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FOREWARD

The steering committee of the *Southern Conservation Tillage Conference for Sustainable Agriculture* emphasized the need for a systems approach for optimum production and profit with the name change to the *Southern Conservation Tillage Systems Conference* held at Florence, SC. During the Florence conference, the steering committee identified the need to further broaden the conference scope to address all practices that conserve resources and producer “inputs”. The 2006 *Southern Conservation Systems Conference* implemented these name changes as well as substituting a moderated farmer panel in lieu of a keynote speaker.

These changes seem timely for this year’s *Southern Conservation Systems Conference* in relation to resource utilization. In testimony presented before U.S. Senate Committee on “Foreign Relations” June 7, Mr. Alan Greenspan identified the increasing price of oil as a result of global competition for resources that would increase unless alternative fuels such as fuel ethanol (from switch grass) were developed. Competition for resources can similarly alter crop production costs and, consequently, agricultural profitability. Not only is production agriculture competing for resources, but also to market worldwide the food and fiber produced throughout the United States. In this year’s theme, "*Improving conservation technologies to compete for global resources and markets*," we highlight the connection between all types of conservation systems and the farmer’s bottom line profit. That is, conservation practices such as residue management not only can increase storage of precipitation as soil water and consequently the yield of dryland crops, but also decrease inputs such as water through directed irrigation application technologies.

This years Proceedings are found on the included CD. Those papers and abstracts report research results from projects devoted to characterizing soil properties in relation to tillage practices, evaluating water savings using improved irrigation technologies, comparison of various technologies for input savings and crop productivity, overviews of the beef and dairy cattle industry, and research efforts to adapt conservation tillage systems for use with integrated crop-livestock production.

We appreciate the privilege to host the 2006 *Southern Conservation Systems Conference,* and thank the authors, sponsors, and participants for their contributions.

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INTEGRATED CROP–LIVESTOCK SYSTEMS TO CONSERVE SOIL AND WATER RESOURCES IN THE SOUTHEASTERN USA

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ABSTRACT

Agricultural production and natural resource conservation need to be balanced to meet the needs of society. To achieve goals of high agricultural production while protecting the environment, modifications to current production systems are needed. Melding new and existing technologies to achieve these two societal goals is possible. Crop rotations with pastures could enhance nutrient cycling, suppress diseases, and help control pests. Ruminant livestock could consume lignocellulosic crop byproducts to add value to farming operations. Animal manures could become more effectively utilized as nutrient sources in farming systems to reduce the cost of fertilizer inputs. Covering the soil with surface residues using conservation tillage and perennial pastures could greatly improve water quality and stop the insidious spoil of soil erosion. By integrating crop and livestock production systems, more farmers will be able to farm the land because of (i) greater stability of income from diverse sources of operations and (ii) greater environmental protection of soil and water resources that will develop from the closer water, nutrient, and energy cycles shared by crop and livestock operations.

INTRODUCTION

The southeastern USA has many contrasting environmental and social characteristics that have often limited the attainment of balanced agricultural production with natural resource conservation. For example, the rich climatic resources (i.e., warm and mild temperatures with abundant precipitation) contrast with the relatively poor condition of soil resources (i.e., low soil organic matter, soil pH, nutrient reserves, and water-holding capacity). Culturally, the region has blossomed and been subsequently admonished from various developments, such as slavery and immigration (European settlers, Latin American laborers, and affluent businessmen). Historically, land was often cleared for farming and subsequently abandoned as productivity declined; early settlers often moving west to more fertile and available land. Even as recently as the 1970s when soybean hit record high prices, woodlands were cleared, and pastures were converted to crop production. With the decline in yield and price soon thereafter, land was converted to Conservation Reserve Program or again abandoned.

Agricultural production and natural resource conservation require continual adaptation of existing technologies with historical knowledge and emerging research and development. Progressive adaptation to socio-economic conditions and political pressures will lead to less stressful changes than abrupt developments caused by tragedy and disaster. The current separation of crop and livestock operations is commonplace throughout the USA, but it is not a natural or sustainable development. Cropping without animals requires extensive external inputs of inorganic fertilizer and pesticides, all based on a finite supply of fossil fuels. Confined animal production requires large inputs of grain, often produced outside of the region, which when processed through animals, becomes an environmental liability, because of concentrated waste disposal. There are many good reasons to re-integrate crop and livestock production systems, both from production and environmental perspectives. However, another immediate reason to develop modern integrated crop–livestock production systems is to capture the experiences of farmers with knowledge of historical conservation practices and meld this information with modern conservation technologies.

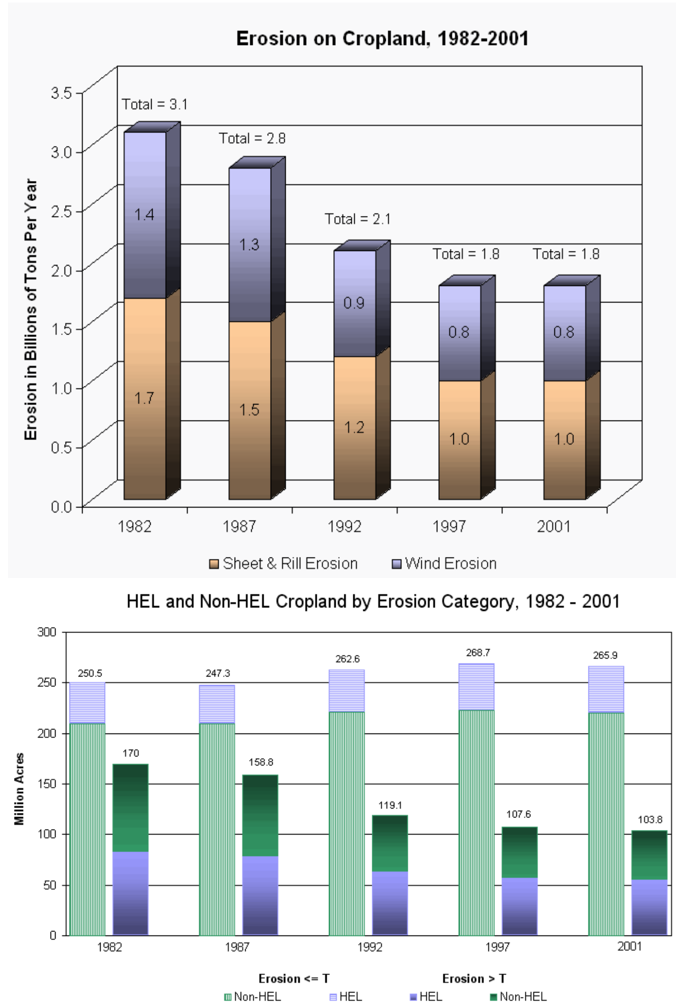

Figure 1. Soil erosion in the USA from 1982 to 2001. HEL is highly erodible land. T is the soil loss tolerance (maximum rate of annual soil erosion) that will permit crop productivity to be sustained economically and indefinitely. From http://www.nrcs.usda.gov/Technical/land/nri01/erosion.pdf.

Soil erosion has been, and continues to be, a major concern of agricultural production throughout the USA and around the world. Although there has been a positive trend in the USA for declining erosion rates during the past few decades (Fig. 1), the fact that 28% of the crop land in the USA may still be experiencing excessive soil erosion (erosion > T) is a cause for immediate concern, requiring remedial action of a nature beyond current approaches. Soil erosion is a disfiguration of the landscape that destroys the long-term integrity of one of our key natural resources that is vital to all of agriculture and society, who depend greatly upon the soil for their food and fiber needs.

One of the most effective management practices for controlling soil erosion is planting of permanent grass cover. Pastures, therefore, can provide environmental protection from soil erosion, as well as be managed for profit with the production of grazing animals. Once sufficient soil cover is achieved with perennial vegetation, soil erosion can be immediately abated even though water runoff may continue until longer term soil physical improvement occurs (Fig. 2). Many investigations have shown the benefit of sod-based cropping systems for controlling soil erosion and water runoff (Hendrickson et al., 1963a, b; Thomas et al., 1967, 1968).

Integration of crops and livestock was a common approach to agricultural production throughout the southeastern USA prior to World War II. Technological advances in plant genetics, machinery, and synthetic chemicals improved agricultural production many-fold, and eventually shifted diverse agricultural enterprises into specialized production facilities. Today, agriculture is faced with challenges and opportunities, not necessarily unique from the past, but melded with a diverse range of societal and ecological concerns about how the world and its people can be sustained. A growing awareness is emerging that the stability and resiliency of agricultural landscapes appear to be impaired by enterprise specialization, concentration of operations, and expansion of scale, which have spatially and temporally compartmentalized and disrupted energy and nutrient cycles in a manner far removed from natural ecosystem cycling (Gates, 2003). Returning agricultural systems to more integrated crop and livestock production has the potential to greatly improve the environment and to support sustainable agricultural production by:

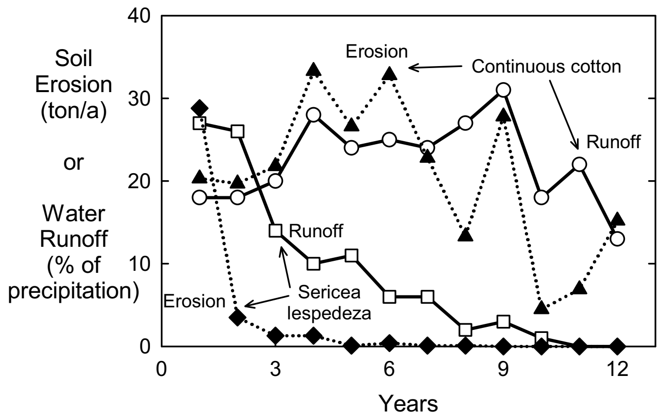

Figure 2. Soil erosion and water runoff from conventionally-tilled continuous cotton and sericea lespedeza planted as permanent cover. Data from Barnett (1965).

- Reducing soil erosion
- More efficiently utilizing natural resources
- Exploiting natural pest control processes
- Reducing nutrient concentration and consequent environmental risk
- Improving soil structure and productivity

Ruminant livestock should be considered an important part of an integrated approach, because they can convert cellulosic feedstuffs from traditional pastures and crop residues into high-value meat and milk products (Oltjen and Beckett, 1996). Pastures grazed by ruminant livestock can be an effective management option to reduce soil erosion (Hendrickson et al., 1963b; Harden et al., 1999).

Our aim in this paper was to outline some specific integrated crop–livestock production scenarios that comprise viable options to conserve soil and water resources for agricultural producers throughout the southeastern USA, while simultaneously reducing the cost of production and/or increasing productivity.

INTEGRATED CROP-LIVESTOCK PRODUCTION SCENARIOS

Rotation of Long-Term Pastures with Crops

Although considered a historical practice, rotation of pastures with crops has the potential to provide many agronomic, environmental, and economic advantages. The development of herbicide-tolerant crop varieties and improved machinery for conservation-tillage production systems has created new opportunities for producers to make a profit, in addition to protecting the environment, when employing sod-based agricultural production strategies.

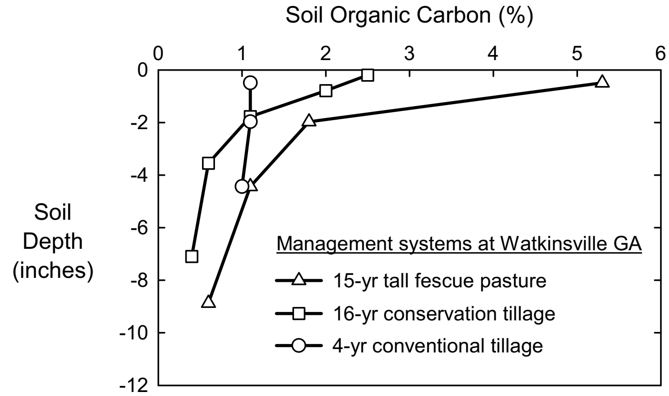

Figure 3. Soil organic C depth distribution as affected by long-term management on Cecil sandy loam in Georgia.

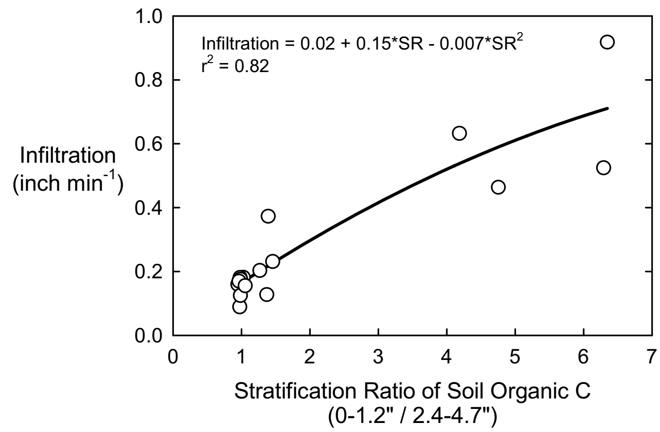

Figure 4. Water infiltration rate as affected by the stratification ratio of soil organic C in a Cecil sandy loam in Georgia (Franzluebbers, 2002).

Accumulation of soil organic matter often occurs at a high rate under pastures as a result of the perennial vegetation and high input of organic materials from animal feces, ungrazed forage, and roots (Franzluebbers et al., 2000). Much of the accumulation of soil organic matter in the southeastern USA is near the soil surface (Fig. 3), a zone in which weather causes maximum variation in soil thermal and hydraulic properties to help preserve it, but also a zone that helps mitigate compaction and allows for high water infiltration (Fig. 4). Many studies have shown the positive benefits of greater soil organic C on various other soil chemical, physical, and biological properties, which can promote greater crop production (Studdert et al., 1997; Diaz-Zorita et al., 2002; Garcia-Prechac et al., 2004). Annual crops planted after long-term pastures benefit from the slow release of nutrients sequestered in soil organic matter (Giddens et al., 1971). On farmers' fields in Argentina, wheat grain yield was positively related to soil organic C (Diaz-Zorita et al., 1999). In addition, no-tillage planting in sod preserves the macropores necessary for high water infiltration in non-cracking soils, while retaining cover to minimize soil erosion.

As one example, the following protocol is suggested for cropping following warm-season perennial sod, either managed as grazed pasture or as Conservation Reserve Program land:

- ✓ Plant Roundup-Ready corn or soybean varieties in spring, with planting date based on latitude. Apply Paraquat or glyphosate to control existing vegetation (paraquat defoliates plants rapidly and conserves soil moisture). This will destroy cool-season vegetation. The presence of some persistent broadleaf weeds may require a mixture of 2,4-D or dicamba with glyphosate as a pre-plant herbicide application. Fields should be scouted to determine the best herbicide and timing. After the crop has emerged and warm-season perennial vegetation has begun to green up (e.g., 3 to 4 weeks after planting), apply glyphosate over the top. If annual grasses and broadleaf weeds are anticipated as a problem, add atrazine or other herbicide with second glyphosate application. Competition from the vigorously developing corn or soybean crop will suppress most subsequent weed growth. Soil test and apply lime and nutrients, as needed. Apply N as broadcasted ammonium nitrate or knife in other forms of N. Broiler litter adds nutrients and mulch cover. The C factor for the USLE should range from 0.01 to 0.001 for this management strategy, which will permit cropping of many upland sites without creating an unacceptable erosion hazard. With erosion minimized using good management on upland sites (corn yield of 120-150 bu acre^{-1}), perhaps it is time to rethink our definition of marginal land. With mulch cover, water is conserved from reduced evaporation and increased infiltration, especially on soils that do not crack and rely on macropores for infiltration. Corn can either be harvested for grain or grazed by steers. Grazing would add value to both the animals and crop. Also, harvest by grazing would not require the producer to own a combine or arrange for custom harvest. Large steers (800-900 lb head^{-1}) stocked at 1.5-2 head acre^{-1} have gained 2 lb day^{-1} with 90% of animals grading at choice or select. Animals can be introduced at the R3 stage of corn and allowed to creep-graze 5-10% of the crop area, starting at a water source. As corn is consumed, the fence is moved so that feed is never limiting. Crops could be rotated in subsequent years, so that herbicides can be changed to control problem weeds. Harvest by cattle grazing attracts wildlife species, which could also become an additional source of income from fee hunting. Doves are especially attracted to this management strategy. Whether this practice could be worked into a Wildlife Habitat Enhancement Program should be investigated.

