similar results were achieved at the lower depths. No significant differences between treatments were observed for the Mehlich 3 P and total P concentrations. However, a trend was observed with the use of Mehlich 3. The Mehlich 3 extraction solution resulted in an increased P concentration with the gypsum sources and lime treatment additions. Information from this study may be useful in helping land managers and producers reduce the potential loss of P from agricultural fields.

INTRODUCTION

Concerns for environmental quality have prompted interest in recent years to develop agricultural practices that mitigate nutrient loss to the environment. This is of great concern, because in the southeastern USA, where the poultry industry is steadily increasing, management and disposal of poultry waste is becoming a top priority.

One approach to reduce runoff losses of P is to treat manure or the soil receiving manure with chemical amendments. Use of gypsum as a soil amendment seems promising. Studies have shown that the addition of gypsum can effectively reduce soluble P in runoff from soil with high soil test P (Stout et al., 1998) and from poultry litter additions (Watts and Torbert, 2009). Gypsum reduces P losses by decreasing the disaggregation of soil particles, thereby reducing the amount of P transported with sediment (McCray and Sumner, 1990). It is also suggested that a reduction in P losses can arise from the formation of an insoluble Ca phosphate complex when gypsum reacts with soluble phosphate (Brauer et al., 2005). This is a result of insouble hydroxyapatite and fluorapaptite forming when soluble P reacts with Ca (Linsday, 1979).

Mined Gypsum is often used as a calcium additive supplement for peanuts, but is not commonly used in hay and other row crop production systems due its high cost. Flue gas desulfurization (FGD) gypsum may be an alternative to mined gypsum. Use of FGD scrubbers to remove sulfur from the flue gas of coal-burning power plants for electricity production yields gypsum as a byproduct of the scrubber process. Presently, FGD gypsum is used primarily by the wallboard industries. However, installation of FGD scrubbers is expected to significantly increase in response to new and existing air pollution regulations, with a concomitant increase in FGD gypsum. The current wall board markets are not expected to be able to utilize all of the FGD gypsum produced. The beneficial uses of gypsum on agricultural land could provide an additional use for FGD gypsum, which represents a low cost alternative to commercially mined gypsum. Also, FGD gypsum has a higher $CaSO_4{\cdot}2H_2O$ content and fewer impurities than commercial mined gypsum and contains much smaller, finer, more uniform particle size (Dontsova et al, 2005; Srivastava and Jozewicz, 2001; Chen et al., 2008). Thus research is needed to evaluate FGD gypsum's impact on reducing the solubility of P in soil.

MATERIAL AND METHODS

Site Description

The field study was conducted in 2008 at Auburn University's Sand Mountain Research and Extension Center located in the Appalachian Plateau region of Northeast Alabama on an established bermudagrass pasture. The soil was a Hartsells fine sandy loam (fine-loamy, siliceous, subactive, thermic Typic Hapludults), which consists of moderately deep, well drained moderately permeable soil that is formed from acid sandstone. The surface soil (6 inches) at the time of study initiation was characterized as 11.9 % clay, 28.9 % silt, and 59.6% sand with an average bulk density of 1.5 g cm^{-3}. Climate in this region is subtropical with no dry season; mean annual rainfall is 52 inches, and mean annual temperature is 61ºF (Shaw, 1982). Prior to initiation of the field study, no known history of fertilization had occurred since the establishment of the Research station in 1929.

Cultural Practices and Treatments

The bermudagrass pasture was cleared of any weeds or senesced plant material prior to establishment of plots. Experimental plots 12 ft wide and 20 ft long were arranged in a randomized complete block design with four replications. The experimental treatments consisted of three gypsum sources (commercially available bag gypsum, FGD-gypsum from TVA, and FGD-gypsum + fly ash from TVA) applied on May 21, 2008 at three different rates for the gypsum source (1, 5, and 10 tons $acre^{-1}$), and compared to lime at 5 tons $acre^{-1}$, mixture of commercial gypsum at 5 tons $acre^{-1}$ + lime at an equivalent Ca content, and control (fertilized with poultry litter only). Poultry litter was applied as the nitrogen source at a rate of 4 tons per acre (maximum 1 time application rate for Alabama) on all plots. Poultry litter was surface broadcasted using a pull behind John Deere Manure Spreader. Poultry litter used in this study was collected from a local poultry production facility and consisted of poultry manure and a bedding material mixture. Following the application of poultry litter, surface broadcast application of the gypsum sources and lime treatments were applied on top of the poultry litter. The bermudagrass was managed as a pasture used for hay production.

Soil Sampling

Soil samples were collected on 14 of August and 8 of November, 2008. Soil was sampled at 0-2 and 2-6 inch depth increments. Eight soil cores (1 inch dia) were collected per plot and composited by depth; surface plant residue was removed from the sample. After returning to the laboratory, soil samples were passed through a 0.08 inch sieve to remove root material. Soil mass was recorded and moisture content was determined gravimetrically. Sub-samples were stored at 39°F until use.

Laboratory Analysis

Laboratory analysis was performed by Ohio State University Soil Testing Laboratory. Specifically, soil pH was determined on 1:1 soil/water suspensions with a glass electrode pH meter. Total P was determined by perchloric/nitric acid digestion, acid extractable P was determined using a Mehlich 3 extracting solution, and water extractable P was determined using 1:5 ratio (soil/water). Both the total P and Mehlich 3 extractable P were analyzed using the ICP, and water extractable P was analyzed colorimetrically.

Statistics

The experimental design was a randomized complete block design, with the four blocks representing replicates. Statistical analysis was performed using a GLM procedure of SAS (SAS Institute, 1985). Statistical comparisons were made at a significance level of $\alpha < 0.10$ established *a priori*. Values that differed at the $0.10 < P < 0.25$ level were considered trends. The term *trend* is used to designate appreciable, but not significant, treatment effects.

RESULTS AND DISCUSSION

The goal of this study was to evaluate the impact commercial gypsum, FGD-gypsum and FGD-gypsum + fly ash have on reducing soluble P in soil resulting from poultry litter application. Higher P concentrations in soil were observed on the first soil sampling day compared to the second sampling time. Also, soils collected from the 0-2 inch depth had significantly higher P compared to the 2-6 cm depth. This was not surprising because the P that is applied to agricultural fields tends to be adsorbed on the soil surface.

Mean water extractable P concentrations as affected by treatment addition are shown in Figure1. Overall, treatment additions of gypsum and lime significantly reduced water extractable P concentrations in the bermudagrass pasture soil compared to the control ($P = 0.0052$). The greatest reduction of P resulting from gypsum and lime addition was observed in the 0-2 inch depth compared to the 2-6 inch depth ($P<0.0001$). This was to be expected since the soil surface contained greater concentrations of P. As gypsum rates increased, regardless of gypsum type (commerical gypsum, FGD-gypsum, FGD-gypsum+fly-ash), water extractable P concentrations in soil significantly decreased ($P = 0.0103$). On August 14, 86 days after poultry litter fertilization, an average 10 ppm water extractable P concentration (control treatment) was observed in the surface 0-2 inches of soil. Averaged across the three gypsum treatments (commercial gypsum, FGD-gypsum, FGD-gypsum+fly ash), water extractable P concentration in soil decreased significantly to 8.5, 6.7, and 5.7 ppm with the addition of 1, 5, 10 lbs acre^{-1} of the gypsum treatment, respectively.

Mehlich 3 extractable P, which is often used as a plant available P index for eastern U.S. soils, resulted in higher concentration of P compared to the water soluble P. This was expected since the Mehlich 3 extraction solution is an acid, which is more effective at releasing P from soil particles. However, the use of this extractant was less sensitive in differentiating between treatments. The only significant differences observed for Mehlich 3 P concentrations was depth ($P = 0.006$). A trend was observed between treatments and application rates. Addition of gypsum sources and lime tended to increase the amount of Mehlich 3 extractable P in soil compared to control ($P = 0.2319$). Increases in Mehlich 3 extractable P in comparison to the control may be attributed to the technique used to measure the P concentration. The Mehlich 3 soil extracts were analyzed using the ICP. Unlike colorimetric procedures for analyzing P, the ICP can measure both inorganic and organic P fractions. Thus, if the P-containing particulates (colloidal materials) were not removed during the filtering process and/or the presence of soluble P complexes with iron (Fe), Aluminum (Al) and/or calcium (Ca) measurement of some fraction of these soluble or suspended P components that would not be measured using colorimetric procedures.

In general, Mehlich 3 P tended to increase in concentration from the 1 to 5 ton acre^{-1} rate and decrease from the 5 to 10 ton acre^{-1} rate for all three gypsum treatments. This was probably attributed to addition of a large quantity of material resulting in a dilution of soil P at the 10 ton acre^{-1}rate. Significant differences were observed between sampling dates. Similar to the water soluble P, concentrations of Mehlich 3 extractable P in soil decreased in November compared to the August sampling date.

No significant differences were observed in total P concentrations. However, similar patterns between treatments and rates were observed between the Mehlich 3 and the total P concentrations. This suggests that the Mehlich 3 P concentrations from the soil extract could have contained some soluble as well as organic fractions. Further research is needed to evaluate the impact of gypsum treatment on reducing soluble P losses from agricultural fields, and to determine how often and optimum rate of application needed to reduce P solubility in soil.

CONCLUSIONS

The addition of gypsum to soil as an amendment has the potential for reducing the amount of water soluble P. Greater water soluble P reductions from soil were also observed with increasing rates. Our data, although short-term, suggest that adding gypsum to manure amended soil would reduce the potential loss and export of P in surface water runoff.

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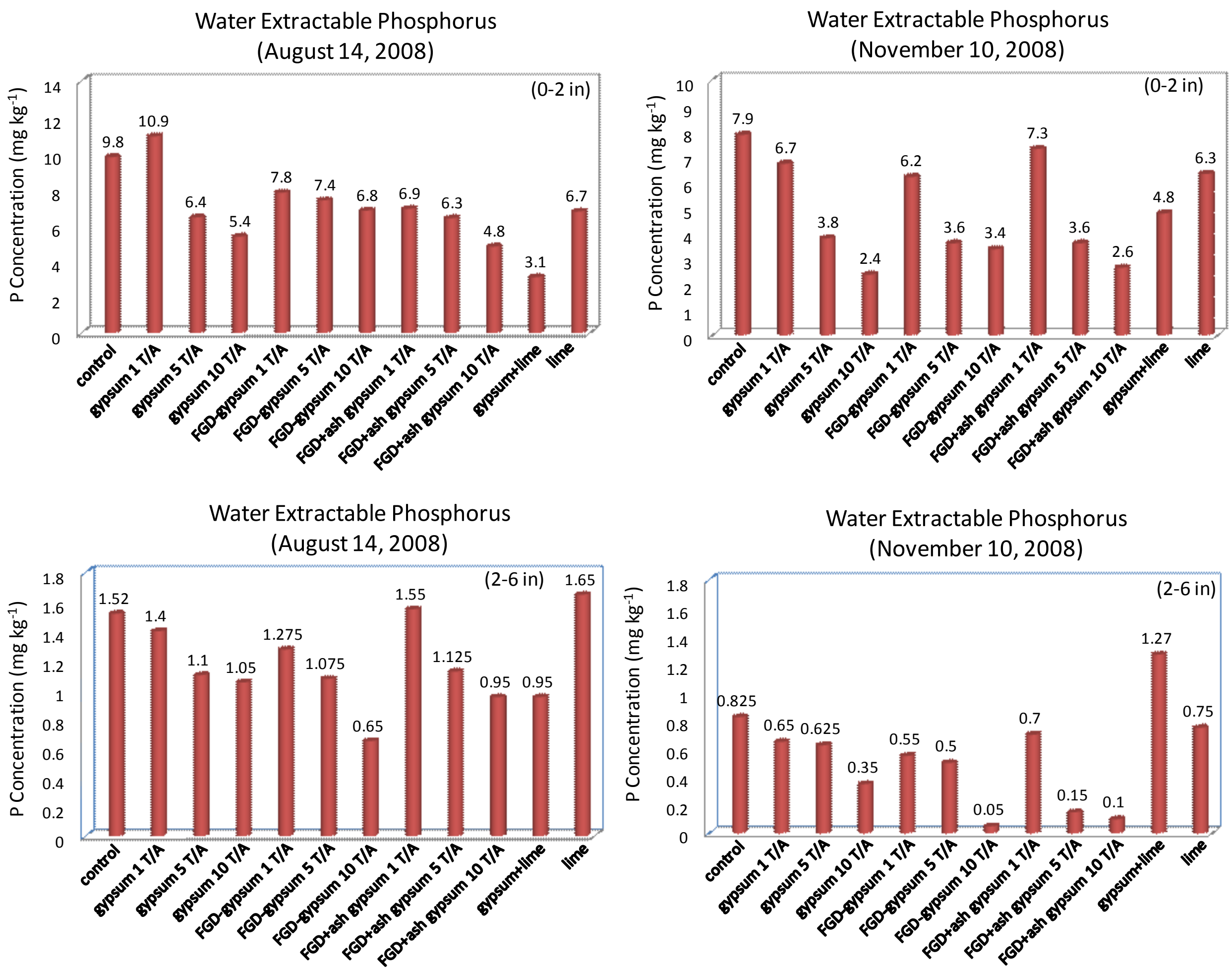

Figure 1. Water soluble P concentrations in soils amended with different gypsum sources and lime treatments at two depths (0-2 and 2-6 inches) from August and November's soil sampling.