Potential benefits of conservation-tillage planting of corn or soybean into pastures could be:

- Elimination of wild forms of endophyte-infected tall fescue, which can reduce animal performance and production (Stuedemann and Hoveland, 1988). Replacement of wild-endophyte-infected tall fescue pastures with non-toxic tall fescue-endophyte associations can cost an estimated \$200 acre^{-1} (David Lang, personal communication), or even up to \$500 acre^{-1} (Zhuang et al., 2005). By growing corn or soybean, herbicide costs can be embedded in the cost of crop production, while obtaining a marketable commodity. Renovation cost could be cut in half with a short-term crop rotation. Cool-season crops can be drilled into the pasture while still occupied by grazing animals.
- Control of problem weeds in pastures. A smutgrass problem in a pasture in southern Mississippi was reduced 90% following grazed, no-tillage corn with two applications of glyphosate (David St. Louis, personal communication). Bermudagrass survived following this treatment. As this management system develops, other weed problems may appear. Typically however, periodic rotation with an annual crop could reduce cost and generate income. Currently, control of smutgrass requires an expensive herbicide (Velpar) and about 2 months with no grazing.
- Greater income potential from upland sites. Cow-calf systems typically return \$15-25 acre^{-1} year^{-1}. Grazing steers on corn has the potential to increase this return. Group IV and V, non-irrigated soybean has consistently yielded $\geq$50 bu acre^{-1} in upland variety trials in Mississippi (2005 MS Soybean Variety Trials, Information Bulletin 425, MAFES). Whether this yield can be achieved with conservation tillage on upland sites is not known, but if possible, then profit should be high (\$300 acre^{-1} gross return with \$130 acre^{-1} input cost).
- Greater labor efficiency. Crop production is characterized by periods of intense activity with other times of no activity. For example, corn and soybean have an optimum planting period lasting 3 to 4 weeks. Harvest season is about the same length. Planting and spraying for crop establishment are rapid, low draft operations. Frequent spring rains limit field time,

because wet soil limits tractor traffic. However, untilled soil supports traffic much better than tilled soil, thereby increasing field operation potential. By using no-tillage management, the number of trips can be reduced and acres covered by a laborer can be increased (Triplett et al., 2002). Partial budgeting practiced by economists does not usually address this issue.

Short-Term Grazing of Cover Crops

Cover crops provide a viable short-rotation opportunity for almost any cropping sequence in the southeastern USA. Although most previous research has been with ungrazed cover crops, adding a cover crop component can improve productivity potential and reduce environmental threats from erosion (Langdale et al., 1991) and nutrient loss (Meisinger et al., 1991; Sharpley and Smith, 1991). Despite extensive research conducted with cover crops (Hargrove, 1991; Sustainable Agriculture Network, 1998), and increasingly in combination with conservation tillage systems during the past two decades, there remains a paucity of information on how cover crops have been successfully integrated into crop–livestock systems.

Benefits from cover crops in cropping systems are numerous, including:

- controlling soil erosion
- reducing water and nutrient runoff
- improving soil tilth, structure, water infiltration, and nutrient cycling
- modifying soil moisture, by increasing uptake and reducing evaporation at different times of the year. In the southeastern USA, the soil profile will almost always by fully recharged over winter, but moisture use and delayed planting of warm season crops to achieve greater cover crop growth in spring (as well as greater N fixation by legumes) should be considered.
- contributing to soil organic C sequestration and soil biological diversity
- controlling weeds through competition, allelopathy, and microclimatic alteration
- controlling insect and disease pressures ecologically
- serving as a nutrient trap in high-fertility systems
- if leguminous, providing biologically fixed N to the cropping system

As summarized by Gardner and Faulkner (1991), having ruminant livestock utilize cover crops in a crop production system could increase the value of cover crops, because “planting and caring for a crop that apparently serves no immediate economic and harvestable purpose is both a foreign and unknown practice in much of the world . . . details, time, and skill required to manage both crops and livestock are obvious adoption barriers to seeing cover crops as pasture”. They also stated that the most basic barrier to adoption of integrated crop–livestock systems today is that many producers are reluctant to obtain or manage grazing livestock, because of a lack of experience and/or time during critical crop management periods. Livestock increased labor required on an average North Dakota farm by 56%, but only ⅓ of the additional time competed directly during critical crop management (Gardner and Faulkner, 1991).

Adams (1950) wrote “There is no substitute for good rotations in a diversified agriculture. By establishing good stands of close-growing legumes on the land, an excellent base for crop rotations is provided.” Vetch as a cover crop for continuous corn production can supply enough N that corn grain yield would not respond to additional N fertilizer (Fig. 5). With N fertilizer price rising to $\geq$\$0.50 lb^{-1} N, the cost of seeding a legume cover crop to obtain biologically fixed

N has become much more competitive than in previous decades (e.g., seed and application costs of crimson clover and other legumes would be approximately \$20-40 acre^{-1} compared with \$50 acre^{-1} with the application of 100 lb N acre^{-1}). The recent development of glyphosate-tolerant alfalfa promises to improve forage production and N fixation for subsequent crops in rotation. On suitable, well-drained sites, extending the life of alfalfa by one or two years will spread the cost of establishment over a longer period. A ≥2-year stand of alfalfa can be killed with herbicide and furnish enough N for 150 bu acre^{-1} of corn (Triplett et al., 1979).

A fully replicated field experiment investigating crop, animal, and soil responses to three management factors was initiated in 2002 near Watkinsville GA. Land previously in 20 yr of grazed tall fescue paddocks was converted to two cropping systems (sorghum grain + rye cover crop or wheat grain + pearl millet cover crop) managed under two tillage systems (no tillage or conventional with initial moldboard plow followed by disk tillage) and two cover crop scenarios (cover crop left ungrazed or grazed by cattle). During the first 2 years of production, sorghum and wheat grain yields were unaffected whether cattle were allowed to graze cover crops or not (Franzluebbers and Stuedemann, 2005a). Cover crops were more productive under no tillage than under conventional tillage (Fig. 6). Because of the greater productivity of cover crops, both cattle performance and total gain on paddocks were also greater under no tillage than under conventional tillage. From an agronomic perspective, cattle grazing of cover crops did not harm crop production. The integration of livestock with crops improved production from a whole-farm

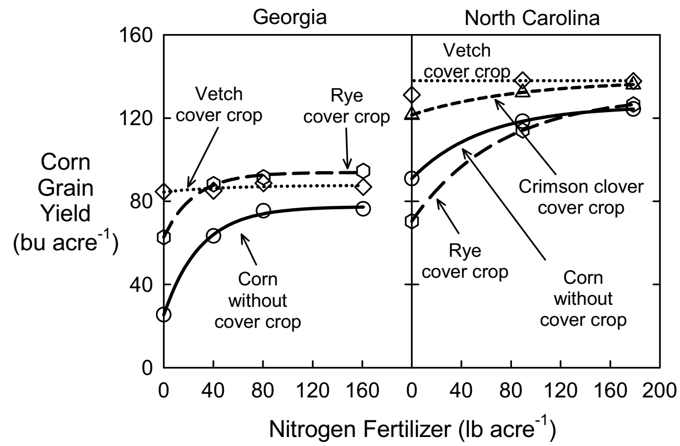

Figure 5. Corn grain yield response to N fertilizer application as affected by winter management. Georgia data from 1958 to 1964 near Watkinsville (Adams et al., 1970a). North Carolina data from 1984 (McLeansville) and 1985 (Reidsville) (Wagger, 1989).

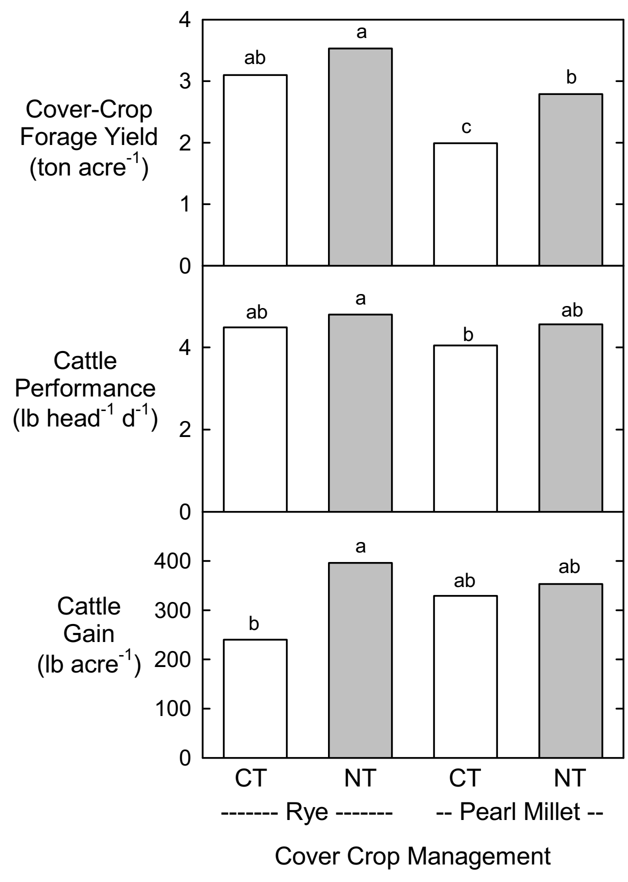

Figure 6. Cover crop forage mass production, calf performance, and cow/calf weight gain as affected by cover crop type and tillage management (CT is conventional tillage and NT is no tillage) averaged across two years. Data from Franzluebbers and Stuedemann (2005a).

perspective by utilizing cover crop biomass as a forage for cattle production. Producing crops with conservation tillage was superior to that with conventional tillage.

The effect of grazing cattle on soil properties was variable. Soil penetration resistance tended to be higher under grazed than ungrazed condition, but values depended largely upon antecedent soil water content at the time of measurement (Franzluebbers and Stuedemann, 2005b). Soil organic C concentration was initially highly stratified with depth and remained so with no tillage, but became uniform with depth following termination of perennial pasture with moldboard plowing. A change in soil organic C due to the presence of grazing cattle was not evident. Initial soil responses to grazing appear to be minimal, suggesting that the greater economic return and diversity by grazing of cover crops could benefit production and economics without damage of the environment. This research needs to be continued for validation of these implications.

Relay or Inter Cropping

Planting of annual crops into long-term pasture has been investigated in the past (Welch et al., 1967; Adams et al., 1970b; Carreker et al., 1973; Box et al., 1980; Harper et al., 1980; Wilkinson et al., 1987). These studies have included winter small grains drilled into bermudagrass, as well as corn planted into partially or completely killed tall fescue sod. Goals of such systems were to obtain simultaneous benefits from a number of opportunities within such a system:

- elevate agroecosystem productivity to match the region's climatic potential
- control erosion without full-width tillage by sowing into well-established sods that have proven erosion control effectiveness
- invigorate a pasture by disturbing the sod, but obtaining a harvestable yield component
- create a heavy nutrient demand for application of disposal rates of broiler litter
- harvest the ephemeral benefits of rotation from soil physical (aggregation, water retention), chemical (N mineralization, cation availability), and biological (disease suppression, microbial activity) improvements

Modern pasture-crop intercropping systems could also be developed with success, because of the new technologies that would allow more effective weed control and precision planting and harvesting.

In Mississippi, annual ryegrass for winter grazing is grazed out and land stays idle during summer. By relay intercropping, corn for grazing could be established while utilizing the ryegrass. Winter grazing could be re-established while grazing the corn. Wheat would be a good winter grazing crop prior to corn, because peak biomass production would occur earlier to accommodate early corn planting.

Agroforestry

Most agroforestry systems involve grazing perennial forages. With wide tree spacing, annual crops such as corn or soybean can be grown during the time when trees are too small for grazing animals to be present. Grain harvest would generate income on the front end of the tree stand. In Mississippi, corn has been grazed by cattle in such a system, rather than harvesting by machine. During initial research, accelerated tree growth from fertilizer applied to corn has been observed, which would shorten the tree rotation. This management system improves potential for weed control in the tree stand with ground equipment and herbicide selection. With wide alleys between twin rows of trees, limbs have to be pruned next to the open area. With increasing maturity of trees and as annual crops become shaded, planting of perennial forages would become better suited as an understory.

SUMMARY AND CONCLUSIONS

Conservation of soil and water resources is a necessity in our world of ever-changing and competing human activities. Meeting the food and fiber demands of a growing world population will only become more difficult with competing energy and natural resource commitments. Integration of crops and livestock has great potential to improve resource efficiency of agricultural production in the southeastern USA and around the world. A few examples of how this can be accomplished were presented, but much more research is needed to optimize systems within the unique circumstances of local and regional conditions.

ACKNOWLEDGMENTS

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COMPLEMENTARY GRAZING SYSTEMS FOR COW-CALF PRODUCTION

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ABSTRACT

A multi-year study is evaluating characteristics of dryland cow-calf production systems in the Texas Panhandle. Systems evaluated are range-only (RO), range plus a wheat-fallow-grain sorghum-forage sorghum rotation (RROT), and range plus wheat and forage sorghum cropped continuously (RCONT). RO forage is native short grass prairie rangeland. RROT forages include rangeland as in RO, along with dryland cropland maintained in a wheat-fallow- grain sorghum-forage sorghum rotation since 1998. RCONT includes rangeland as in RO, combined with separate plots of continuously cropped dryland wheat and forage sorghum. British-cross cows or cow-calf pairs are stocked on each forage system as feed production dictates. Rangeland is stocked as required to provide sustainable range condition using accepted range management principles. RROT and RCONT cropland is grazed by stocker cattle when forage quantity and quality is typically sufficient to support economical gains. Cows or cow-calf pairs utilize RROT and RCONT crops as supplementary grazing and when stocker grazing is not justified. Rangeland supported 12.8 Animal Unit Days (AUD) per acre during 2004 and 12.7 AUD per acre in 2005. RROT sorghum-sudan grazed by cows supported 67.8 AUD per acre in 2004 and 48.5 AUD per acre in 2005. RCONT sorghum-sudan grazed by cows provided 35.2 AUD per acre in 2004 and 36.5 AUD per acre in 2005. RROT wheat grazed by cows in 2005 provided 61.35 AUD per acre. RCONT wheat grazed by cows in 2005 provided 35.6 AUD per acre. RONT wheat also supported 83 pounds of stocker gain per acre in 2005.

SUMMARY

Indicators related to the Ogallala aquifer suggest a future reduction in irrigated acreage in the Texas Panhandle. Transition to dryland agricultural production systems therefore justifies study. Dryland grain production is economically risky due to precipitation risk. Dryland forage crop systems are also unpredictable, as precipitation may be insufficient to produce yields that justify stocker grazing or haying. Use of the cow-calf enterprise to harvest low-yielding and/or lower quality forages provides an alternative system. Cow-calf production has been profitable during recent years but is also susceptible to drought risk. Complementary dryland forage systems that utilize multiple forages (range, crop, warm season, cool season) with both cow-calf and stocker enterprises may provide a means of efficiently harvesting forages while reducing risks. Few studies of complementary cow-calf production systems have been conducted in the Texas Panhandle. The objectives of this study are to determine characteristics of three dryland cow-calf production systems in the Texas Panhandle.

Three dryland forage production systems for cow-calf operations are being evaluated with the following treatments: Range plus a crop rotation of wheat, grain sorghum, sorghum-sudan, fallow (RROT), and range plus wheat and sorghum-sudan planted continuously (RCONT). A range-only (RO) system serves as a control treatment. British-cross cows and cow-calf pairs were randomly allotted to the three treatment groups. RROT forages include rangeland and 228 acres of dryland cropland maintained in rotation since 1998. RCONT includes rangeland and 100 acres each of continuously cropped dryland wheat and sorghum-sudan. Rangeland is rotationally-grazed native short-grass prairie. British cross cows or cow-calf pairs were stocked on each system as forage production dictated. Crossbred steers were grazed on each system when adequate forage was available. Rangeland was stocked as required to sustain range condition using accepted range management principles (take half-leave half). All cattle were weighed at the beginning and end of grazing periods on cropland. Cows and cow-calf pairs were weighed at least quarterly when on rangeland in order to maintain accurate animal unit estimates.

Rangeland supported 12.8 animal unit days (AUD) of grazing per acre from January 1 through October 15, 2004. Rangeland supported 19,043 AUD of grazing, and 12.7 AUD per acre during calendar year 2005. Stocking decisions were based on forage estimates made from representative clipped plots taken during the fall of 2004 and throughout 2005. A range land stocking rate of approximately 12 – 14.5 AUD per acre is typical for the region.