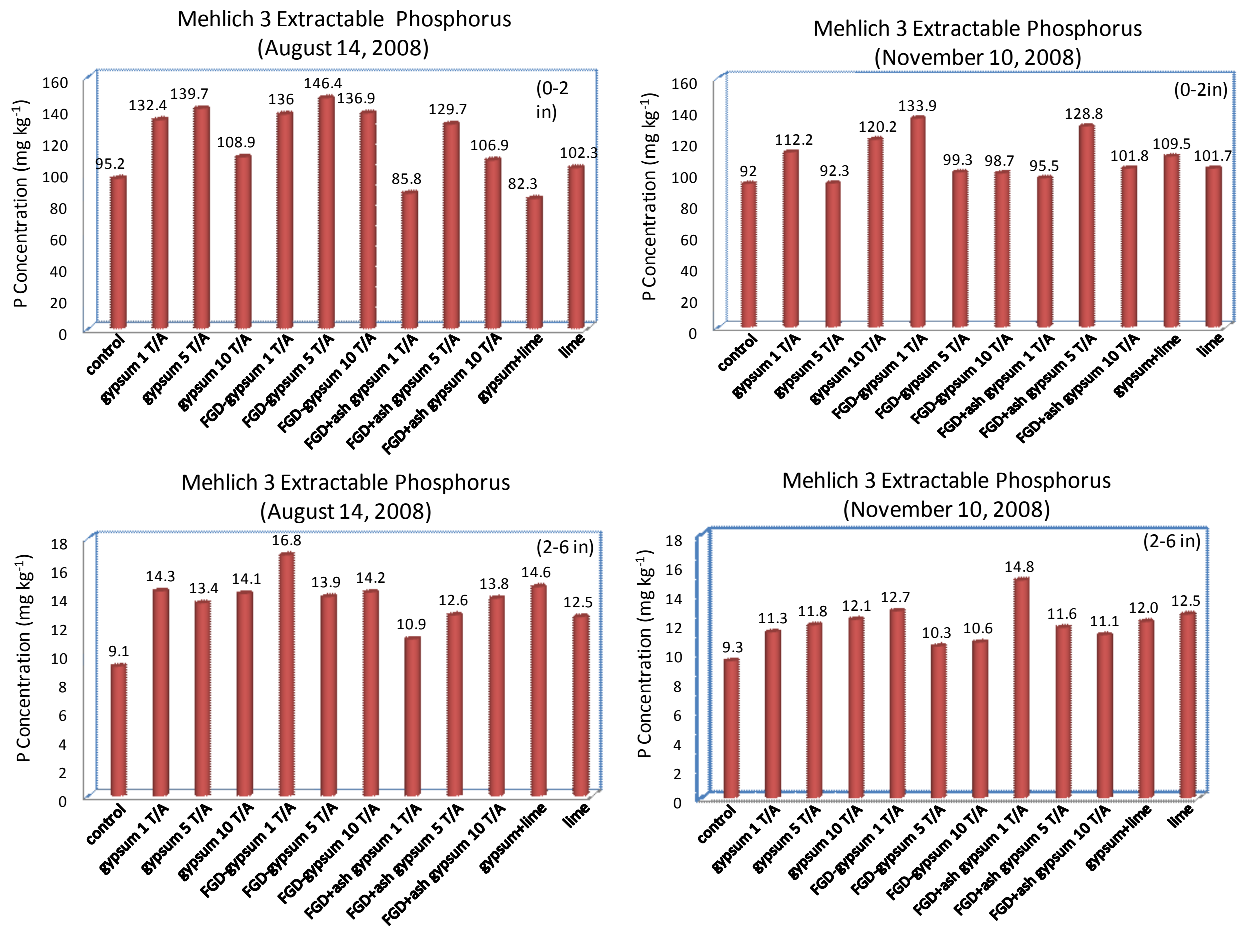

Figure 2. Mehlich 3 P concentrations in soils amended with different gypsum sources and lime treatments at two depths (0-2 and 2-6 inches) from August and November's soil sampling.

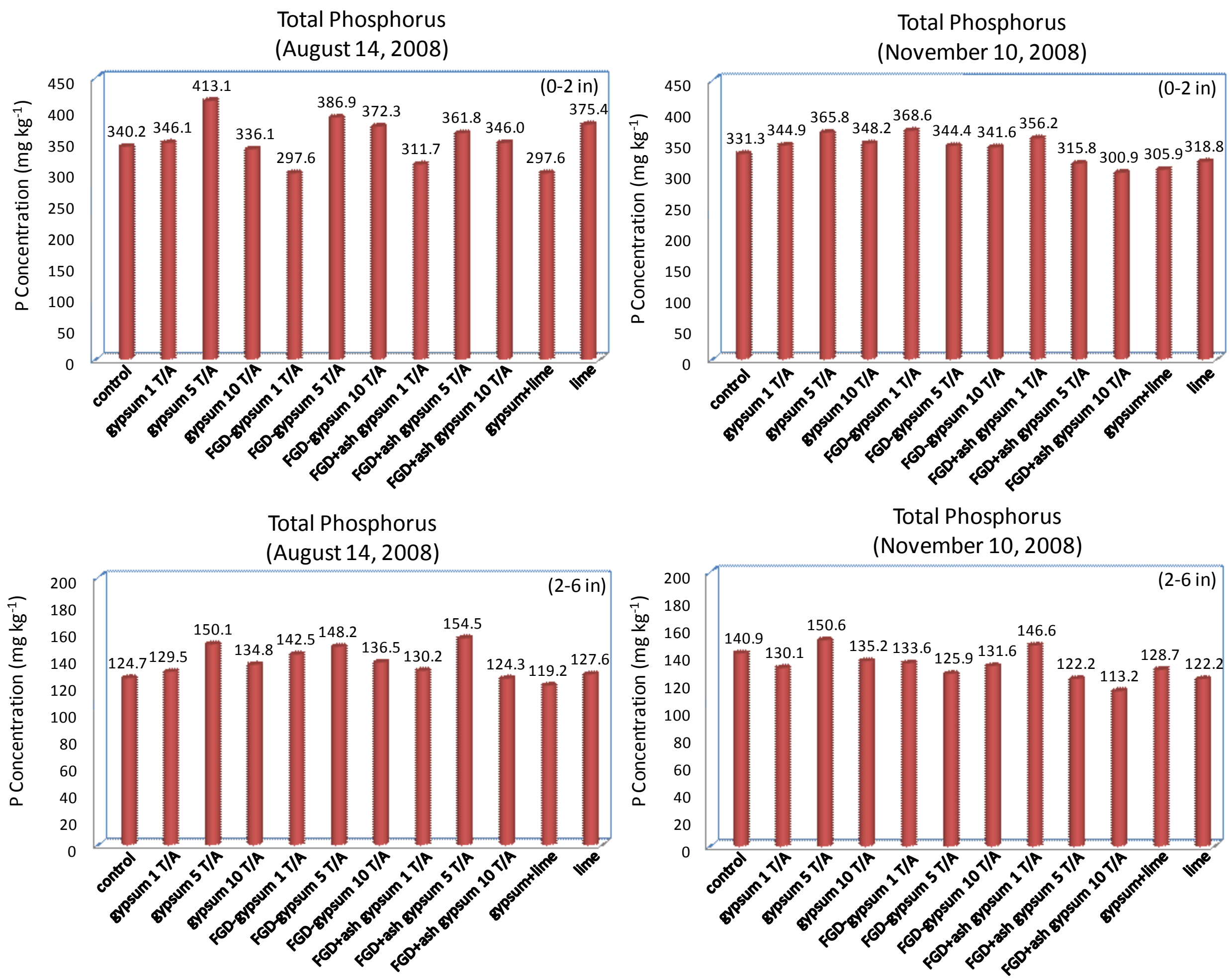

Figure 3. Total P concentrations in soils amended with different gypsum sources and lime treatments at two depths (0-2 and 2-6 inches) from August and November's soil sampling.

EFFECT OF POULTRY LITTER ON *HETERODERA GLYCINES* REPRODUCTION

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SUMMARY

Soybean cyst nematode (SCN), Heterodera glycines, management in soybean production relies on use of incompletely resistant cultivars to reduce SCN reproduction and associated potential risk of yield loss. A poultry litter study was initiated to change soil biological composition and potentially reduce SCN reproduction. Our objective was to use Normalized Difference Vegetation Index (NDVI), soybean yield, plant height, leaf area index (LAI), and SCN egg population density to quantify the impact of poultry litter application on SCN reproduction and plant response. Data were collected for three years as part of a field study with two rates of poultry litter applied annually in the spring compared with conventional fertilizer application. Plots receiving chicken litter had significantly higher yield in 2008 (P=0.002) and 2009 (P=0.03) than plots fertilized with traditional inorganic material. The 2007 growing season was especially dry and no treatment differences were significant. NDVI and LAI were good predictors of plant height and soybean yield for all years. Post-harvest SCN egg population density was inversely correlated with yield (r=-0.47, P=0.003) during 2007, but was positively correlated with yield in 2008 (r=0.61, P<0.0001) and 2009 (r=0.30, P=0.06).

EFFECTS OF PROLONGED STORAGE ON SURVIVAL AND GROWTH OF BOTTOMLAND OAK SEEDLINGS

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ABSTRACT

A prominent difficulty during bottomland oak seedling establishment is that sites are often flooded during the preferred months of planting (January – March), which results in delayed planting (April – June) and reduced survival. We monitored growth and survival of oak seedlings planted in 11 different months (February through December) after varying periods of humidified cold storage to investigate the hypothesis that seedlings held over the summer months in cold storage and planted in autumn months would fare better than seedlings planted in late spring and summer. Results for Nuttall oak (*Quercus nuttallii* Palmer) generally agreed with this hypothesis, whereas results for overcup oak (*Quercus lyrata* Walt.) did not. Second growing season height growth in both species decreased with increased periods of time in cold storage. These results suggest that although reduced height growth can be expected, long-term storage over the summer months and subsequent planting in autumn need not result in heavy mortality of some bottomland oak species.

INTRODUCTION

Over the course of the past century, considerable acreage of bottomland forest has been deforested and drained for row crop farming throughout the southeastern United States (Turner et al. 1981, MacDonald et al. 1979). Since the 1980's, natural resource professionals and federal and state agencies have focused on restoring portions of these cleared acres to native hardwood trees through various conservation programs (Stanturf et al. 2001). Restoration of bottomland hardwoods has been a recent focus in the management of agricultural wetlands in Tennessee (Johnson 2007).

Professional foresters and contractors often follow conventional tree planting procedures that are well established for upland sites, but prove problematic in bottomlands. High water tables, poor soil drainage, overland flooding and diverse soil properties makes tree planting difficult during the commonly accepted optimum planting period between mid-winter and mid-spring (January through April). These hydrologic obstacles, instead, often cause seedlings to be planted in late spring and summer (from May on). Late planting results in poor survival. In some cases the sites may go unplanted, leading to disposal of seedlings and a follow-up attempt to plant the following year.

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A previous investigation involving upland hardwood seedlings suggested that increasing the length of time in cold storage decreases post-planting root growth and percent bud break, and increases stem dieback and mortality (Englert et al. 1993). We investigated whether results would be similar with oaks on a bottomland site. Our hypothesis was that seedlings held over the summer months in cold storage and planted in autumn months would fare better than seedlings planted in late spring and summer.

MATERIALS AND METHODS

The study was conducted on the University of Tennessee West Tennessee Research and Education Center (WTREC), located in Jackson, Tennessee. The site is located adjacent to the South Fork of the Forked Deer River (35º 37'34" N, 88º51'22" W, 120 m mean elevation). It includes a 400 ft x 302 ft section nested into a larger 121 ac bottomland area that underwent afforestation in winter 2004. The predominant soil type is Waverly silt loam (0 to 2 percent slope), which is deep and poorly drained (Sease and Springer 1957). Flooding of the site occurs five to six times per year (Hayes 2009) and inundation often lasts several days. The site was used for row crop farming until 2004 when it was enrolled into the Conservation Reserve Program (CRP).

Nuttall oak (*Quercus nuttallii* Palmer, NTO) and Overcup oak (*Quercus lyrata* Walt., OCO) were planted in this study. NTO and OCO were selected because both species were previously found to be tolerant of extended inundation on the site available for this study (McCurry et al. 2006). All seedlings planted were 1-0 stock and were grown at the Tennessee Department of Agriculture Forestry Division East Tennessee Nursery in Delano, TN. Initial height measurements were taken to the nearest 0.1 in using a custom-made pvc pipe with markings graduated. The average above-ground height at the time of planting, measured from ground to terminal bud, was 20.2 in for NTO and 41.0 in for OCO. Initial stem caliper was also measured with a Plasti-cal Digital Caliper to the nearest 0.1 in at ground level. The average caliper for NTO was .3 in, and for OCO was .4 in. Prior to shipping from the nursery, the roots were dipped in Viterra root dip (potassium propenoate propenamide copolymers, Amereq, Inc., New City, New York) to conserve moisture. The Viterra root dip was mixed at a rate of .50 oz per gallon of water. After dipping, they were then packaged (without mulch) into bundles consisting of 25 seedlings. After delivery, the seedlings were stored in a humidified cold room with temperature and relative humidity set at 36 degrees F and 94 percent, respectively. An unforeseen, 30-hour power outage occurred on August 24-25, 2007. The maximum temperature in the cold room during the outage reached 77.4 degrees F with an average of 67.3 degrees F. The relative humidity dropped to a low of 81.9 percent.

The study was established as a randomized complete block design with all treatments appearing once in each of three blocks established in relation to elevation of the site. Twelve treatments, corresponding to plantings in every month of the year, were assigned at random to 12 plots within each block, which resulted in a total of 36 plots for the entire study. One row containing 20 NTO seedlings on 3.3 ft spacing and a second row containing 20 OCO seedlings on 3.3 ft spacing were established in each plot. With a total of three replications, 60 NTO and 60 OCO seedlings were planted per month. Seedlings for each month were planted successively between 7:00 and 10:00 a.m. and between the 10th and 20th day of any given month. No seedlings could be planted during the month of January at the outset of the study in 2007 because the study site was flooded. As a result, the January treatment was dropped from the study.

Site preparation, conducted in August of 2006, consisted of a single application of a two percent solution of Roundup (glyphosate, Monsanto, St. Louis, Missouri) 30 in bands applied directly over the designated rows. In addition, during the year of planting (2007) and the two following years, seedlings were side-dressed with the same herbicide at the same rate, once per month (April through September). The band width was 15 in on both sides of each row. Weeds were controlled carefully throughout the entire study in order to minimize effects of differences in the abundance of competing vegetation over the time period of the study. Mowing between the rows occurred each month during the growing seasons. Survival and seedling heights were recorded in September of 2008 and again in 2009.

Data were analyzed through one-way ANOVA with models appropriate for a randomized complete block design. Pairwise comparisons were conducted between months with Tukey's honestly significant difference ($\alpha = 0.05$). All analyses were conducted using SAS, Version 9.9 (SAS 2008).

RESULTS AND DISCUSSION

As of September 2009, mean survival calculated across all treatments and sample periods was 78.3 percent and 32.0 percent for NTO and OCO, respectively. As expected, survival for both of the species was favorable in the Feb – Apr planting treatments, with NTO averaging 90.6 percent and OCO 78.3 percent. Survival for both species was less favorable during the late spring and early summer (May – Aug) with NTO averaging 62.1 percent and OCO 29.2 percent. There were no differences in mean NTO survival between planting dates in this period, but mean survival for OCO was lower during some late spring and summer planting months. The results for the final planting period (Sept – Dec) were promising for NTO. Mean Sept – Dec NTO survival averaged 85.4 percent, and was not different in any of these months from survival in February, March, or April. In contrast, OCO survival during all months within this period was zero (fig. 1). Seedlings were considered dead if there was no indication of living tissue above-ground. Scratch testing to reveal green cambium was conducted on questionable seedlings.

Mean seedling height for both NTO and OCO decreased from early to late planting dates (fig. 2). Mean heights (as of September, 2009) for both species were greatest for seedlings planted in the early months of Feb – Apr, with NTO averaging 68.1 in and OCO 64.6 in. Heights for both species were less for most months within the late spring and summer planting period (May – Aug) than in the Feb – Apr period, with NTO averaging 45.2 in and OCO 37.2 in in the May – Aug planting period. NTO height averaged 30.2 in in the final period (Sept – Dec), and heights were less in this period than in the Feb – Apr period. There were no surviving OCO seedlings in the final period. When observing height measurements over the duration of the project for NTO, Feb – Apr planted seedlings were 131.9 percent taller than Sept – Dec planted seedlings in 2008 and 125.6 percent taller than Sept – Dec planted seedlings in 2009. Although data on resprouting were not formally collected, resprouting of late planted seedlings was observed to be more prevalent.

Due to limitations in the number of species studied, the types of stock examined, and other factors, this study is not a definitive test of the hypothesis that holding seedlings in a humidified cold room over the summer months, and then planting them during the autumn months, is a viable solution to the problem of early season flooding of bottomland restoration sites. The findings do suggest, however, that in the case of NTO, it is at least possible to have acceptable survival rates (80 percent or better) with seedlings planted in September – December. It can be argued that the very different results obtained for OCO may be the result of innate differences in the two oak species. These differences could include differences in respiration rate, desiccation resistance, or other species- specific characteristics. For instance, the two species were shown to differ in carbohydrate changes in response to flooding (McCurry 2006). It is also possible that differences in initial seedling size between the two species influenced the results.

At the time of planting, the initial seedling size and caliper measurements were noticeably larger for the OCO than for NTO. At 41.0 (initially), OCO were 103 percent taller than the NTO. Similarly, OCO, with an initial stem caliper of .4 in, were 33 percent larger in caliper than NTO. It is well documented that seedlings with a larger stem caliper experience more favorable survival than those with a smaller caliper (Weigel 1999). Why this was not the case in our project is not clear.