RROT sorghum-sudan grazed by cow-calf pairs provided 67.8 AUD's per acre in 2004. British cross cow-calf pairs were grazed on RROT sorghum-sudan plots beginning July 19, 2005 and removed September 5, 2005. Sorghum-sudan plots provided 2,764 AUD of grazing, and 48.5 AUD per acre. RCONT sorghum-sudan provided 2,740 AUD and 36.53 AUD per acre for cows. RCONT sorghum-sudan also supported 4,530 lbs of stocker cattle gain and 90.6 lbs of gain per acre. RROT grain sorghum residue was grazed by cow-calf pairs beginning October 3, 2005. Grain sorghum residue provided 2,164 AUD of grazing and 39.3 AUD per acre.

Wheat planted during October 2004 was grazed in March-May 2005. RCONT wheat supported 83 lbs of gain per acre. In addition, RCONT wheat supported 1,780 AUD and 35.6 AUD per acre during cow-calf grazing, and produced 45,090 lbs of hay and 1,803 lbs of hay per acre. RROT wheat was grazed by cow-calf pairs and provided 3,497 AUD of grazing and 61.35 AUD per acre. Wheat was planted on RROT and RCONT plots on September 2, 2005 at the rate of 35 lb per acre. RROT wheat supported total gains of 888 lbs and gain of 16.1 lbs per acre between November 10, 2005 and January 6, 2006. Wheat planted on RCONT cropland did not produce enough forage for grazing.

RCONT sorghum-sudan supported 136.9 lbs of gain per acre (stocker grazing) in 2004.
Total RCONT cropland supported 22.6 AUD per acre, plus 43.41 lbs of gain per acre along with 225 lb of hay per acre. Calves were weaned from all three cattle groups on October 3, 2005. Average weaning weights for RO, RROT, and RCONT groups were 620, 595, and 664 lbs respectively.

Cow-calf production in complementary forage systems may provide useful management options to producers, and may especially be a useful tool for managing precipitation risk. The results presented here are from the first two years of a study designed to evaluate characteristics of such complementary systems. Means for range land, forage production, and animal performance are within typical ranges. Additional data collection and analysis is needed to properly evaluate the risk-reduction potential of complementary cow-calf systems, and to develop decision aids for optimum combinations of forage type and livestock in dryland systems.

Crop Emergence with Alternative SDI Designs in a Pullman Clay Loam Soil

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Abstract

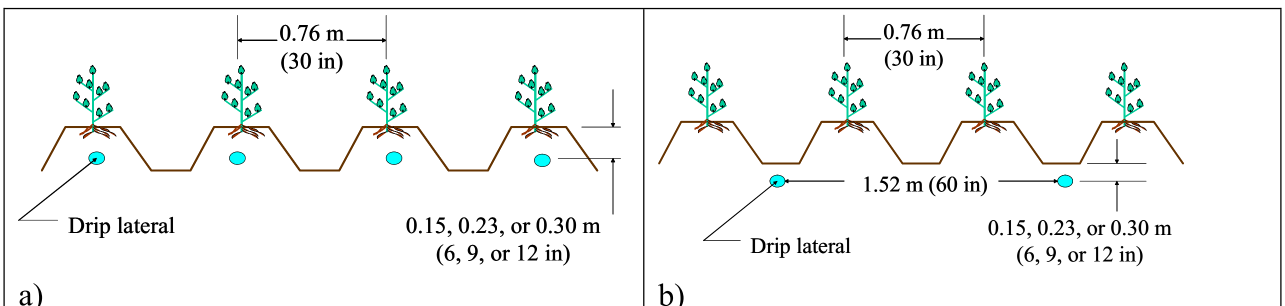
Subsurface drip irrigation (SDI) is gaining popularity with producers in the Southern and Central Great Plains region of the United States. Drip laterals are commonly installed in alternate furrows because it is cost prohibitive to install laterals in every bed for low value crops; however, crop germination can be difficult if preseason precipitation is inadequate. We evaluated soybean emergence and grain yield with laterals installed in wide beds containing two seed rows and compared this to laterals installed in alternate furrows and in every bed. The wide bed design requires the same number of laterals as the alternate furrow design, but the seed row is closer to the lateral. For each bed design, lateral burial depth was 6-, 9-, and 12-in., and irrigation amounts were 33, 66, and 100% of full crop evapotranspiration (ETc). The wide bed design generally resulted in greater plant emergence early in the season than standard beds; however, bed design and lateral installation depth did not usually result in significant differences in final grain yield. This implied that for sparser plant populations, greater water and nutrient availability per plant may have been compensating factors for final yield. This paper reports data for a single soybean crop season, and this experiment will continue for additional seasons and different crops.

Introduction

Subsurface drip irrigation (SDI) is seeing increased adoption by producers in the Texas High Plains, notably in the cotton producing area around Lubbock where water resources (mainly irrigation wells) are extremely limited. Among farmers, there is a general premise that SDI results in greater crop yields, greater water use efficiency, better cotton fiber quality, and enhanced crop earliness relative to other types of irrigation systems, and this is thought to be related to reduced evaporative cooling and the ability to maintain warmer soil temperatures during crop establishment. Colaizzi et al. (2004; 2005) found that SDI resulted in greater crop yield than LEPA or spray irrigation at small irrigation amounts (i.e, $\leq$ 50% or less of full crop ET) for grain sorghum and cotton, and preliminary data reported by Colaizzi et al. (2006) indicated that SDI resulted in greater near-surface soil temperatures than LEPA or spray for a Pullman clay loam soil in Bushland, TX. For some producers, these factors have justified the much greater cost, maintenance, and management requirements inherent in SDI. Producers using SDI also face potential difficulties in crop germination for most High Plains soils if precipitation is inadequate prior to planting. Although SDI represents less than 1% of the 4.0 million acres irrigated area in the Texas High Plains as of 2000 (TWDB, 2001), the recent northward expansion of cotton into areas where corn was traditionally produced, but which are thermally-limited for cotton, may stimulate additional adoption of SDI.

Drip laterals comprise two-thirds or more of the SDI system installation costs when laterals are installed beneath each planted row (Fig. 1a). For lower value row crops such as cotton and corn, drip laterals are commonly installed in alternate furrows (Fig. 1b), which can reduce initial capital costs by 30-40% as well as the frequency of repairs due to mechanical or animal damage (Henggeler, 1995; Camp et al., 1997; Enciso et al., 2005). The alternate-furrow installation, however, requires the wetting front to travel much further from the lateral to the seed bed. This poses considerable risk for crop establishment if the near-surface soil profile is dry and if soil conditions are unfavorable for the horizontal or upward movement of water, such as in the presence of cracks (Howell et al., 1997; Bordovsky and Porter, 2003), soil compaction (Enciso et al., 2005), or relatively low capillary potential (Thorburn et al., 2003). Dry soil conditions at planting have been increasingly common in recent years due to widespread drought throughout much of the Central and Western US, and excessive irrigation water is sometimes required to germinate crops using SDI, especially for cracking soils commonly found in the Texas High Plains, defeating the purpose of SDI.

The wide bed, or twin row design (Fig 1c) has been used successfully in the Southeastern U.S. for corn (Phene, 1974; Phene and Beale, 1979), in Israel for cotton (Oron, 1984), and by producers in Arizona for numerous crops. This design has the same number of SDI laterals and plant rows per unit area as standard beds with laterals in alternate furrows (Fig. 1b), but the seed bed is much closer to the lateral, motivating the hypothesis that better crop establishment and yield would result. The objective of this research was to compare crop emergence and final yield for the alternative SDI designs shown in Fig. 1 for three lateral installation depths (6, 9, and 12 in.).



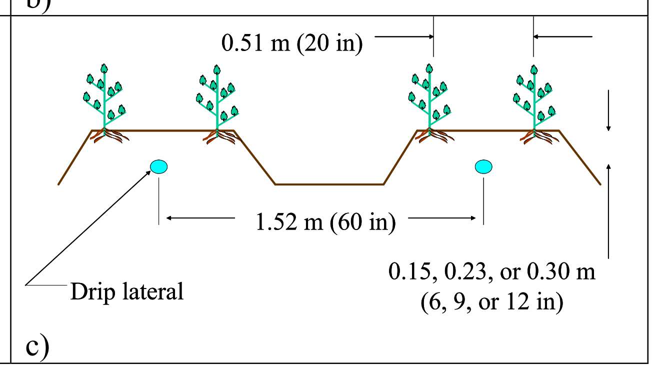


Figure 1. SDI bed and lateral spacing and installation depths, a) laterals in each bed with 30-in. spacing; b) laterals in alternate furrows with 60-in. spacing; c) wide bed (twin row) with laterals centered in each bed with 60-in. spacing.

Materials and Methods

The experiment was conducted in 2005 at the USDA Conservation and Production Research Laboratory at Bushland, Texas (35° 11′ N lat., 102° 06′ W long., 3,510 ft elevation MSL). The climate is semi-arid with a high evaporative demand of about 102 in. per year (Class A pan evaporation) and low precipitation averaging 18 in. per year. Most of the evaporative demand and precipitation occur during the growing season (May to October) and average 61 and 13 in., respectively. The climate is also characterized by strong regional advection from the south and southwest, with average daily wind runs at 6-ft height exceeding 280 mi, especially during the early part of the growing season. The soil is a Pullman clay loam (fine, superactive, mixed, thermic torrertic Paleustoll; USDA-NRCS, 2005), with slow permeability due to a dense B21t layer that is 6- to 15-in. below the surface. A calcic horizon begins about 47 in. below the surface.

A subsurface drip irrigation (SDI) system was installed at the study location with east-west oriented raised beds in a randomized complete block design replicated three times with subplots. Main plot factors consisted of the irrigation treatment (I0, I33, I66, and I100) and bed design (Fig. 1), and the subplot factor was the SDI lateral installation depth (6-, 9-, and 12-in. below the soil surface). The I100 irrigation treatment was sufficient to prevent yield-limiting soil water deficits from developing, and was based on soil water measurements with neutron scattering to the 8-ft depth. Integer values in treatment codes (i.e., I0, I33, I66) indicate the percentage of irrigation applied relative to full (I100) irrigation. From planting to the vegetative growth stage, irrigation water was applied when soil water measurements indicated a deficit of 1 in. less than field capacity over the 5-ft deep root zone in the I100 treatment, after which the appropriate irrigation amount was applied on a weekly basis to replenish soil water to field capacity. The different irrigation treatments were used to estimate production functions, and to simulate the range of irrigation capacities typical in the Texas High Plains. The I0 treatment received only sufficient irrigation to ensure crop emergence. The bed designs included SDI laterals in alternate furrows (Fig. 1b) and wide beds (Fig. 1c) for the I33, I66, and I100 treatments. The design with laterals installed in every bed (Fig. 1a) was used for the I0 plots. This design was also used for three additional plots along the south boundary of the field, which were irrigated identically to the I100 treatment but were outside the randomized complete block design. SDI laterals (commonly termed "drip tape") were Netafim model Typhoon 990[1], 13 mil thickness, with 0.25-gal hr^{-1} emitters spaced 12-in. apart (24-in. apart for laterals in every bed), resulting in an application rate of 0.08 in. hr^{-1} (35 gal min^{-1} ac^{-1}) for all plots. Irrigation treatments were therefore imposed by varying the duration of each irrigation event. Main plots were 285-ft long and were divided into three 85-ft-long subplots along the row direction, separated by a 15-ft transition area to change the SDI lateral installation depth. Each plot had 12 rows for the standard bed design (Figs 1a and 1b, 30-in. bed centers) and 6 rows for the wide bed design (Fig. 1c, 60-in. bed centers).

Agronomic practices were similar to those in the Texas High Plains for irrigated corn and soybean production (Table 1). Preplant herbicide (Laymaster) was applied at 1 qt ac^{-1} on 14 April, and corn (*Zea mays L*., cv. Pioneer 33B54) was planted on May 11, 2005 at 34,000 plants per acre, but was destroyed by two severe hail storms on 10-11 June. Liquid nitrogen (32-0-0) was injected into the subsurface drip irrigation (SDI) system and totaled 60 lbs ac^{-1} for all plots when the hail storms occurred. The hail-damaged corn was removed 20 June, and the field was replanted in soybeans (*Glycine max* cv. Pioneer 94M90) on 22 June at 180,000 plants per acre. No other chemicals or fertilizer were applied for the remainder of the season.

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[1]The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by the USDA-Agricultural Research Service.

Table 1. Agronomic and irrigation parameters for 2005 corn and soybean season.

Corn Planting Date	5/11/05		
Corn Variety	Pioneer 33B54		
Plant Density	34,000	Plants ac^{-1}	
Nitrogen	60.0	lbs ac^{-1}	
Herbicide (Laymaster)	1.0	qt ac^{-1}	
Hail Storms	6/10-6/11/05		
Corn Removed	6/20/05		
In-season rain (corn)		4.5	in.
In-season irrigation (corn)	I0	1.3	in.
	I33	2.2	in.
	I66	2.8	in.
	I100	3.6	in.
Soybean Planting Date	6/22/05		
Soybean Variety	Pioneer 94M90		
Plant Density	180,000	Plants ac^{-1}	
Harvest Date	10/26/05		
In-season rain (soybeans)		5.5	in.
In-season irrigation (soybeans)	I0	0.0	in.
	I33	3.1	in.
	I66	6.4	in.
	I100	9.3	in.

The number of plants emerged were counted at four locations in each subplot (rows 3, 4, 9, and 10 in a 39-in. distance) on 29 June, 5 July, 14 July, and 21 July. Volumetric soil water was measured in the top 6-in. soil layer at the same time and location of the plant emergence counts using a portable Time-Domain Reflectometry (TDR) system (Evett et al., 2005). Soil water was also measured on a weekly basis in the 8-ft profile using a Campbell Pacific Nuclear (Martinez, CA) model 503DR neutron moisture meter, but only in subplots with the 9-in. lateral installation. The neutron moisture meter was calibrated according to procedures described by Evett and Steiner (1995), and a depth control stand was used for calibration, measurement, and standard counts (Evett, 2003). The depth control stand was required to achieve a calibrated accuracy of ≤ 0.01 ft^3 ft^{-3}, which included the top 4-in. soil layer (Hignett and Evett, 2002). The profile measurements were used to compute seasonal water use (irrigation + rainfall + change in soil water) and to verify that irrigation was sufficient so that no water deficits developed in the I100 treatment. Plants were harvested by hand in two 21.5-ft^2 areas of each subplot (rows 3-4 and 9-10) on 17 Oct to determine grain yield, seed weight, harvest index, plant height, and plant density; the remainder of the field was harvested by machine on 26 Oct.

Plant emergence at 13 and 29 days after planting (DAP) (5 and 21 July, repsectively) and grain yield were tested for differences for each bed design and lateral depth using the SAS mixed model (PROC MIXED, Littell et al., 1996). In PROC MIXED, fixed and random effects are specified separately. Fixed effects were bed design, irrigation treatment, and lateral depth. Random effects were block replicates, block by bed design, block by irrigation treatment, and block by bed design by irrigation treatment. Differences of fixed effects were tested using least square means ($\alpha \leq 0.05$) within each irrigation treatment (i.e., the level slice option was used for irrigation treatment). The PROC MIXED procedure was also used to test for differences in grain yield, seasonal water use, water use efficiency (WUE), and irrigation water use efficiency (IWUE) among bed designs and irrigation treatments for each subplot with the 9-in. lateral depth (since available resources restricted soil water profile measurement to these subplots only). Here, WUE was defined as the ratio of grain yield (GY) to seasonal water use (WU) or WUE = GY WU^{-1}. IWUE was defined as the increase in irrigated yield (Y_i) over dryland yield (Y_d) due to irrigation (IR), or IWUE = $(Y_i - Y_d)\ IR^{-1}$ (Bos, 1980).