The potential effects of two occurrences during the study should be noted. First, during the year of implementation (2007), the west Tennessee region experienced an extreme drought. Eight months received below normal precipitation in 2007, and year-end total precipitation was 13.0 in below normal. During the growing season months of May - August, the precipitation deficit was 12.3 in (NOAA 2009). This could have substantially increased mortality overall, particularly in the summer months. Secondly, the power outage that occurred for 30 hours in August that allowed the temperature in the cold room to climb to 77.4 degrees F may have influenced seedling viability. Since none of the OCO planted in September - December (after this power outage) survived, it is possible to speculate that this occurrence may have had a greater effect on OCO than NTO, although the reasons for this are unclear. If these events had not taken place during the study, survival could have been greater for all planting dates in the study.

Results suggest that, at least in the first two growing seasons, height growth is suppressed by delayed planting. The average height of autumn planted NTO seedlings, when measured two years after establishment (September 2009), was considerably less than those planted in the spring. The percent difference in height had declined slightly from 2008 to 2009, and if this trend continues, early height differences could become less substantial over the duration of the rotation. Initial height can be important, however, in influencing the competitive status of planted seedlings relative to other vegetation.

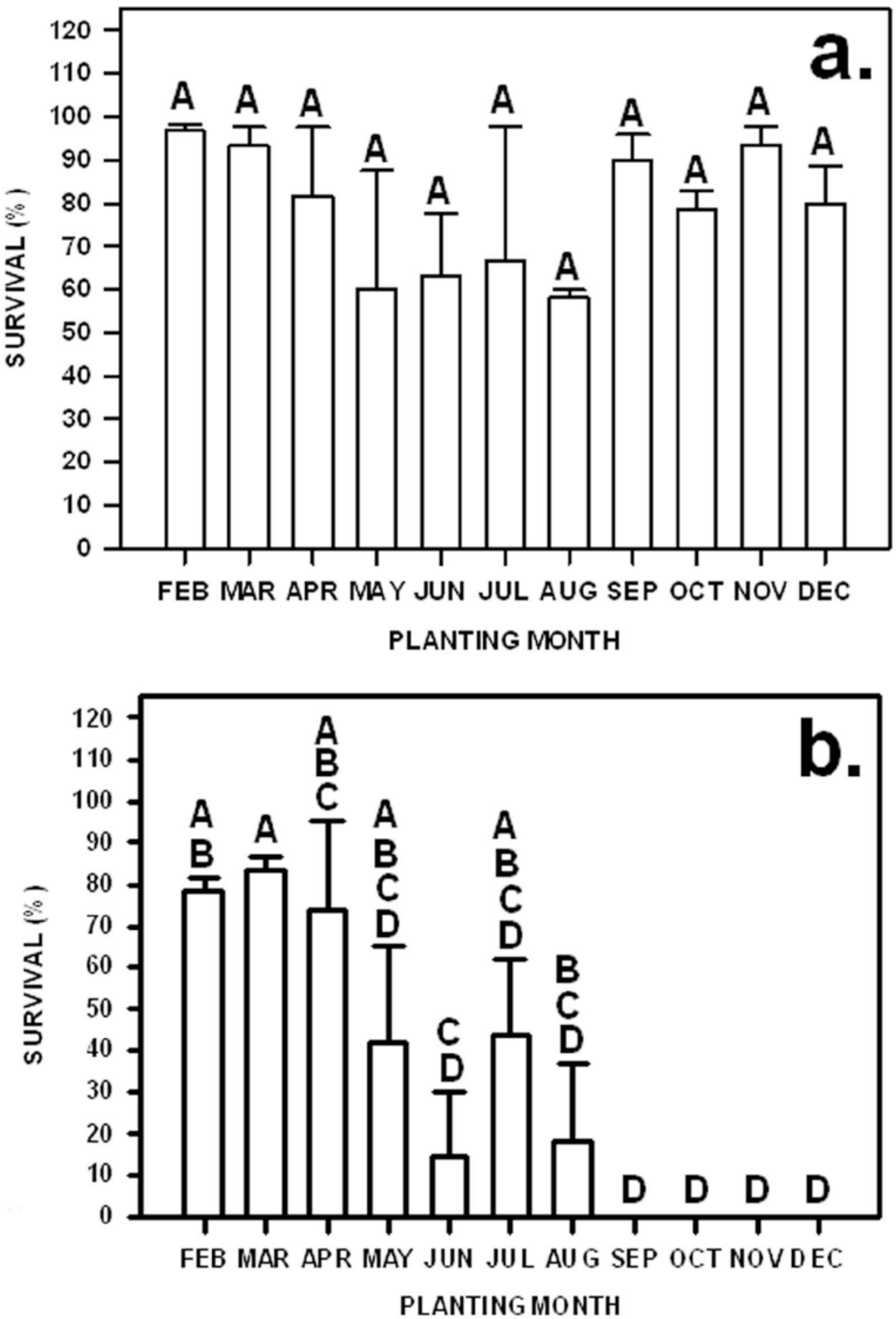

Figure 1. Mean percent survival of Nuttall oak (a.) and Overcup oak (b.) as of September 2009 by planting month treatment. Bars with the same letters are not significantly different at the alpha=0.05 level. Error bars represent 1 standard error.

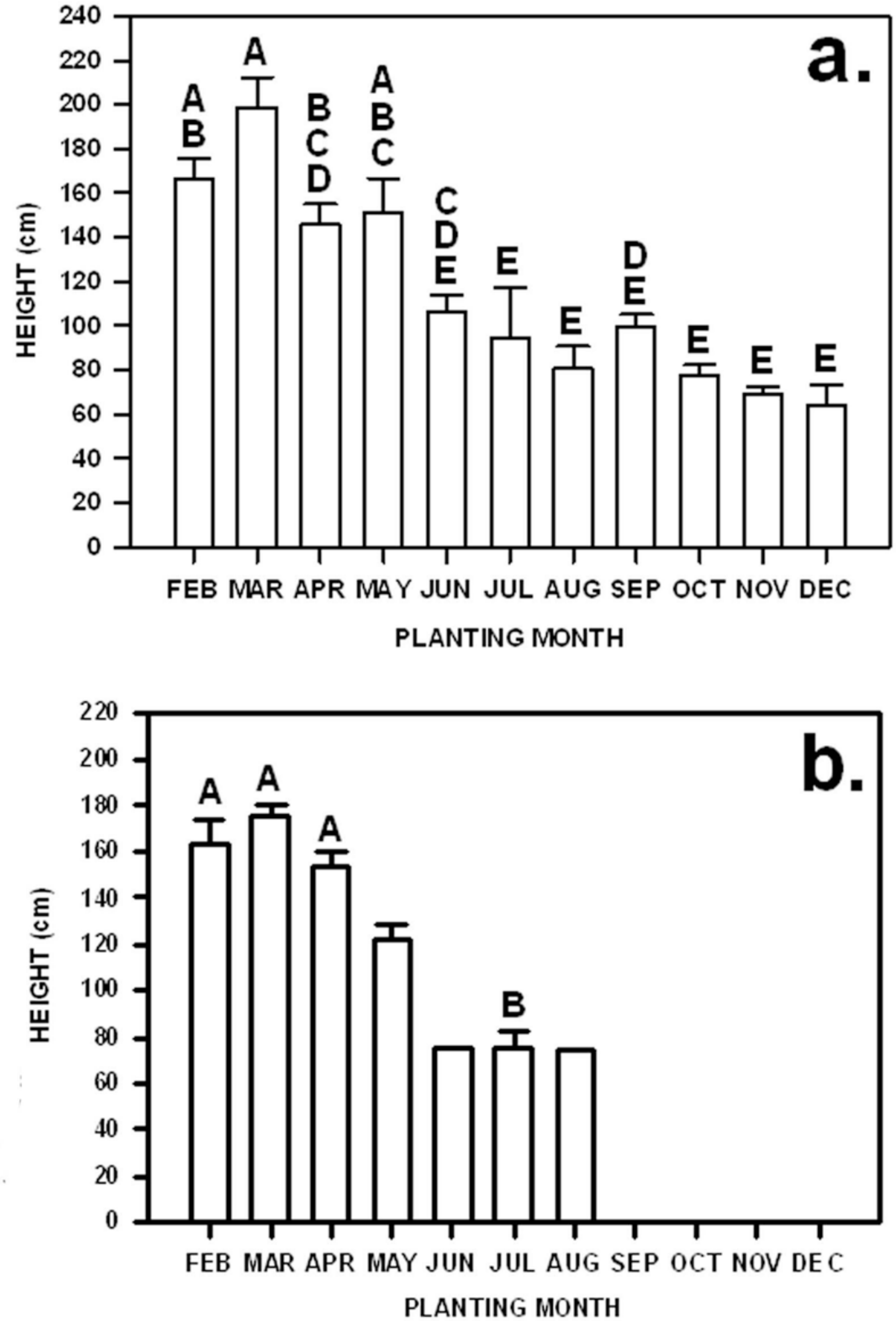

Figure 2. Mean height of Nuttall oak (a.) and Overcup oak (b.) as of September 2009 by planting month treatment. Bars with the same letters are not significantly different at the alpha=0.05 level. Error bars represent 1 standard error.

CONCLUSIONS

The promising results obtained for NTO in this study suggest that additional research involving the performance of delayed plantings of other species used in bottomland hardwood restoration is warranted. Examination of the viability of a range of seedling size classes for an expanded set of species stored for various periods of time in a cold room is planned.

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PROPAGULE DENSITIES OF *MACROPHOMINA PHASEOLINA* IN SOYBEAN TISSUE AND SOIL

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SUMMARY

All current commercial soybean cultivars are susceptible to charcoal rot, a disease caused by *Macrophomina phaseolina.* Efforts to manage charcoal rot through non-genetic means have not been effective. A field experiment was conducted in 2002 through 2004 at Stoneville, MS, to determine the population dynamics of *Macrophomina phaseolina* (Tassi) in soybean stem and root tissues at harvest and in soil at planting and harvest as affected by tillage, cover crop and herbicide. Colony forming units (CFU) in soybean tissue were greater under the conventional till (CT) than no-till (NT) and were greater for hairy vetch and no cover crop than rye. Application of glyphosate did not affect the CFU in stem and root tissues or in the soil. The CFU from soil at harvest was significantly higher than at planting. The CFU in soil at planting and harvest was only affected by tillage and not by cover crop system. The CFU from stem and root tissues was greater than in soil suggesting that quantification of CFU in tissue may provide a better estimate of treatment effects at harvest. These results also suggest that charcoal rot may be better managed in the NT rather than in the CT system.

ASSESSING PHOTOSYNTHETIC LEAF AREA OF CORN UNDER DIFFERENT TILLAGE SYSTEMS AND SOIL ZONES

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ABSTRACT

The photosynthetic leaf area may be influenced by soil texture. The objective of this experiment was to evaluate photosynthetic leaf area under different soil textures, based on soil electric conductivity (EC) measurements, tillage systems, and N rates in dryland corn (*Zea mays* L.) from 2007 to 2009. A commercially available soil electric conductivity (EC) measurement system (Veris Technologies 3100) was used to identify soil texture variations prior to planting wheat (*Triticum aestivum* L.) cover crop and create soil zone maps. Corn was planted across four different soil zones (based on soil EC measurements and ranging from 1 - sandy soils to 4 – clay soils) under three tillage systems (no-till, conventional, and strip-till) and two N applications at planting (40 and 80 lb N/acre). The leaf area index (LAI) meter was used to measure photosynthetic leaf area during corn vegetation at 2 months after planting. The results showed that plant LAI was generally higher with higher soil EC for no-till and conventional tillage systems. However, plant LAI was not influenced by soil EC under strip-till at either 40 or 80 lb N/acre. These results indicate that soil EC and plant LAI measurements may be utilized to help improve soil and crop management recommendations.

INTRODUCTION

Due to high variability in soil texture in the Southeastern United States, plant growth varies across the fields due to mostly nitrogen (N) utilization. Previous research has shown that N utilization depends on seasonal changes in soil temperature, water content, soil structure, and organic matter distribution (Radke et al., 1985; Johnson and Lowery, 1985; Wagger, 1989; and Ranells and Wagger, 1992) and therefore affects crop growth.

Soil management like tillage is a major factor affecting soil profiles (Miyamoto et al., 2003). Tillage operations change the soil characteristics and hydrodynamic processes in soils (Miyamoto et al., 2001). Grant et al. (2001) noted that tillage system may influence grain yield more in clay loam than sandy loam. A significant relationship was observed between the permittivity of a material and its water content (Robinson, et al., 2003). In dry farming areas, the water content in soil also varies during the growth cycle due to tillage operations, which drastically alter both the total pore space and the relationship between macro- and micro-pores (Josa and Hereter, 2005). Water is the main limiting factor to rainfed corn yield and efficient retention of precipitation is essential to maximize crop growth (Roygard et al., 2002).

Light interception and crop growth is affected by leaf area index (LAI) (Pearce et al., 1965). Wilhelm et al. (2000) indicated that measurement of leaf area index (LAI) is critical to understanding many aspects of crop development, growth, and management. Therefore, plant LAI is a key variable in agricultural modeling for quantitative measurements (Baez-Gonzalez et al., 2005), and analysis of water use, foliage density, and crop growth (Tewolde et al., 2005). A significant correlation was found for corn LAI at V7 to 9 stage and grain yield (r=0.87) (Bavec and Bavec, 2002). Other research reported that LAI of at least 3.5 is needed by early reproductive stage of soybean in order to have optimum light interception (Board and Harville, 1993; Board and Tan, 1995). Board and Harville (1996) noted that plant LAI was positively correlated with soybean grain yield.

A commercially available soil electrical conductivity (EC) measurement system (Veris Technologies 3100) helps to identify variations in soil texture across the field and create soil zone maps using global positioning system (GPS) and geographic information systems (GIS). For the Southeastern U.S., there is limited information on assessing of photosynthetic leaf area of corn under different and soil zones, which are derived based on the EC measurements. Therefore, the objective of this study was to evaluate corn LAI under different soil zones, tillage systems, and N application rates.

METHODS AND MATERIALS

This experiment, part of a larger study, was conducted on Dothan loamy sand (fine loamy, kaolinitic, thermic Plinthic Kandiudult) at Clemson University, Edisto Research and Education Center near Blackville, SC from 2007 to 2009. Prior to planting wheat cover crop in 2006, soil electrical conductivity (EC) measurement system (Veris Technologies 3100) was used to identify variations in soil texture across the field and create soil zone maps using global positioning system (GPS) and geographic information systems (GIS). Feed wheat planted in early December of 2006 and Pioneer 26R12 wheat planted on 21 November 2007 and 4 December 2008 was killed on 26 February 2007 and 6 March in 2008 and 2009, respectively. Field was divided into 4 different soil zone areas based on the soil EC readings. Great Plains Turbo Till was used in the no-till (NT) sections and worksaver following disk was used in the conventional (CV) sections of the study prior to planting corn.

Pioneer 31G65 corn was planted at aproximately 28,000 seeds/acre in CV and NT sections using a John Deere 7300 MaxEmerge II Vaccum planter on 13 March 2007 and strip-till (ST) sections were planted using a Univerferth Ripper-Stripper (Unverferth Mtg. Co., Inc., Falida, OH) and John Deere 1700 MaxEmerge XP Vaccum planters on 14 March 2007. In 2008 and 2009, the Univerferth Ripper-stripper implement was used in ST and Pioneer 31G65 corn was planted in all plots, at the same rate as 2007, using a John Deere 7300 MaxEmerge II Vaccum planter on 18 and 23 March, respectively. Plots size was 20 ft by 12.7 ft (4 rows) and the row with was 38 inches. Liquid fertilizer (25N-0-0-25S) was applied at 40 and 80 lb N/acre on both sides of rows to selected plots using a fertilizer applicator (Reddick Equipment Co., Inc., Williamson, NC) following corn planting. Weed control was based on the South Carolina Extension recommendations.