RESULTS AND DISCUSSION

The number of plants emerged at 13 and 29 days after planting (DAP) were compared for each lateral installation depth and bed design among irrigation treatments (Table 2; Fig. 2). For the I33 and I66 irrigation treatments at 13 DAP, the wide bed design (WIDE) resulted in significantly greater emergence than standard beds with laterals in alternate furrows (STD-af) at the 9- and 12-in. lateral depths, and numerically greater emergence than standard beds with 6-in. laterals. For the I100 treatment at 13 DAP, the wide beds resulted in significantly greater emergence than the standard beds with 12-in. lateral depths, although emergence for the standard bed 6-in. lateral depth was largest at 3.9 plant ft^{-1}. Trends were similar by 29 DAP, but differences tended to be more numerical. The I100 treatment with laterals in every bed (I100, STD-eb) resulted in the greatest emergence for both 13 and 29 DAP; however, these plots were not randomized and so could not be compared on a statistical basis. Furthermore, producers in the Texas High Plains perceive it cost prohibitive to install laterals in every bed at 30-in. centers for most low-value crops, despite the obvious advantages in plant emergence (Enciso et al., 2005). As expected for standard beds, the 6-in. lateral depth resulted in greater emergence than deeper laterals for all irrigation treatments, but we experienced much greater mechanical and rodent damage with this shallow lateral depth. For the wide bed design by 29 DAP, emergence was slightly greater for the 9-in. lateral depth than the 6- or 12-in. depths for all irrigation treatments (Fig. 2b), which may reflect a tradeoff between providing adequate water without excessive seed bed cooling. We have not completed the analysis of the near-surface soil water measurements using the portable Time Domain Reflectometry (TDR) system. We may see a greater emergence response during the 2006 growing season as conditions have been extremely dry since the end of the 2005 season.

Final grain yield was compared for each lateral installation depth and bed design among irrigation treatments in a manner similar to plant emergence (Table 2, Fig. 3). Grain yield was not as responsive to the bed design or lateral depth factors as plant emergence. Yield differences were numerical among all irrigation treatments except for I33, where yield for the wide bed with a 9-in. lateral depth (28.8 bu ac^{-1}) was significantly less than that for the wide bed with the 12-in. lateral depth (36.2 bu ac^{-1}). This result was not expected, as this treatment had the greatest plant emergence by 29 DAP for the I33 treatment (Fig. 2b). Yields for the 6- and 12-in. lateral depths were nonetheless numerically greater than those for the standard beds. For the I66 treatment, yields for all standard bed lateral depths were numerically greater than the wide bed 6- and 12-in. lateral depths, also unexpected considering early plant emergence trends (Fig. 2). The greater yield for sparser plant populations may have resulted from greater water and nutrient availability per plant. For the I100 treatment, yields were greater for all wide bed lateral depths than those for the standard beds, and the 12-in. lateral depth resulted in the largest yield (47.0 bu ac^{-1}) observed for the 2005 season (Fig. 3).

Table 2. Plants emerged at 13 and 29 days after planting (DAP), and final grain yield for 2005 soybean season.

Bed design	Irrigation treatment	Drip lateral depth (in.)	13 DAP Plant emergence (ft^{-1})		29 DAP Plant emergence (ft^{-1})		Grain yield (bu ac^{-1*})	
STD30	I0	6	2.7	a	3.1	a	28.0	a
STD30	I0	9	2.2	a	2.3	a	26.0	a
STD30	I0	12	2.4	a	2.8	a	27.4	a
STD60	I33	6	2.5	bc	2.8	bcd	28.3	ab
STD60	I33	9	1.8	c	2.1	d	29.9	ab
STD60	I33	12	1.7	c	2.5	cd	29.0	ab
WIDE60	I33	6	3.3	ab	3.3	abc	34.5	ab
WIDE60	I33	9	3.5	ab	3.7	a	28.8	b
WIDE60	I33	12	3.6	a	3.5	ab	36.2	a
STD60	I66	6	2.5	a	3.2	a	40.1	a
STD60	I66	9	1.3	b	2.2	b	41.1	a
STD60	I66	12	0.4	b	2.1	b	37.2	a
WIDE60	I66	6	3.2	a	3.4	a	36.8	a
WIDE60	I66	9	3.4	a	3.8	a	40.3	a
WIDE60	I66	12	2.9	a	3.4	a	36.3	a
STD60	I100	6	3.9	a	3.8	a	36.4	a
STD60	I100	9	3.0	ab	3.4	a	40.5	a
STD60	I100	12	2.5	b	3.2	a	35.7	a
WIDE60	I100	6	3.8	a	3.6	a	42.2	a
WIDE60	I100	9	3.8	a	3.7	a	43.3	a
WIDE60	I100	12	3.7	a	3.4	a	47.0	a
STD30	I100	6	4.8		4.4		45.0	
STD30	I100	9	4.2		4.3		37.8	
STD30	I100	12	4.3		4.6		42.4	

* 13% moisture basis.

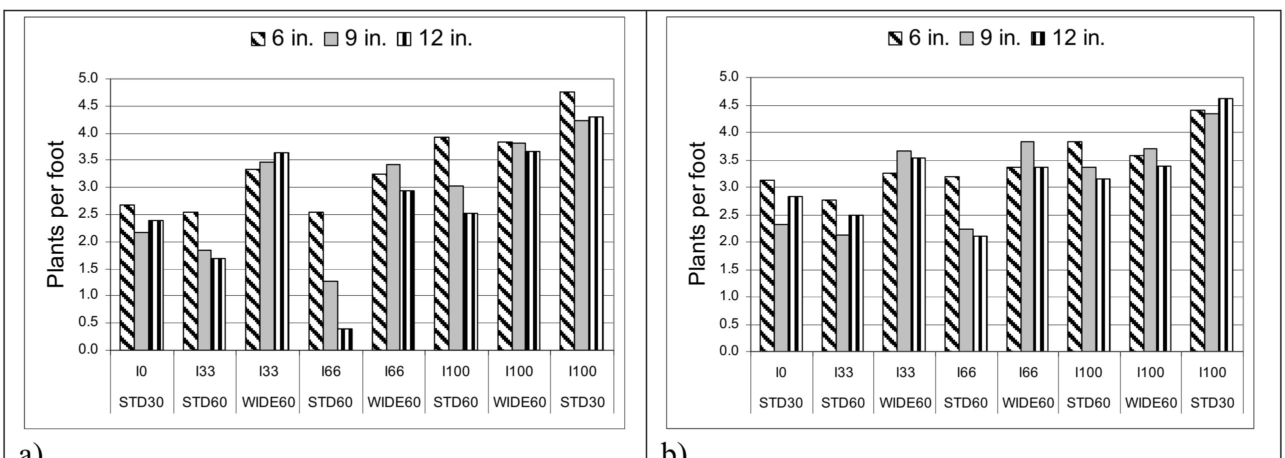

Figure 2. Plants emerged after a) 13 days after planting; b) 29 days after planting.

Seasonal water use, grain yield, water use efficiency (WUE), and irrigation water use efficiency (IWUE) were compared between irrigation treatments and bed designs for subplots with the 9-in. lateral installation depth. Seasonal water use varied by irrigation treatment but did not appear sensitive to bed design (Table 3). A significant linear relationship between grain yield and seasonal water use was observed for the I0, I33, and I66 treatments, but not for the I100 treatment (Fig. 4). The range of grain yield vs. seasonal water use observed here was similar to that reported by Payero et al. (2005) for soybeans under solid set and surface drip irrigation at North Platte and Curtis, NE. But yields were approximately 25% less than those for full SDI irrigation for flat-planted soybeans at the same location observed by Evett et al. (2000) in 1996 and 1998, possibly due to the shorter growing season for the present study. No significant differences were observed for WUE and IWUE, but these were numerically greatest for the I66 treatment (Table 3). WUE values were similar to those reported by Evett et al. (2000).

Table 3. Seasonal water use, yield, water use efficiency (WUE), and irrigation water use efficiency (IWUE) for 2005 soybean season (9-in. drip lateral depth subplots only).

Bed design	Irrigation treatment	Seasonal water use (in.)		Grain yield (bu ac^{-1*})		WUE (bu ac^{-1} in.$^{-1}$)		IWUE (bu ac^{-1} in.$^{-1}$)	
STD30	I0	14.3	b	23.9	b	1.7	a	----	
STD60	I33	16.6	b	29.6	b	1.8	a	15.0	a
WIDE60	I33	17.3	b	29.7	b	1.7	a	16.5	a
STD60	I66	20.0	ab	41.9	a	2.0	a	24.4	a
WIDE60	I66	20.1	ab	41.7	a	2.0	a	24.6	a
STD60	I100	24.1	a	41.8	a	1.8	a	17.2	a
WIDE60	I100	25.2	a	41.7	a	1.7	a	16.8	a
STD30	I100	24.6		37.8		1.5		13.0	

* 13% moisture basis.

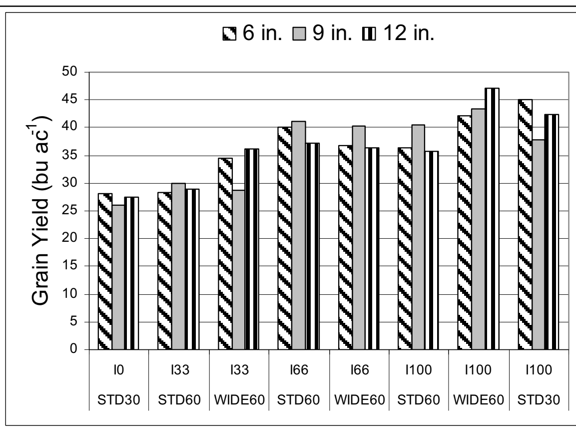

Figure 3. Soybean yield for irrigation rates, bed designs, and drip lateral installation depths for the 2005 season.

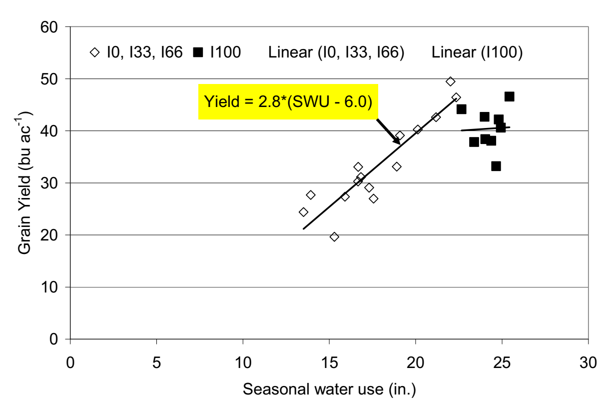

Figure 4. Production functions for 2005 soybean season.

CONCLUSIONS

Plant emergence and soybean grain yield were evaluated for alternative subsurface drip irrigation (SDI) designs and lateral installation depths among a range of irrigation treatments. Although the wide bed design generally resulted in greater plant emergence early in the season than that for standard beds (with SDI laterals in installed in alternate furrows), bed designs and lateral installation depths usually did not result in significant differences in final grain yield. For the I33 and I100 treatments, grain yield was numerically greater for the wide beds, with the exception of the wide-bed I33 treatment with the 9-in. lateral installation depth, for which grain yield was significantly less than that for the 12-in. lateral depth. For the I66 treatment, grain yield was similar between the wide and standard bed designs, although early season plant emergence was often significantly less for the standard beds. This implied that for sparser plant populations, greater water and nutrient availability per plant may have been compensating factors for final yield. No consistent correlation between lateral installation depth and final yield was observed for the single season of data reported here. Although these results suggest there are no advantages to the wide bed design, this study will continue for additional seasons and different crops, which may have vastly different responses than the single season of soybean data presented here.

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ESTIMATING DAILY AND SEASONAL CROP WATER USE OF HIGH PLAINS CROPPING SYSTEMS USING REMOTE SENSING AND CROP MODELING

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ABSTRACT

A procedure is described for estimating daily and seasonal crop water use (CWU) using a "spectral crop coefficient" determined from remote sensing data. This procedure is easy to evaluate from available weather and remote sensing data, and provides results that are specific to individual fields. The approach is demonstrated using data from 26 agricultural fields (mostly cotton and pasture) in the Texas High Plains.

INTRODUCTION

Conservation of water resources has become a critical issue in the Texas High Plains and other semi-arid and arid portions of the world. Strategies for conserving scarce water resources might involve the use of cropping systems that require less water while still providing an attractive economic return to producers. Critical to the comparison of different cropping systems is the ability to assess the amount of water actually used in growing a crop. This is commonly called the crop water use (*CWU*), and it is essentially equal to the transpiration of the crop. Knowing *CWU*, one can determine the water use efficiency (WUE) of the crop (in terms of the biomass produced per unit of water transpired), along with the efficiency of applied irrigation (in terms of *CWU* per unit of irrigation applied to the crop).

Many procedures have been suggested for estimating *CWU*. A common, relatively simple approach to estimating daily *CWU* involves multiplying a crop coefficient K_c by the daily value of potential evapotranspiration ET_0 for a well-watered vegetated surface (Allen, 2003),

$$CWU = K_c \times ET_0 \quad \text{[Eq. 1]}$$

Here, ET_0 is calculated from ambient weather conditions, and K_c is determined empirically for a specific crop. The value of the crop coefficient normally varies over the duration of the growing season, increasing from a value near zero early in the season to a value near 1 in mid-season.

Maas et al. (2004, 2005) extended this concept by evaluating the crop coefficient from remote sensing observations. Equation 1 may be re-written,

$$CWU = K_{sc} \times ET_0 \quad \text{[Eq. 2]}$$

where K_{sc} represents a "spectral crop coefficient" numerically equivalent to crop ground cover (GC). GC can be easily estimated from remote sensing observations, and its use in place of the standard empirically determined K_c allows the estimation of *CWU* to be specific for each field application. Using data obtained from a dryland cotton field near Littlefield, TX, Maas et al. (2005) showed that this approach was capable of reasonably estimating *CWU* at various times during the growing season.

Crop GC can be easily estimated using satellite remote sensing observations in the red and near-infrared spectral bands. Since satellite observations occur infrequently due to the overpass schedule of the satellite and the availability of cloud-free sky conditions, a method is needed to estimate *CWU* for the days without remote sensing observations. The approach used in this study relies on a crop growth simulation model (Maas, 1993a, 1993b; Ko et al., 2005) to estimate crop GC on each day of the growing season, allowing calculation of daily *CWU* using Equation 2. Daily values of *CWU* can then be summed over the course of the growing season to produce seasonal estimates of *CWU*. In this article, we present preliminary results obtained for a number of cropping systems that demonstrate the efficacy of this approach.

MATERIALS AND METHODS

Results of the spectral crop coefficient approach were obtained for 26 agricultural fields in the Texas High Plains during the 2005 growing season. Landsat-5 images containing the study region were analyzed to determine ground cover (GC) in each study field. Five Landsat images (Table 1) were used for this analysis.

Table 1. Landsat-5 overpass dates.

10 May 2005
13 July 2005
30 August 2005
1 October 2005
17 October 2005

Daily weather data used in running the model simulations for each field were obtained from the West Texas Mesonet. These data were also used in calculating daily potential evapotranspiration (ET_0) for each day of the growing season for use in Equation 2.

RESULTS AND DISCUSSION

An example of simulated crop GC and daily *CWU* is presented in Figures 1 and 2, respectively, for an irrigated cotton field in the study. In Figure 1, the daily values of GC simulated by the model provide a continuous description of ground cover for the crop over the growing season, and may be compared to the five observed GC values derived from Landsat observations. The shape and magnitude of the GC curve affects the distribution of daily *CWU* values in Figure 2, which exhibits a peak in *CWU* values during the period of maximum ground cover.

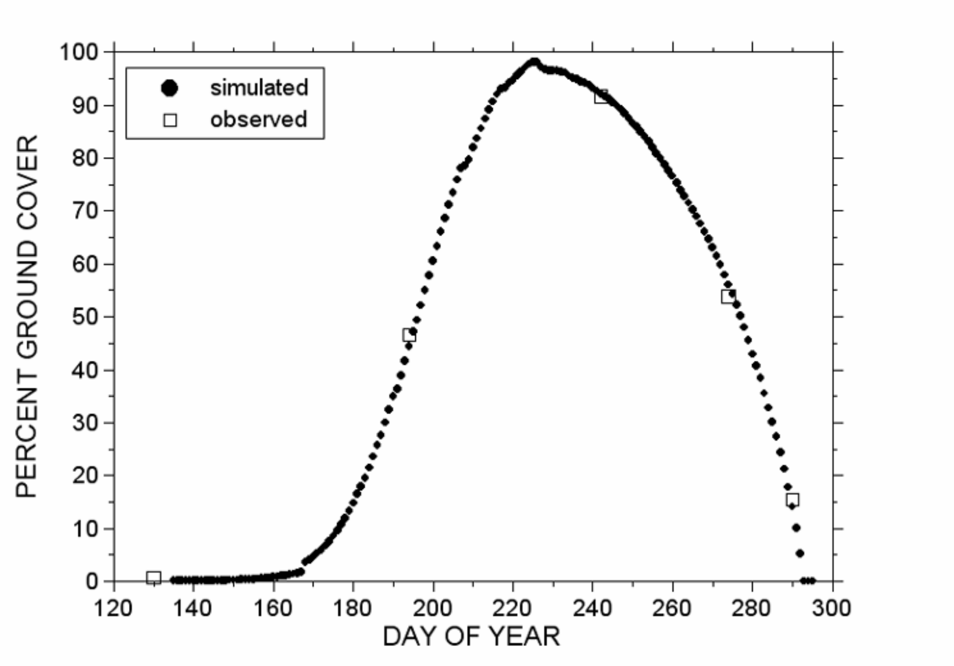

Figure 1. Simulated and observed values of crop ground cover for an irrigated cotton field in the study.