The leaf area index (LAI) was recorded from the two adjacent middle rows of each plot. The LAI was measured within a 3 m long rows of the center rows at 2 months after planting (MAP) corn using LAI-2000 (Li-Cor, Lincoln, NE). The experimental design was a split split-plot with four replications. The PROC Mixed (SAS, 1999) was used to compare treatments. The difference between treatments was considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

The influence of soil zone on leaf area index (LAI) at 2 months after planting corn (V8) in conventional tillage at 40 and 80 lb N/acre applied at planting is shown in Fig. 1 and 2. Significantly lower plant LAI was observed from soil zone 1 than soil zone 2; however, there was no significant difference between soil zones 1, 3, and 4 at 40 lb N/acre. With increased N rate of 80 lb N/acre, plant LAI was lower from soil zone 1 than zone 4, while no significant difference was observed between zones 1, 2, and 3.

Plant LAI was also influenced by soil zone under no-till at 40 and 80 lb N/acre (Fig. 3 and 4). It was lower for soil zone 1 than 3 and 4 at 40 lb N/acre, and lower for zone 1 compared to other zones at 80 lb N/acre. As for strip-till, there was no significant difference between soil zones at 40 and 80 lb N/acre (Fig. 5 and 6).

These results indicate that plant LAI was mostly influenced by soil zone, except under strip-till. Greater plant LAI in high soil EC zones under conventional and no-till could be due to higher biomass carbon and soil mineral nitrogen production in clay loam than sandy loam as indicated by Banerjee et al. (1999). However, plant LAI did not increase under strip-till in heavier soils (higher EC) compared to sandy soils (low EC) due to most likely insufficient rainfall.

When compared main effects, there was no significant difference between tillage systems and N rates (data not shown). Other research also reported that with limited rainfall, the difference of water distributions between the minimum tillage and conventional tillage sites was small (Miyamoto et al., 2001). Williams et al. (2000) noted similar soil water content in the surface when comparing tillage systems. Strachan et al. (2002) reported that corn growth is a function of the availability of N and water, and mid-season water deficits would override the effect of N, despite duration, if there were no other limiting factors present. However, according to Josa and Hereter (2005), soils under minimum tillage system store more soil water than under conventional tillage. They also indicated that applying no-tillage and not incorporating crop residue to soils increases the amount of water. This could be due to the fact that the no-till system had as great or greater hydraulic conductivity as conventional systems owing to either a greater continuity of pores or to water flow through a few very large pores (Benjamin, 1993).

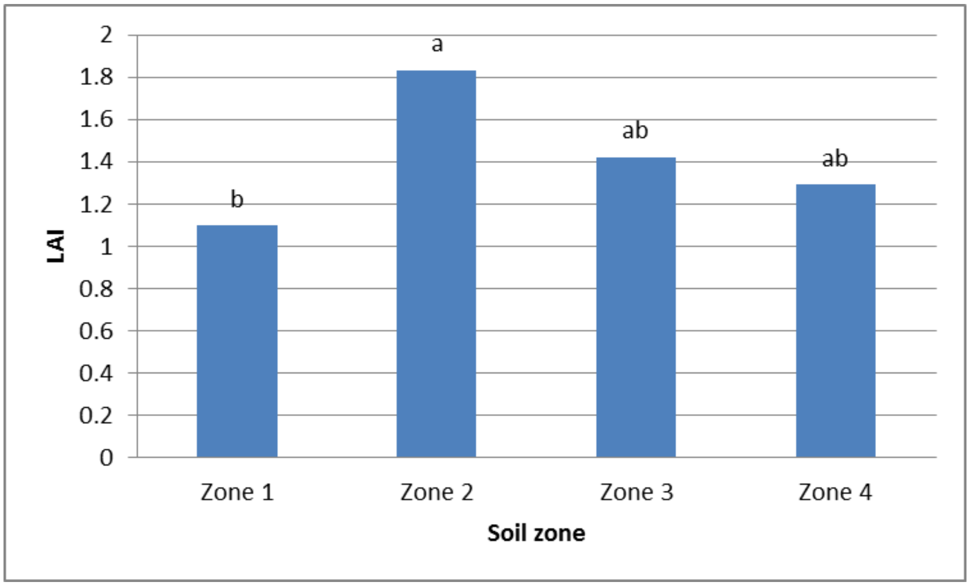

Fig. 1. Influence of soil zone on leaf area index (LAI) at 2 months after planting corn (V8) in conventional tillage and 40 lb N/acre applied at planting. Letter separation indicates significant difference at *P*≤0.05.

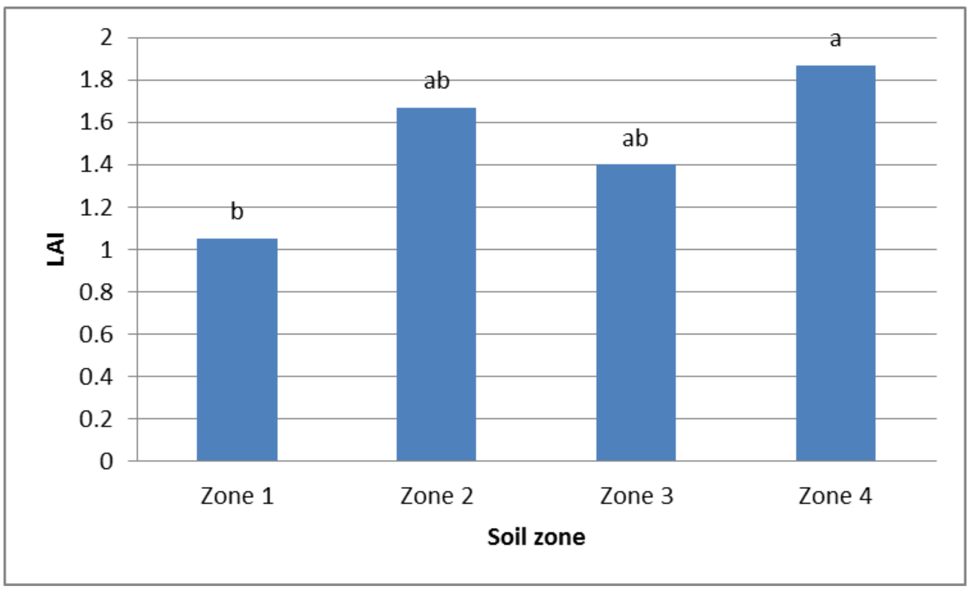

Fig. 2. Influence of soil zone on leaf area index (LAI) at 2 months after planting corn (V8) in conventional tillage and 80 lb N/acre applied at planting. Letter separation indicates significant difference at *P*≤0.05.

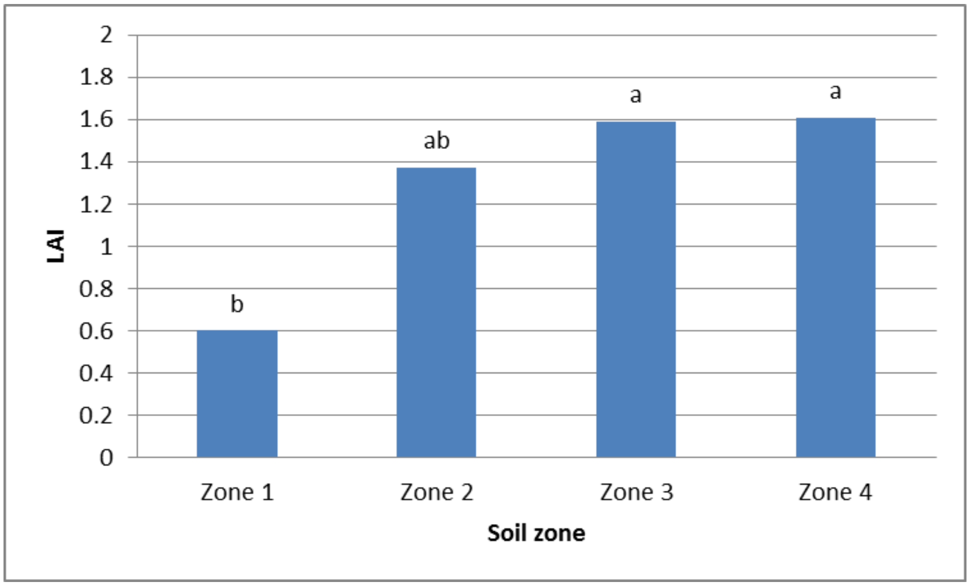

Fig. 3. Influence of soil zone on leaf area index (LAI) at 2 months after planting corn (V8) in no-till and 40 lb N/acre applied at planting. Letter separation indicates significant difference at $P \leq 0.05$.

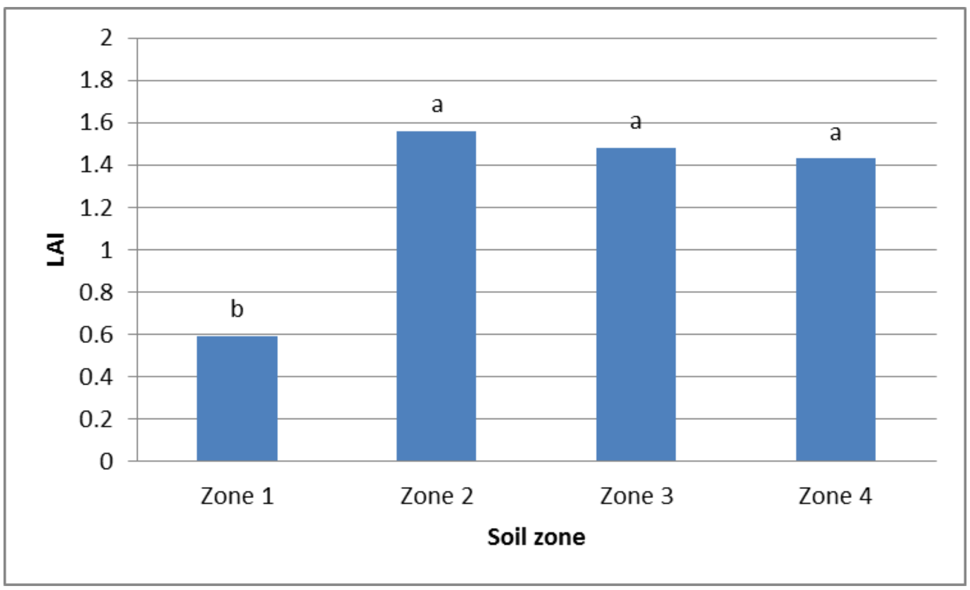

Fig. 4. Influence of soil zone on leaf area index (LAI) at 2 months after planting corn (V8) in no-till and 80 lb N/acre applied at planting. Letter separation indicates significant difference at $P \leq 0.05$.

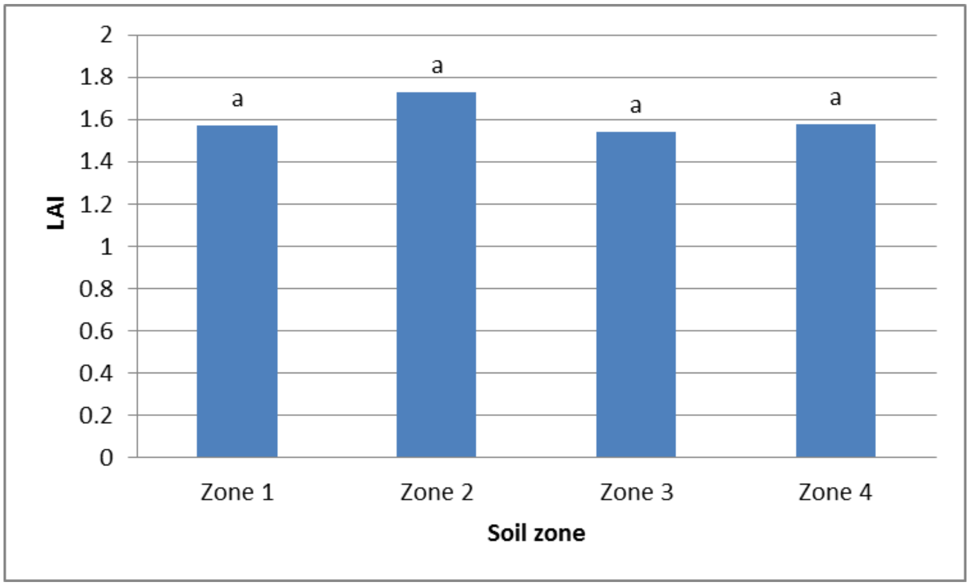

Fig. 5. Influence of soil zone on leaf area index (LAI) at 2 months after planting corn (V8) in strip-till and 40 lb N/acre applied at planting. Letter separation indicates significant difference at *P*≤0.05.

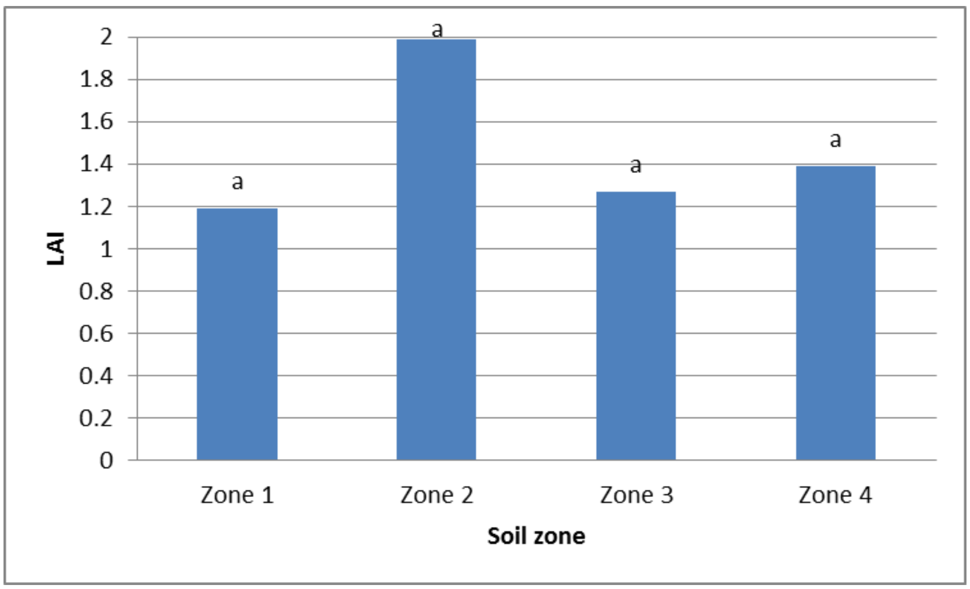

Fig. 6. Influence of soil zone on leaf area index (LAI) at 2 months after planting corn (V8) in strip-till and 80 lb N/acre applied at planting. Letter separation indicates significant difference at *P*≤0.05.

CONCLUSION

Soil zones mostly affected plant LAI under no-till and conventional tillage systems, but there was no difference between soil zones under strip-till. The plant LAI values varied, but generally showed greater plant LAI from higher soil EC zones and soils with lowest soil EC values had the least plant LAI. These results indicate that soil EC and plant LAI may be used as tools in improving soil and plant management.

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Disclaimer

Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the USDA.

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