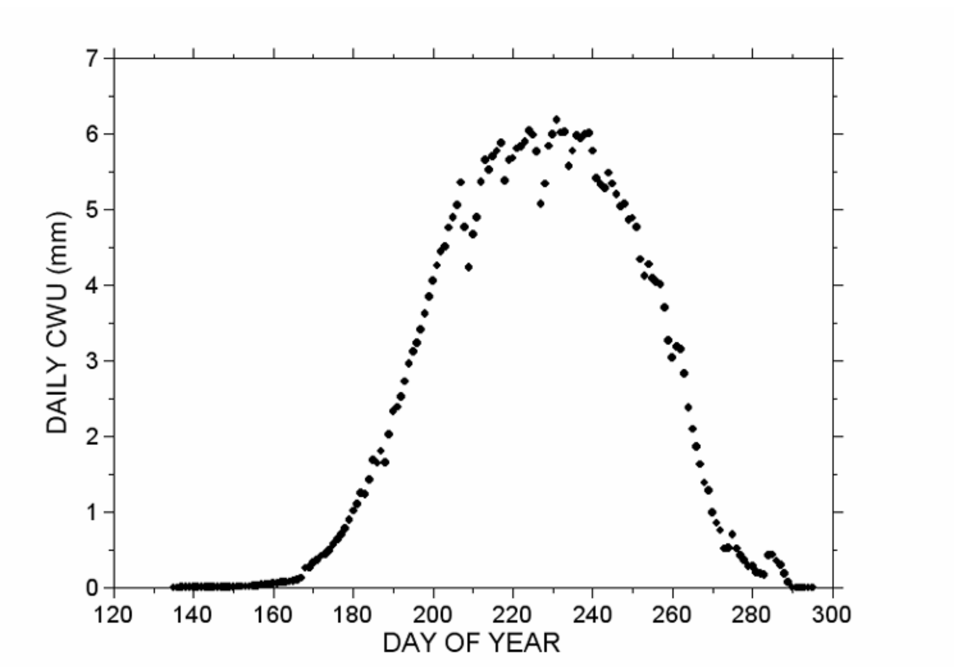

Figure 2. Estimated daily crop water use for the field in Figure 1 computed using Equation 2.

Table 2. Accumulated daily *CWU* over the period from day 121 through day 295 for various fields in the study.

Crop	*CWU* (mm)	*CWU* (in)
irrigated cotton	408	16.1
irrigated cotton	389	15.3
irrigated cotton	421	16.6
irrigated cotton	267	10.5
irrigated alfalfa	819	32.2
irrigated cotton	303	11.9
irrigated cotton	391	15.4
irrigated pasture	293	11.6
irrigated pasture	289	11.4
irrigated pasture	281	11.1
irrigated pasture	282	11.1
irrigated pasture	345	13.6
irrigated pasture	413	16.3
irrigated cotton	345	13.6
irrigated pasture	173	6.8
irrigated cotton	290	11.4
irrigated pasture	209	8.2
irrigated cotton	381	15.0
irrigated pasture	265	10.4
irrigated pasture	345	13.6
irrigated cotton	242	9.5
irrigated cotton	260	10.2
irrigated cotton	224	8.8
dryland cotton	138	5.4
dryland cotton	173	6.8
irrigated cotton	259	10.2
irrigated cotton	340	13.4
irrigated cotton	279	11.0
irrigated cotton	312	12.3
irrigated pasture	465	18.3
irrigated cotton	441	17.4
irrigated cotton	345	13.6
irrigated cotton	358	14.1
irrigated cotton	358	14.1
irrigated cotton	280	11.0
irrigated cotton	280	11.0
irrigated cotton	402	15.8
irrigated cotton	322	12.7
irrigated cotton	386	15.2
irrigated cotton	378	14.9

Table 2 shows estimates of seasonal *CWU* for various fields in the study. Total potential evapotranspiration (ET_0) for the growing season was 1033 mm (40.7 in). Seasonal *CWU* for irrigated crops and pastures was considerably more than corresponding values for dryland crops. The greatest seasonal *CWU* (819 mm, or 32.2 in) was estimated for irrigated alfalfa, with a value approaching 80% of the potential value.

CONCLUSIONS

The spectral crop coefficient approach was able to show differences in daily and accumulated *CWU* among the fields in this study. Differences appeared to be related to vegetation type and irrigation. These preliminary results on *CWU* were obtained during a year with above-average rainfall during the first half of the growing season. Results may be different in years with different precipitation characteristics.

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ECONOMIC ANALYSIS OF CONSERVATION TILLAGE WINTER SMALL GRAINS FORAGE PRODUCTION IN ARKANSAS

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ABSTRACT

Winter grazing of stocker cattle on small-grain pastures may be a profitable income option for cattle and wheat producers in Arkansas. However, a large portion of land area that could potentially benefit from this production system is highly erodible, and care should be placed on choosing the appropriate forage production method to ensure the existing natural resource base is not degraded over time. This study evaluates the profitability of reduced till and no-till production of winter wheat/rye forage using two years of small grains pasture and steer weight gain data from the Livestock and Forestry Branch Station (LFBS) near Batesville, Arkansas. The results indicate that both conservation tillage methods are profitable when compared with conventional "clean till" small grains forage production.

INTRODUCTION

Winter wheat is one of the most common winter annuals grown in the United States due to its high forage quality and adaptability to a wide rage of climates. Soft red winter wheat is the common wheat type grown in the southern United States and is the primary wheat type produced in Arkansas. Soft red winter wheat is almost exclusively harvested for grain in Arkansas with over 90 percent of total wheat area planted in the Delta region of the state. Production systems that integrate stocker cattle with soft red winter wheat production may have value both in Arkansas and the southern United States. Grazing stocker cattle on soft red winter wheat may provide an alternative income source to Arkansas wheat and cattle producers.

Research conducted from 1996 to 2001 at the Livestock and Forestry Branch Station (LFBS) near Batesville, Arkansas has shown that stocker calves can be productively grazed on soft red winter wheat during the winter (Daniels et. al., 2002). However, conventional "clean till" planting methods were used exclusively in this research. Soil erosion is a major concern with conventional till production of winter small grains forage. Much of the land area that could potentially be used for winter wheat forage production in Arkansas is highly erodible, and practices that maintain surface residue such as reduced till or no-till may be more appropriate in areas susceptible to soil erosion.

Rainfall is also critical for forage production and can be an important consideration when either inadequate or overabundant. While dry conditions limit forage establishment and growth with conventional till management, mud affects livestock footing and increases grazing difficulty. Reduced till and no-till practices, which leave stubble on the ground, have been shown to conserve summer moisture by limiting weed growth and reducing evaporative losses. Under wet conditions, no-till managed forage might permit grazing on lands that would otherwise be unsuitable at the same moisture content under conventional till management.

Profit generation is an important consideration when evaluating alternative winter small grains forage production methods. Conventional till requires the use of large and expensive pieces of equipment and is very fuel and labor intensive. Reduced till and no-till require less machinery and equipment and are less fuel and labor intensive. However, reduced till and no-till substitute herbicides either partially or exclusively for tillage for weed control, and the additional cost of herbicide applications can be substantial (Epplin et al., 1982). This study evaluates the profitability of grazing stocker calves on soft red winter wheat and rye forage produced with conventional till, reduced till, or no-till methods. Steer weight gain data and forage production data from two years of winter small grains forage research at the LFBS are used to calculate the costs and returns of forage production and stocker grazing for the three tillage treatments.

MATERIALS AND METHODS

The three tillage treatments evaluated in this study are Conventional Till (CT), Reduced Till (RT), and No-Till (NT). The CT strategy consists of chisel plowing to a depth of 10 inches and heavy disking followed by use of a light disc or cultivator for weed control. Winter wheat and rye seed are planted into the prepared seedbed using a no-till drill. The RT strategy consists of applying glyphosate one week prior to planting, followed by no more than two light disking passes with 50 percent residue remaining on the soil surface. A broadcast spreader is used to plant winter wheat and rye seed and a harrow was used to drag the field to cover the seed. The NT strategy controls weeds exclusively using one application of glyphosate 2 weeks prior to planting. Wheat and rye seed is planted directly into the stubble using a no-till drill.

An enterprise budget approach was used to evaluate the economic costs and returns of winter small grains grazing for each tillage method. Budgets were developed for both pasture (winter wheat/rye forage) and non-pasture (animal) expenses following methods used by Doye and Krenzer (1989) and Daniels et al. (2002). Annual winter wheat and rye forage production budgets were developed for each tillage method for the grazing periods Fall 2003 - Spring 2004 and Fall 2004 - Spring 2005 using the Mississippi State Budget Generator. The budgets were generated using input and field operation data from experimental winter small grains pastures at the LFBS. Per acre annual forage production budgets by tillage method and grazing period are presented in Table 1. All cost data are reported in 2004 dollars. Both RT and NT have smaller pasture production costs than CT due to savings in labor, fuel, and machinery fixed expenses resulting from fewer land preparation operations.

Non-pasture (animal) production costs were calculated on a per steer basis for the 2003-2004 and 2004-2005 fall and the spring grazing periods to reflect expenses associated with steer receiving, death loss, and hauling. Non-pasture production costs were estimated based on historical receiving data from the LFBS. Feed and hay expenses and mineral expenses were estimated at $0.38/day/steer and $0.07/day/steer, respectively, for each receiving period. Steer receiving began September 15 for the fall period and January 15 for the spring period and continued until the date when steers were turned out onto small grains pastures. The fall and spring receiving periods for 2003-2004 totaled 43 and 47 days, respectively, for all tillage treatments. The fall receiving period for 2004 varied by tillage treatment and totaled 83 days for reduced till, 80 days for conventional till, and 63 days for no-till. The spring receiving period for 2005 totaled 55 days for all tillage treatments. Death loss was estimated assuming a 3.5 percent mortality rate multiplied by steer purchase value. All animal non-pasture costs were converted to a per-acre basis by multiplying by the stocking rate used in each grazing period (1.5 steers per acre and 2.25 steers per acre for fall and spring 2003-2004, respectively; 1.01 steers per acre and 2.28 steers per acre for fall and spring 2004-2005, respectively). Per-acre non-pasture production costs are presented by tillage method and grazing period in Table 2.

Steer purchase and sales prices were calculated using 1991-2000 Arkansas feeder cattle price data from Cheney and Troxel (2004). All price data were adjusted to 2004 dollars using the Producer Price Index. Fall steers were bought on September 15 at 425 lbs per steer, while spring steers were bought on January 15 at 478 lbs per steer. September Medium and Large No.1 400-500 lb steer price data was used to calculate the average purchase price for fall steers, while January Medium and Large No.1 400-500 lb steer price data was used to calculate the average purchase price for spring steers. The ten-year average fall and spring purchase prices were $102.60/cwt and $104.85/cwt, respectively. Steers were sold upon completion of small grains grazing in late January through early February for the fall grazing period and in late April through early May for the spring grazing period. January-February Medium and Large No.1 500-600 lb steer price data were used to calculate the average sales price for steers grazed in the fall-winter, while April-May Medium and Large No.1 600-700 lb steer price data were used to calculate the average sales price for steers grazed in the winter-spring. The ten-year average fall and spring sales prices were $97.75/cwt and $93.38/cwt, respectively. The fall and spring purchase and sales weights used in the analysis along with gains per steer and gains per acre are presented by tillage method and grazing period in Table 3.

RESULTS AND DISCUSSION

Per-acre costs and returns of winter small grains production and grazing are presented by tillage method and grazing period in Table 4. Accompanying cost and returns data on a per-steer basis and a per-pound of gain basis are presented in Table 5 and Table 6, respectively. Costs and returns were calculated for the fall grazing period alone (September-January), the spring grazing period alone (January-May) and both the fall and spring grazing periods combined (September-May).

Net returns per acre were generally low or negative when steers were grazed using either the fall grazing period only or the spring grazing period only. The NT strategy was the only tillage method to produce a positive average net return during the fall grazing period ($4.68/acre). The NT strategy produced enough revenue to cover all costs during the fall 2003-2004 grazing period ($14.59/acre), but was unable to cover pasture costs during the fall 2004-2005 grazing period and generated a net loss of -$5.22/acre in that year. None of the strategies produced a positive average net return during the spring grazing period.

Net returns were more favorable when steers were grazed in both the fall and the spring. The combined fall and spring returns to non-pasture costs were generally sufficient to cover pasture costs during both study years. The one exception was the CT strategy, which was unable to cover its pasture costs in 2004-2005 (-$50.50/acre) and resulted in an average net loss of -$15.85/acre during both years. Both conservation tillage strategies outperformed the CT strategy in profitability. The NT strategy produced the largest average net return ($85.32/acre), followed by the RT strategy ($38.76/acre). Higher weight gains rather than pasture cost savings appear to be the reason for higher profitability of the conservation tillage strategies relative to CT. Both NT and RT produced larger average gains per acre than CT over the two-year period (Table 3).

It must be noted that costs for controlling ryegrass were included in the return calculations of this study. Ryegrass was controlled in the study to maintain pure plots for accurate wheat and rye forage measurements. Ryegrass would be more of a concern if winter wheat were harvested for grain in addition to being grazed by steers. Cattle producers may not be concerned with ryegrass in a typical grazeout strategy in which wheat is not harvested for grain. However, producers would incur the same costs if they wished to control for some other grass species like fescue prior to planting winter small grains forage.

The costs of ryegrass control were $19.62/acre for CT (the cost of disking twice in the summer following grazing) and $13.03/acre for both RT and NT (the cost of applying glyphosate following grazing). If these costs were not incurred (i.e., ryegrass were not a concern), the average net returns over the two-year period would be $ 3.77/acre for CT, $51.79/acre for RT, and $98.35/acre for NT.

CONCLUSIONS

The results indicate that conservation tillage is profitable for production of winter small grains forage in Arkansas. The economic benefits of conservation tillage over conventional "clean till" management appear to be both savings in pasture production costs and increased gross revenues resulting from larger steer weight gains. Larger steer weight gains appear to be the primary factor driving higher profitability of conservation tillage relative to conventional till.

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Table 1. Per Acre Winter Wheat and Rye Pasture Production Expenses by Tillage Method and Grazing Period, 2004 Dollars.

	Fall 2003 - Spring 2004			Fall 2004 - Spring 2005			Average		
Expense Item	**CT** [a]	**RT**	**NT**	**CT**	**RT**	**NT**	**CT**	**RT**	**NT**
Crop Seed	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
Diesel Fuel	16.84	4.95	4.29	18.12	4.95	4.29	17.48	4.95	4.29
Fertilizer & Lime, Fall	46.40	42.05	43.68	41.14	36.45	42.53	43.77	39.25	43.10
Fertilizer, Spring	16.32	16.32	16.32	16.32	16.32	16.32	16.32	16.32	16.32
Herbicides	0.00	18.00	18.00	0.00	18.00	18.00	0.00	18.00	18.00
Operator Labor	19.09	5.84	7.30	20.91	5.84	7.30	20.00	5.84	7.30
Repairs and Maintenance	10.56	2.93	4.18	11.32	2.93	4.18	10.94	2.93	4.18
Total Direct Expenses:									
Fall	116.89	97.77	101.45	115.49	92.17	100.30	116.19	94.97	100.87
Spring	16.32	16.32	16.32	16.32	16.32	16.32	16.32	16.32	16.32
Total Fixed Expenses	23.77	25.47	24.62	6.53	6.53	6.53	9.07	9.07	9.07
Total Expenses	156.98	157.28	157.13	120.62	115.02	117.82	126.84	125.69	126.26

[a] CT = Conventional Till; RT = Reduced Till; NT = No-Till.

Table 2. Per Acre Non-Pasture Steer Production Costs by Tillage Method and Grazing Period, 2004 Dollars.

Item	CT [a]	RT	NT
		Fall 2003	
Feed and Hay	24.51	24.51	24.51
Labor	6.90	6.90	6.90
Minerals	4.52	4.52	4.52
Vet and Medical	18.00	18.00	18.00
Death Loss	22.90	22.90	22.90
Hauling	6.00	6.00	6.00
Total	82.82	82.82	82.82
		Spring 2004	
Feed and Hay	40.19	40.19	40.19
Labor	6.90	6.90	6.90
Minerals	7.40	7.40	7.40
Vet and Medical	18.00	18.00	18.00
Death Loss	39.47	39.47	39.47
Hauling	9.00	9.00	9.00
Total	120.96	120.96	120.96
		Fall 2004	
Feed and Hay	30.77	31.92	24.23
Labor	6.90	6.90	6.90
Minerals	5.67	5.88	4.46
Vet and Medical	12.15	12.15	12.15
Death Loss	15.45	15.45	15.45
Hauling	4.05	4.05	4.05
Total	74.98	76.35	67.24
		Spring 2005	
Feed and Hay	47.60	47.60	47.60
Labor	6.90	6.90	6.90
Minerals	8.77	8.77	8.77
Vet and Medical	18.22	18.22	18.22
Death Loss	39.95	39.95	39.95
Hauling	9.11	9.11	9.11
Total	130.54	130.54	130.54

[a] CT = Conventional Till; RT = Reduced Till; NT = No-Till.

Table 3. Weight Data Used in the Economic Analysis by Tillage Method and Grazing Period.

Item	CT [a]	RT	NT
		Fall 2003	
Purchase Weight (lbs/steer)	425	425	425
Initial Grazing Weight (lbs/steer) [b]	457	459	462
Sales Weight (lbs/steer)	547	550	588
Total Gain/Steer (lbs)	91	92	125
Total Gain/Acre (lbs)	137	138	188
		Spring 2004	
Purchase Weight (lbs/steer)	478	478	478
Initial Grazing Weight (lbs/steer)	510	508	520
Sales Weight (lbs/steer)	647	646	655
Total Gain/Steer (lbs)	137	138	135
Total Gain/Acre (lbs)	308	311	304
		Fall 2004	
Purchase Weight (lbs/steer)	425	425	425
Initial Grazing Weight (lbs/steer)	489	496	473
Sales Weight (lbs/steer)	600	587	620
Total Gain/Steer (lbs)	111	92	147
Total Gain/Acre (lbs)	112	93	149
		Spring 2005	
Purchase Weight (lbs/steer)	478	478	478
Initial Grazing Weight (lbs/steer)	505	494	499
Sales Weight (lbs/steer)	612	632	629
Total Gain/Steer (lbs)	106	138	130
Total Gain/Acre (lbs)	241	314	296
		Total Gain/Acre (lbs):	
2003-2004	445	449	491
2004-2005	354	407	445
Average	399	428	468

[a] CT = Conventional Till; RT = Reduced Till; NT = No-Till

[b] Steer weight at beginning of small grains grazing period and at termination of receiving period.

Table 4. Per Acre Returns and Costs by Tillage Method, 2003-2004 and 2004-2005 in 2004 Dollars.

	2003-2004			2004-2005			Average		
Item	**CT [a]**	**RT**	**NT**	**CT**	**RT**	**NT**	**CT**	**RT**	**NT**
				Per Acre Returns and Costs, Fall Period					
Gross Returns	802.03	806.43	862.15	593.62	580.76	613.40	697.82	693.59	737.78
Purchase Costs	654.22	654.22	654.22	441.44	441.44	441.44	547.83	547.83	547.83
Non-Pasture Costs	82.82	82.82	82.82	74.98	76.35	67.24	78.90	79.59	75.03
Pasture Costs	140.66	104.30	110.52	140.96	98.70	109.94	140.81	101.50	110.23
Net Returns Above Total Specified Costs:	-75.67	-34.92	14.59	-63.77	-35.74	-5.22	-69.72	-35.33	4.68
				Per Acre Returns and Costs, Spring Period					
Gross Returns	1359.37	1357.27	1376.18	1301.45	1343.98	1337.60	1330.41	1350.62	1356.89
Purchase Costs	1127.62	1127.62	1127.62	1141.32	1141.32	1141.32	1134.47	1134.47	1134.47
Non-Pasture Costs	120.96	120.96	120.96	130.54	130.54	130.54	125.75	125.75	125.75
Pasture Costs	156.98	120.62	126.84	157.28	115.02	125.69	157.13	117.82	126.26
Net Returns Above Total Specified Costs:	-46.19	-11.94	0.76	-127.69	-42.90	-59.95	-86.94	-27.42	-29.59
				Per Acre Returns and Costs, Fall and Spring Periods					
Gross Returns, Fall	802.03	806.43	862.15	593.62	580.76	613.40	697.82	693.59	737.78
Purchase Costs, Fall	654.22	654.22	654.22	441.44	441.44	441.44	547.83	547.83	547.83
Non-Pasture Costs, Fall	82.82	82.82	82.82	74.98	76.35	67.24	78.90	79.59	75.03
Net Returns above Non-Pasture Costs, Fall	64.99	69.39	125.11	77.19	62.96	104.72	71.09	66.18	114.91
Gross Returns, Spring	1359.37	1357.27	1376.18	1301.45	1343.98	1337.60	1330.41	1350.62	1356.89
Purchase Costs, Spring	1127.62	1127.62	1127.62	1141.32	1141.32	1141.32	1134.47	1134.47	1134.47
Non-Pasture Costs, Spring	120.96	120.96	120.96	130.54	130.54	130.54	125.75	125.75	125.75
Net Returns above Non-Pasture Costs, Spring	110.79	108.69	127.60	29.59	72.12	65.74	70.19	90.40	96.67
Total Returns to Non-Pasture Costs	175.78	178.08	252.70	106.78	135.09	170.46	141.28	156.58	211.58
Pasture Costs	156.98	120.62	126.84	157.28	115.02	125.69	157.13	117.82	126.26
Net Returns above Total Specified Costs	18.80	57.45	125.86	-50.50	20.07	44.77	-15.85	38.76	85.32

[a] CT = Conventional Till; RT = Reduced Till; NT = No-Till

Table 5. Returns and Costs Per Steer by Tillage System, 2003-2004 and 2004-2005 in 2004 Dollars.

	2003-2004			2004-2005			Average		
Item	**CT** [a]	**RT**	**NT**	**CT**	**RT**	**NT**	**CT**	**RT**	**NT**
Returns and Costs Per Steer, Fall Period									
Gross Returns	534.69	537.62	574.76	586.49	573.79	606.04	560.59	555.70	590.40
Purchase Costs	436.14	436.14	436.14	436.14	436.14	436.14	436.14	436.14	436.14
Non-Pasture Costs	55.22	55.22	55.22	74.08	75.43	66.43	64.65	65.33	60.83
Pasture Costs	93.77	69.54	73.68	139.27	97.52	108.62	116.52	83.53	91.15
Net Returns Above Total Specified Costs:	-50.45	-23.28	9.73	-63.00	-35.31	-5.16	-56.73	-29.29	2.28
Returns and Costs Per Steer, Spring Period									
Gross Returns	604.16	603.23	611.63	571.48	590.16	587.36	587.82	596.69	599.50
Purchase Costs	501.17	501.17	501.17	501.17	501.17	501.17	501.17	501.17	501.17
Non-Pasture Costs	53.76	53.76	53.76	57.32	57.32	57.32	55.54	55.54	55.54
Pasture Costs	69.77	53.61	56.37	69.06	50.51	55.19	69.42	52.06	55.78
Net Returns Above Total Specified Costs:	-20.53	-5.31	0.34	-56.07	-18.84	-26.32	-38.30	-12.07	-12.99
Returns and Costs Per Steer, Fall and Spring Periods									
Gross Returns, Fall	213.87	215.05	229.91	180.46	176.55	186.47	197.17	195.80	208.19
Purchase Costs, Fall	174.46	174.46	174.46	134.20	134.20	134.20	154.33	154.33	154.33
Non-Pasture Costs, Fall	22.09	22.09	22.09	22.80	23.21	20.44	22.44	22.65	21.26
Net Returns above Non-Pasture Costs, Fall	17.33	18.50	33.36	23.47	19.14	31.84	20.40	18.82	32.60
Gross Returns, Spring	362.50	361.94	366.98	395.64	408.57	406.63	379.07	385.25	386.81
Purchase Costs, Spring	300.70	300.70	300.70	346.96	346.96	346.96	323.83	323.83	323.83
Non-Pasture Costs, Spring	32.26	32.26	32.26	39.68	39.68	39.68	35.97	35.97	35.97
Net Returns above Non-Pasture Costs, Spring	29.54	28.98	34.03	9.00	21.92	19.99	19.27	25.45	27.01
Total Returns to Non-Pasture Costs	46.87	47.49	67.39	32.46	41.07	51.82	39.67	44.28	59.60
Pasture Costs	41.86	32.17	33.82	47.81	34.97	38.21	44.84	33.57	36.02
Net Returns above Total Specified Costs	5.01	15.32	33.56	-15.35	6.10	13.61	-5.17	10.71	23.59

[a] CT = Conventional Till; RT = Reduced Till; NT = No-Till

Table 6. Returns and Costs Per Pound of Gain by Tillage System, 2003-2004 and 2004-2005 in 2004 Dollars.

Item	2003-2004			2004-2005			Average		
	CT [a]	RT	NT	CT	RT	NT	CT	RT	NT
Returns and Costs Per Pound of Gain, Fall Period									
Gross Returns	5.88	5.84	4.60	5.28	6.24	4.12	5.58	6.04	4.36
Purchase Costs	4.79	4.74	3.49	3.93	4.74	2.97	4.36	4.74	3.23
Non-Pasture Costs	0.61	0.60	0.44	0.67	0.82	0.45	0.64	0.71	0.45
Pasture Costs	1.03	0.76	0.59	1.25	1.06	0.74	1.14	0.91	0.66
Net Returns Above Total Specified Costs:	-0.55	-0.25	0.08	-0.57	-0.38	-0.04	-0.56	-0.32	0.02
Returns and Costs Per Pound of Gain, Spring Period									
Gross Returns	4.41	4.37	4.53	5.39	4.28	4.52	4.90	4.32	4.52
Purchase Costs	3.66	3.63	3.71	4.73	3.63	3.86	4.19	3.63	3.78
Non-Pasture Costs	0.39	0.39	0.40	0.54	0.42	0.44	0.47	0.40	0.42
Pasture Costs	0.51	0.39	0.42	0.65	0.37	0.42	0.58	0.38	0.42
Net Returns Above Total Specified Costs:	-0.15	-0.04	0.00	-0.53	-0.14	-0.20	-0.34	-0.09	-0.10
Returns and Costs Per Pound of Gain, Fall and Spring Periods									
Gross Returns, Fall	1.80	1.80	1.76	1.68	1.43	1.38	1.74	1.61	1.57
Purchase Costs, Fall	1.47	1.46	1.33	1.25	1.08	0.99	1.36	1.27	1.16
Non-Pasture Costs, Fall	0.19	0.18	0.17	0.21	0.19	0.15	0.20	0.19	0.16
Net Returns above Non-Pasture Costs, Fall	0.15	0.15	0.25	0.22	0.15	0.24	0.18	0.15	0.25
Gross Returns, Spring	3.06	3.03	2.80	3.68	3.30	3.01	3.37	3.16	2.90
Purchase Costs, Spring	2.54	2.51	2.30	3.23	2.80	2.57	2.88	2.66	2.43
Non-Pasture Costs, Spring	0.27	0.27	0.25	0.37	0.32	0.29	0.32	0.30	0.27
Net Returns above Non-Pasture Costs, Spring	0.25	0.24	0.26	0.08	0.18	0.15	0.17	0.21	0.20
Total Returns to Non-Pasture Costs	0.40	0.40	0.51	0.30	0.33	0.38	0.35	0.36	0.45
Pasture Costs	0.35	0.27	0.26	0.44	0.28	0.28	0.40	0.28	0.27
Net Returns above Total Specified Costs	0.04	0.13	0.26	-0.14	0.05	0.10	-0.05	0.09	0.18

[a] CT = Conventional Till; RT = Reduced Till; NT = No-Till

CONSERVATION SYSTEMS FOR TOMATOES AND COTTON IN CALIFORNIA

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ABSTRACT

Labor shortages, rising diesel fuel costs, and regulations aimed at improving air quality are major factors impacting crop production systems in California's San Joaquin Valley. Since 1999, we have evaluated conservation tillage (CT) tomato and cotton production practices with and without winter cover crops as a means to address these factors. CT reduced tractor trips across the field by 50% for tomatoes and 40% for cotton compared to standard tillage. Yields have been generally maintained in the conservation tillage tomato systems, but 11 – 14% lower for the CT without cover crop system and 6 – 36% lower for the CT with cover crop cotton system. Fuel use was reduced by the CT systems, however, because only about 20% of operating costs for these crops are for preplant tillage operations, the cultural costs of production were reduced by only about 10 percent. Production problems with the cotton crops included difficulties with consistent and uniform stand establishment.

INTRODUCTION

Since the development of water resources in California's San Joaquin Valley (SJV) during the 1930's through the 1960's, this region has become a major production zone for a number of crops. Six SJV counties, Fresno, Tulare, Kern, Merced, Stanislaus and San Joaquin, are consistently among the nation's top ten producing counties in recent years (California Agricultural Resource Directory, 2005). Whereas conservation tillage practices have become common in other regions of the country, they are not widely used in the SJV (CTIC, 2002).

CT practices have been developed in other regions for several of the crops grown in the SJV including corn, wheat, cotton, and beans (CTIC, 2002). No-till techniques for growing tomatoes have also been described for other areas (Abdul-Baki and Teasdale, 1993), though their adoption has not been widespread (Abdul-Baki, Personal communication).

In the fall of 1999, we established a field comparison of conservation and standard tillage cotton and tomato rotations with and without winter cover crops at the University of California West Side Research and Extension Center in Five Points, CA. The objective of the study was to compare conservation tillage and conventional tillage practices in crop rotations common to the SJV in terms of productivity and profitability, key soil quality indicator properties, and the quantity of dust produced. We report here aspects of how the tillage systems generally performed during the first four years of this ongoing study.

MATERIALS AND METHODS

An 8 acre field in the map unit of Panoche clay loam (fine-loamy, mixed, supernatic, thermic Typic Haplocambids) (Arroues, 2000) was used for the study and a uniform barley (*Hordeum vulgare*) crop was grown over the entire field before beginning the treatments. The field was divided into two halves; a tomato (*Lycopersicon esculentum*)-cotton (*Gossypium hirsutum* L.) rotation was used in one half, and a cotton-tomato rotation was pursued in the other half to enable comparisons of both tomatoes and cotton in each year. Management treatments of standard tillage without cover crop (STNO), standard tillage with cover crop (STCC), conservation tillage without cover crop (CTNO), and conservation tillage with cover crop (CTCC) were replicated four times in a randomized complete block design on each half of the field. Treatment plots consisted of six beds, each measuring 30 x 270 ft. Six-bed buffer areas separated tillage treatments to enable the different tractor operations that were used in each system. A cover crop mix of Juan triticale (*Triticosecale* Wittm.), Merced ryegrain (*Secale cereale* L.) and common vetch (*Vicia sativa*) was planted at a rate of 100 lbs per acre (30% triticale, 30% ryegrain and 40% vetch by weight) in late October in the standard and conservation tillage plus cover crop plots and irrigated once in 1999. In each of the subsequent years, no irrigation was applied to the cover crops due to the advent of timely early winter rains. The cover crops were then chopped in mid-March of the following years using a Buffalo Rolling Stalk Chopper (Fleischer, NE). In the STCC system, the chopped cover crop was then disked into the soil to a depth of about 8 in. and 5 ft. wide beds were then reformed prior to tomato transplanting. The chopped cover crop in the CTCC was sprayed with a 2% solution of glyphosate after chopping and left on the surface as a mulch.

Conventional intercrop tillage practices that knock down and establish new beds following harvest were used in the standard tillage (ST) systems. The conservation tillage systems were managed from the general principle of trying to reduce primary, intercrop tillage to the greatest extent possible. Zone production practices that restrict tractor traffic to furrows were used in the CT systems and planting beds were not moved or destroyed in these systems during the entire four years.

Tomatoes (‘*8892*’) were then transplanted in the center of beds at an in-row spacing of 12 in. during the first week of April in each year using a modified three-row commercial transplanter fitted with a large (20 in.) coulter ahead of each transplanter shoe. All systems were fertilized the same. Dry fertilizer (11-52-0 NPK) was applied preplant at 100 lbs per acre. Additional N was sidedress applied at 125 lbs. per acre. The *RoundUp Ready*™ cotton (*Gosypium hirsutum*) variety, ‘*Riata*,’ was used each year in all cotton systems and was established using a John Deere (Moline, IL) 1730 No-till Planter. All tractor traffic was restricted to the furrows between planting beds in the CT systems; no tillage was done in the CT plots following tomatoes and preceding the next cotton crop, and only two tractor passes were conducted following cotton and preceding each subsequent tomato crop. These operations included shredding and uprooting the cotton stalks in order to comply with “plowdown” regulations for pinkboll worm control in the region and a furrow sweep operation to clean out furrow bottoms to allow irrigation water to move readily down the furrows. Crop yields were determined in each year using field weighing gondola trailers following the commercial machine harvest of each entire plot.

During the four years of this study, the number of tractor trips across the field was reduced by about 50% for tomato (Table 1) and 40% for cotton (Table 2) in the CT systems relative to the ST approaches. Differences in the tillage intensity between systems were due primarily to

Table 1. Comparison of standard and conservation tillage system operations with and without cover crops for tomato.

	With cover crop		Without cover crop	
Operation	Standard	Conserve	Standard	Conserve
Shred cotton	X		X	
Undercut Cotton	X		X	
Disc	XXXX		XX	
Chisel	X		X	
Level (Triplane)	X		X	
List beds	XX		X	
Incorporate/Shape beds	X		X	
Clean Furrows		X		X
Shred Bed		X		X
Spray Herbicide: Treflan	X		X	
Incorporate Treflan (Lilliston)	X		X	
Spray Herbicide: Roundup			X	X
Spray Herbicide: Shadeout	X	X	X	X
Cultivate – Sled Cultivator	XXX		XXX	
Cultivate – High Residue Cultivator		XXX		XXX
Roll Beds				
Plant Tomatoes	X	X	X	X
Fertilize	XX	XX	XX	XX
Plant Cover Crop	X	X		
Mow Cover Crop	X	X		
Harvest-Custom	X	X	X	X
Times Over Field	23	12	19	11

reductions in those soil disturbing operations commonly associated with postharvest "land preparation," including disking, chiseling, leveling and relisting beds, - operations that are typically performed in the fall. The operations listed in Tables 3 and 4 represent average sequences for all years; slight differences occurred in certain years. For instance, we originally performed two operations following cotton harvest in the CT systems, - a one-pass Shredder-Bedder (Interstate Mfg., Bakersfield, CA) to shred and undercut the cotton plant, and a furrow sweeping operation using a Buffalo 6000 High Residue Cultivator (Fleischer Mfg., Columbus, NE) modified and fitted with only furrow implements. However, in 2003, we fitted our no-till tomato transplanter with furrow "ridging wings" and thereby cleared out residues from furrow bottoms at the time of transplanting.

The general CT approach pursued in this study was to more severely restrict tillage operations than is customarily done today. As a result of this, more residues accumulated on the soil surface, particularly in the CTCC systems and this at least partly explains the lower numbers of cotton plants that were established in this system in each year relative to the STNO system (data not shown).

Table 2. Comparison of standard and conservation tillage operations with and without cover crops for cotton.

	With cover crop		Without cover crop	
Operation	Standard	Conserve	Standard	Conserve
Disk	XX		XXXX	
Chisel	X		X	
Level (Triplane)				
List beds	X		XX	
Incorporate/Shape beds				
Clean Furrows				
Compact Furrows				
Spray Herbicide: Treflan	X		X	
Incorporate Treflan (Lilliston)	XX		XX	
Spray Herbicide: Roundup	XX	XXXX	X	XXX
Cultivate – Rolling Cultivator	XX		X	
Cultivate – Sled Cultivator				
Open/close Ditch for Irrigation				
Chain Beds	X	X		
Plant Cotton	XX		X	X
Fertilize (Water Run)				
Plant Cover Crop			X	X
Mow Cover Crop			X	X
Spray Insecticides/Growth Reg	XX	XX	XX	XX
Spray: Defoliate	X	X	X	X
Spray Insecticides	XX	XX	XX	XX
Custom Defoliate				
Custom Spray Insecticides				
Spray Insecticides	X	X	X	X
Harvest-Custom	X	X	X	X
Times Over Field	19	12	22	13

In addition, we were initially concerned that residues would interfere with the action of the "over-the-top" tomato herbicide *ShadeOut*, which can be sprayed after transplanting and sprinkled in to activate. By 2003, however, we used it in all systems with observed benefits. Though we did not consistently monitor weed populations during this study, we did generally observe more weeds under CT for both tomato and cotton. For CT cotton, we relied solely on 1 or 2 in-season applications of *RoundUp*; no cultivation was done in these systems. For tomatoes, we typically cultivated 2 to 3 times, but this did not achieve a comparable level of weed control in the CT systems as in the ST systems in all years and this is one aspect of the approach taken here that needs to be improved.

It is important to point out that while the CT systems we employed in this study dramatically reduced overall tillage and soil disturbance relative to today's norms for the SJV, they by no means constitute what is customarily considered "no-till" production. In classic no-till, or "direct seeding" systems, crops are planted directly into residues and no additional soil disturbance is generally done prior to harvest. We employed the intermediate or incremental tillage reduction strategy described here in part because of California Department of Food and Agriculture mandates for pink bollworm control that require considerable soil disturbance, and because of the need to maintain somewhat clear channels for irrigation water movement down furrows.

RESULTS AND DISCUSSION

Yield results during the first four years of this study show that tomato yields were maintained in the CT system relative to the ST system in each year (Table 3). Processing tomato yields in 2000 were slightly lower in each of the cover cropped systems relative to both the standard can conservation tillage systems without cover crops. This occurrence may have been caused in part by the slower early season tomato growth that was observed in each of the cover cropped systems and this growth reduction may have resulted from nitrogen immobilization following cover crop termination in each spring, and, in the case of the CTCC system, lower soil and near-surface air temperatures. Additional testing is now underway to evaluate each of these hypotheses. Data from the 2001 tomato harvest indicate that yields in the CT both with and without cover crops were similar to those in the standard till plots, with an elimination of several tillage operations following the preceding year's cotton crop in the CT plots relative to the standard till systems. In both 2002 and 2003, the highest yielding system was the conservation tillage system without a cover crop. Using a cover crop meant lower yields for the conservation tillage system in all years. Interestingly, for the standard tillage system, a cover crop increased yields in 2001 and again in 2003. Using the average of 2001 – 2003, conservation tillage without a cover crop resulted in 8.7 tons per acre more than the standard tillage, while with a cover crop the average yield was .8 tons lower.

Cotton yields were low in all systems in 2000 due to a devastating infestation of mites in the field that persisted all season and were exacerbated by pesticide resistance that developed presumably because the same miticide was sprayed repeatedly in the field during the same season (Table 4). 2001 cotton yields were lower in both conservation tillage crop systems relative to the standard tillage control system. In 2001 and 2003, yields were comparable, but higher for the standard tillage systems than the conservation tillage systems both with and without cover crops. A cover crop increased yields only in 2003. Average yields for 2001 – 2003 were higher for standard tillage with and without cover crops (277 and 207 pounds per acre, respectively). Reasons for the reduced yields in the CT systems as well as in the STCC system in 2001, we believe, relate largely to difficulties we experienced establishing the crops in these systems. Further work to refine and improve our planting and establishment of cotton in these contexts is underway.

Although conservation tillage reduced the number of operations in half, the cultural cost of tomato production was reduced by only about 10 per cent. This is explained by realizing that 41 percent of costs are for harvest and 14 percent are for seed. Only 20 percent of operating costs are for preplant tillage operations. The value of the savings from reducing labor and fuel use will increase as labor rates and fuel costs per gallon increase. For example, conservation tillage reduced fuel use by 16 gallons per acre. At a price of $1 per gallon the savings is $16 but at a price of $3 per gallon the savings is $39 per acre.

The summary findings presented here indicate short-term outcomes and issues associated with a conversion to CT production in an irrigated region such as California's Central Valley.

Table 3. Processing tomato yields (tons/acre) for standard and conservation tillage systems with and without cover crops in Five Points, CA.

	2000	2001	2002	2003
Standard tillage no cover crop	58 a	61 b	46 b	42 c
Standard tillage cover crop	53 b	63 a	43 b	45 b
Conservation tillage no cover crop	56 a	64 a	56 a	54 a
Conservation tillage cover crop	51 b	61 b	43 b	52 a

Different letters within columns indicate statistical significance at P = 0.05.

Table 4. Cotton yields (lbs lint/acre for standard and conservation tillage systems with and without cover crops in Five Points, CA.

	2000	2001	2002	2003
Standard tillage no cover crop	360 a	1784	1930 a	1228 ab
Standard tillage cover crop	360 a	1405	1921 a	1336 a
Conservation tillage no cover crop	200 a	1579	1736 b	1058 b
Conservation tillage cover crop	372 a	1454	1252 c	1157 ab

Different letters within columns indicate statistical significance at P = 0.05.

These preliminary results suggest that establishing and harvesting processing tomatoes and cotton with conservation tillage systems is possible given some equipment modification and that yields may be maintained for tomato, but were reduced in the case of cotton, relative to standard tillage in CT crop residue environments. A number of possible constraints to the adoption of these high residue production systems were observed during this "transition" period and these require further investigation (Table 5). First, the continued, long-term accumulation of surface residues may eventually present problems in terms of planting, cultivating and harvesting of both tomatoes and cotton. Transplanting and cultivating tomatoes took more time in the CTCC plots relative to the standard till systems. Second, although we did not attempt to quantify the actual amount of residue that gets picked up by harvesting equipment, there would seem to be at least the possibility that high surface residue systems may eventually result in greater "material other than tomatoes" being harvested, which will ultimately require increased cleaning effort and perhaps expense at harvest. Third, although "zone production" theory might suggest that soil compaction constraints may, to a large extent, be avoided by keeping tractor traffic away from "crop growth zones," (Rechel *et al.*, 1987), longer-term studies that investigate implications of reduced till regimes on compaction are needed.

This study is the first of its kind in California to systematically compare tillage system alternatives through a crop rotation. The extent to which such alternatives are adopted in this region will ultimately depend on their profitability, whether or not weed, insect and disease pests can be adequately managed over time, and possibly, whether processors and ultimately consumers find sufficient value in these types of production approaches to provide cost offsets to support their adoption.

Table 5. Major difficulties with CT cotton and tomato production systems and possible solutions

Cotton	
Problems	*Possible solutions that are being pursued in subsequent evaluations*
Erratic, weak and delayed stand establishment	Plant into adequate moisture (earlier than for traditional "cap planted" systems
Soil moisture dries up at seeding time	Plant earlier or closer to time of "pre-irrigation" than with traditional "cap planted" systems
In-season weed control is weaker in CT systems that only received one application of glyphosate	Apply diverse IPM weed management interventions including cultivation
Tomato	
Problems	*Possible solutions that are being pursued in subsequent evaluations*
Early season tomato growth is delayed in heavy cover crop residues	Consider strip-tilling residues in the transplant line
	Develop improved early season fertility program for CT tomatoes
Season-long weed control	Use both "over-the-top" transplant line herbicides at transplanting and season-long cultivations

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GROWING DRYLAND CROPS IN CLUMPS: WHAT ARE THE BENEFITS?

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ABSTRACT

Stored soil water and growing season precipitation generally support early-season growth of summer crops such as grain sorghum (*Sorghum bicolor* L. Moench) in dryland areas but are insufficient to prevent water stress during critical latter growth stages. The objective of this study was to determine if growing plants in clumps affected early season growth and subsequent grain yield compared to uniformly spaced plants. We hypothesized that growing corn and grain sorghum plants in clumps would result in fewer tillers and less vegetative growth so that more soil water would be available during the grain filling period. A corn (*Zea mays*) study was conducted at Canyon, TX and grain sorghum studies were conducted at Bushland, TX and Tribune, KS. Results showed that planting plants in clumps reduced tiller formation and vegetative growth. Grain sorghum yields were increased by clump planting by as much as 100% when yields were in the 1000 kg ha^{-1} range and 25 to 50% in the 2000 to 3000 kg ha^{-1} range, but there was no increase or even a small decrease at yields above 5000 kg ha^{-1}. The results suggest that plants in clumps rather than spaced uniformly conserves soil water use until later in the season and may enhance grain yields in semiarid dryland environments.

INTRODUCTION

The southern High Plains is a hostile environment for growing crops without irrigation. Although the region is classified as semiarid, much of it is very close to being arid. The aridity index (Stewart, 1988) is commonly used to classify climates and is determined by dividing the average annual precipitation by the average annual potential evapotranspiration (PET). A location with an index > 0.20 and < 0.50 is considered semiarid. Amarillo, TX has an index of about 0.25. Perhaps even more important, there is not a single month in Amarillo when the average precipitation is as much as 50 percent of the average monthly PET. Therefore, successful dryland cropping in the region depends on plant available water stored in the soil profile at time of planting to supplement the growing season precipitation.

Grain sorghum is a major crop grown under semiarid conditions in the United States and other parts of the world. It is one of the most widely grown dryland crops in the southern Great Plains, but grain yields are generally low and highly variable because of sparse and erratic growing season precipitation. Average yields from 1972 to 2004 were 2530 (CV 28) for southwest Kansas, 2280 (CV 23) for the North Texas High Plains, and 1860 kg ha^{-1} (CV 28) for the South Texas High Plains (National Agricultural Statistics Data Base, 2006). Yields would be considerably lower if based on planted areas because only 90 (CV 8), 79 (CV 18) and 81% (CV 22) of the average planted areas actually were harvested for grain (National Agricultural Statistics Data Base, 2006). The yields and percent of area harvested tend to decrease moving from north to south as drier conditions occur. A lack of water during the reproduction and grain filling stages is common and the major cause of low grain sorghum yields in the U.S. southern

Great Plains. Craufurd et al. (1993) reported that water stress during booting and flowering stages resulted in grain yield reductions of up to 85%. Strategies such as reduced plant populations, different spacing between rows, and skip row configurations have been used with varying degrees of success to enhance soil water contents later into the growing season (Blum and Naveh, 1976; Larson and Vanderlip, 1994).

EFFECTS OF TILLERS

A tiller is a shoot that sprouts from the base of a grass plant. Tillers are very common on grain sorghum (*Sorghum bicolor* L. Moench) plants, and to a lesser extent on corn *(Zea mays)* plants. Although the factors for tiller formation are many and complex, tillers generally signal favorable growing conditions. Tillers are morphologically the same as the main stalk and can form their own roots, nodes, leaves, and panicles or ears. Tillers can even form additional tillers when conditions are favorable. However, since tillers develop later than the main stalk, they often lose out in the competition for water, nutrients, and light and quit growing or even die.

Tillers can compensate for skips in a row and for main stalks damaged by hail, frost, wind, etc. Therefore, tillers are considered by many scientists and producers to be a positive trait. Others, however, believe that tillers can lead to a reduction of grain yields and it was once common for farmers in the Cornbelt to remove tillers from corn plants (Nielsen, 2003). The consensus thinking of agronomists in the Cornbelt today, however, is that tillers on corn plants do not have a negative effect of the ears of the main stalks (Thomison, 2003). Water is often not limiting in the Cornbelt whereas it is essentially always the limiting factor for crops grown without irrigation in the southern Great Plains.

My interest regarding the effects of tillering on plant growth and development began by years of observing grain sorghum plants under dryland conditions. The primary management practice that scientists and farmers tried to conserve stored soil water for use during the latter growth stages was to reduce plant density. Many extension specialists and scientists recommended grain sorghum plant populations as low as 3 plants m^{-2}. Even with these low plant populations, severe water stress occurred in most years. Numerous observations and studies showed that as plant densities decreased, the number of tillers per plant increased. In some cases, the tillers produced panicles and contributed to grain yield, but in many cases the tillers did not produce panicles or if they did, the number and size of grains were small. Therefore, much of the expected benefit of a lower plant density was negated by an increased number of tillers that also depleted soil water for vegetative growth.

The reason that growing dryland grain sorghum plants in the southern Great Plains, particularly when the plants are widely spaced, form several tillers is easily understood by analyzing the PET and growing season precipitation data. Using Bushland, TX as an example (Table 1), there is enough precipitation to meet a substantial portion of the PET during the vegetative growth stages. Also, there is generally a significant amount of plant available water stored in the soil at the time of seeding. Jones and Johnson (1996) showed in a 9-yr study at Bushland that dryland grain sorghum used 84 mm of stored soil water. This accounted for 22% of the ET, and much of it was used for vegetative growth. Therefore, early season precipitation and stored soil water are generally adequate for dryland grain sorghum during the early growth stages and along with warm temperatures, good soil fertility, and abundant sunshine, growing conditions are favorable and conducive for tiller formation. However, average precipitation during the reproduction and grain filling stages is less than 30 percent of the PET (Table 1), and with much of the stored soil water already utilized, water stress during these critical stages is common and often severe.

My interest in plant geometry was further stimulated by Brown (1985) discussing the way the Hopi and Papago Indian Tribes grow corn in deserts of Arizona and New Mexico. The corn is planted in hills about 2 m apart with 10 to 12 plants per hill. They learned that the clumping of plants within a relatively small space reduces the desiccation of the foliage, the anthers and silk thereby allowing normal fertilization to occur in that extremely arid environment. Weatherwax

Table 1. Long-term average precipitation during various growth stages of grain sorghum seeded on June 1 at Bushland, TX.

Crop Stage	Days	PET, mm	Precipitation, mm	Pct./PET (%)[†]
Day 1 to 3-leaf	23 (9) [†]	64 (11)	50 (87)	78
3-leaf to flag leaf	30 (7)	151 (9)	64 (65)	42
Flag leaf to flowering	21 (10)	131 (11)	37 (69)	28
Flowering to black layer	37 (11)	191 (8)	57 (71)	30
Total	111 (6)	537 (7)	208 (44)	39

Source: 14 yr potential evapotranspiration (PET) data from Texas A&M University Research and Extension Center (2005)

[†]Percentage of potential evapotranspiration supplied by precipitation for the various growth stages.

[‡]Numbers in parentheses are CV values.

(1954) also describes growing corn in clumps in his book, *Indian Corn in Old America*. When Weatherwax asked a Native American why corn plants are grown this way, the Native American answered that "he has tried various way, and this one yields more corn" Weatherwax pressed him for more details and the Indian answered: "but sometimes he says that in the compact cluster the plants suffer less damage from the wind."

My students, colleagues, and I have carried out a number of studies with corn and grain sorghum to study the effect of tillers on plant development and grain yields. Our hypothesis has been that growing plants in clumps will increase plant competition so that growing conditions in the vegetative stages will be less favorable than when plants are spaced several cm apart as commonly done under semiarid conditions. The increased competition will result in less use of water, nutrients, and sunlight by the clump plants and there will be less vegetative growth, largely because of less tillering. This will leave more water for use by the plants during the reproduction and grain filling growth stages and result in higher grain yields. Limiting resources early in the season will limit yield potential, but under dryland conditions, early season yield potential is usually not a realistic goal. Brief summaries of these studies follow.

1990 GRAIN SORGHUM STUDY AT BUSHLAND, TX

Brar and Stewart (1991) conducted a field experiment with two planting geometries (clump and row) and three densities (3, 6, and 9 plants m^{-1}). Rooting depth measurements indicated that rooting was significantly deeper with clumps than with traditional row planting before panicle formation and a reversed trend occurred after panicle formation. The deeper rooting during early growth stages was contributed to increased plant competition because of a higher plant density. Observations of biomass and grain yields indicated a superiority of clumps compared to rows but this was not borne out by statistics.

1999 CORN STUDY AT CANYON, TX

Ashizawa (2000) grew corn in two different spacing patterns in rows 1 m apart. The plant spacings within the rows were single plants 33 apart and 3 plants in a clump with 1 m between clumps. After 52 days, there was an average of 2 tillers for each uniformly spaced corn plant compared to only 0.5 tillers for each plant in a clump. The clump plants yielded 4,550 kg ha^{-1}, 240 kg ha^{-1} more than the uniformly spaced plants, but the difference was not statistically significant. The uniformly spaced plants produced 10,990 kg ha^{-1} aboveground biomass that was significantly more than the 9,570 kg ha^{-1} produced by the clumps. The difference in the dry matter production occurred mostly early in the season and was largely attributed to tillers. The harvest index (dry weight of grain / dry weight of aboveground biomass) values were 0.41 for the clumps compared to 0.34 for the uniformly spaced plants and the difference was significant. The higher harvest index value for the clumps is an indication that the clump plants suffered less stress than the uniformly spaced plants. The clump plants also showed less visual water stress during the latter growth stages.

2002, 2003, AND 2004 GRAIN SORGHUM STUDIES

Field experiments were conducted at the USDA Conservation and Production Research Laboratory at Bushland, TX in 2002, 2003, and 2004, and at the Southwest Research and Extension Center at Tribune, KS in 2004. The hypothesis was that growing grain sorghum plants in clumps would limit tiller formation and change the plant architecture so that less soil water would be used during the vegetative growth period. The objective was to compare clumps of plants to the same number of individually spaced plants and determine the number of tillers produced, biomass and leaf area production during different growth stages, water use during vegetative and reproduction stages, grain yields, and harvest index values. Although the hypothesis and objective remained constant, the number of treatments and complexity of the experiments increased each year as results led to the need for additional approaches and information. The designs, methodologies, and results of these studies have been presented by Bandura et al. (2006) so only selected data and brief summaries of the findings are presented in this paper.

2002 BUSHLAND, TX STUDY

Uniformly spaced grain sorghum plants developed 3 tillers per plant while plants in clumps had only 1 tiller. However, the clumped plants produce 2230 kg ha^{-1} grain compared to only

1290 kg ha^{-1} for the uniformly spaced plants. The yields were lower than anticipated for the region and were attributed to the lack of growing season precipitation and an insufficient supply os stored soil water during critical growth stages. The harvest index (grain / aboveground biomass) was 0.44 for the clump plants, almost double the 0.24 value for the uniformly spaced plants. The clump plants also reached the 50% bloom stage 5 d earlier and this could be an important factor for increasing water use efficiency.

2003 BUSHLAND, TX STUDY

Early season precipitation was above average resulting in favorable growing conditions during initial plant development. However, precipitation for the remainder of the growing season was less than 50% of the average and led to extreme water stress at anthesis and during grain filling growth stages (Bandaru, 2006). There were approximately 3 tillers for every plant when the plants were spaced approximately 17 cm apart within rows spaced 75 cm apart. In comparison, plants growing in clumps of 6 plants spaced 75 cm apart averaged less than 1 tiller per plant (Table 2). The clump plants produced significantly less biomass during the first 60 d and had a smaller leaf area index. Although the treatment with the uniformly spaced plants had many more tillers and therefore had the potential of producing many more panicles, the treatment with clumps actually produced more panicles and this resulted in a higher grain yield. These results indicate that much of the stored soil water was used to produce tillers during the early growth stages and that these tillers could not be sustained so they did not produce panicles and the increased water stress reduced panicle formation on many of the main stalks. Grain yields were low but the clump plants produced about two times as much grain as the uniformly spaced plants and a significantly higher harvest index (Table 2).

Table 2. Mean values of grain sorghum measurements in the 2003 Bushland, TX experiment[†].

	Pioneer 87G57		NC+5C35	
	Spaced plants	Clump plants	Spaced plants	Clump plants
Tillers per plant	0.6b[‡]	3.1a	0.6b	3.0a
Biomass 60 d (kg ha^{-1})	2687b	3697a	2717b	3440a
Leaf area index 60 d	1.03b	1.50a	1.04b	1.48a
Panicles m^{-2}	6.9a	4.3b	6.2a	4.3b
Grain yield (kg ha^{-1})	1135a	544b	1007a	607b
Harvest index	0.28a	0.13b	0.27a	0.13b

[†]Adapted from Bandaru et al., 2006.
[‡]Letters are that different in a row indicate significant differences by LSD mean separation at the $P < 0.05$ level.

2004 BUSHLAND, TX STUDY

Five plant configurations were included in six field experiments. The experiments were located on the upper, middle, and bench positions of a bench-terraced watershed that included both stubble-mulched and no-tilled areas. The different positions contained different amounts of stored soil water at time of planting and there were also different amounts of runoff and run-on of precipitation during the growing season. The six experiments were conducted simultaneously and were adjacent to one another but they were analyzed statistically as individual experiments. Plants were spaced uniformly every 25 cm in a row (SP-25), every 25 cm in a row with all tillers removed (SP-25-TR), every 38 cm in a row (SP-38), clumped every 75 cm in a row with three plants in a clump (C3-75), and clumped every 100 cm in a row with four plants in a clump (C4-100, Fig. 1). All plots were hand-planted with Pioneer-8699 seed and thinned to the desired populations. Final plant densities for the Sp-25, C3-75, C4-100, and SP-25-TR treatments were equal at 5.4 plants m^{-2}, and 3.6 for the R-38 treatment.

Weather conditions during 2004 were more favorable for grain production than for 2002 and 2003. The June through September precipitation was 306 mm, 42 mm above the long-term average.

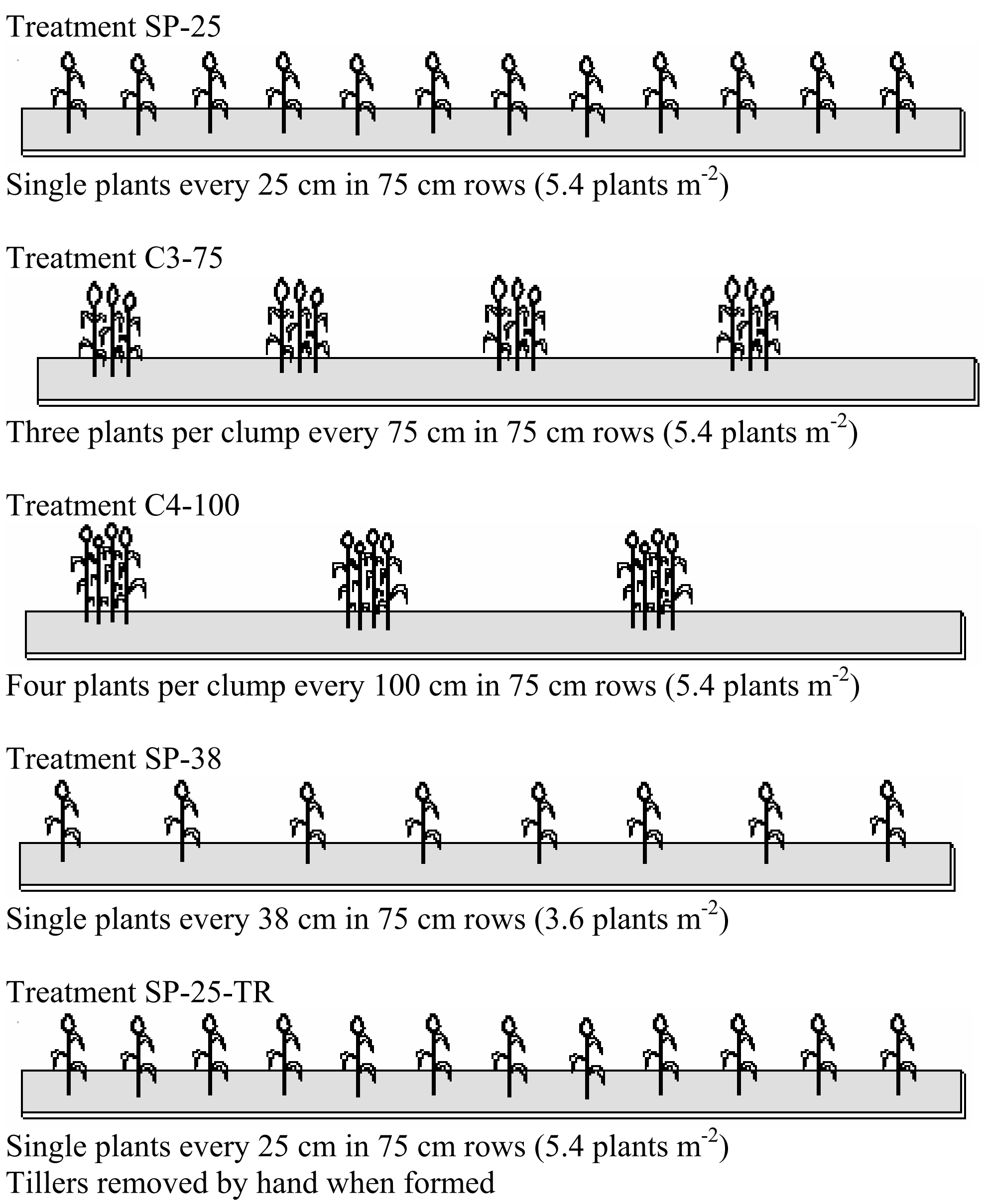

Figure 1. Schematic showing plant geometries for the treatments used in the 2004 experiments at Bushland, TX and Tribune, KS.

Planting geometry had a significant effect on the number of tillers produced in all experiments. Results from the three experiments located on the stubble-mulched tillage area are shown in Table 3 were similar to those for the no-tilled area. The SP-25 treatment represents a commonly used geometry for dryland grain sorghum in the southern Great Plains. Plants produced approximately two tillers per plant. Although the experiments located on different positions cannot be compared statistically, there was a trend for plants on the middle and bench position to produce more tillers than those growing on the upper position where water conditions were less favorable. Tiller numbers were also influenced by distance between plants as shown by comparing the results for the SP-25 and SP-38 treatments (Table 3).

Aboveground biomass and leaf area produced during the initial 42 d of growth were closely related to tiller production (Table 3). Treatment SP-25 produced approximately 75% more dry matter and leaf area than the C4-100 treatment. The SP-25-TR treatment that had the tillers removed as they were formed produced essentially the same amounts of dry matter and leaf area as the C4-100 treatment, supporting the hypothesis that the increased dry matter and leaf area for the SP-25 treatment was the result of more tillers.

Although there were large differences in the number of tillers for the various treatments (Table 3), the differences in the number of panicles produced were much smaller. This was because a large percentage of the tillers, particularly for the experiment located on the upper position of the benched-terrace where water stress was more severe, did not produce panicles.

Grain yields were relatively high for experiments located on the bench position (Table 3) because this position received runoff from experiments located on other slope positions. There were no differences in yields between the clump treatments C3-75 and C4-100, and the spaced plant treatments SP-25 and SP-38 for experiments on the bench. However, the yield of the SP-25-TR treatment that had tillers removed was reduced. This reduction was likely caused by an insufficient number of panicles for the yield level achieved with the favorable water conditions.

The results were vastly different for the experiment on the upper slope position where water was very limited. For this experiment, the clump treatments produced more grain than the SP-25 treatment (Table 3). The C4-100 treatment produced more grain than the C3-75 treatment. The SP-38 treatment had one-third fewer plants ha^{-1} than the SP-25 treatment and there was a trend for increased grain yield but the increase was not statistically significant. The clumps also produced higher yields when compared to the uniformly spaced plants for the experiment conducted on the middle slope position, although the percentage increase was not as great as for the upper position experiment. The increased grain yields for the clump treatments were because of a higher harvest index (weight grain/weight aboveground biomass) and not because of increased biomass production.

2005 Tribune, KS Study

The winter and early spring precipitation was extremely low. However, amounts during June, July, and August were among the highest ever recorded (Bandaru, 2006). This led to very favorable growing conditions for dryland grain sorghum and resulted in grain yields similar to those for irrigated fields.

The number of tillers produced on the various treatments at Tribune in 2004 (Table 4) closely paralleled those found at Bushland in that year (Table 3). The clump treatments produced fewer tillers than the uniformly spaced plant treatments.

Table 3. Mean values for measurements of grain sorghum as affected by five planting geometries in 75-cm rows in 2005 Bushland, TX study on upper (Upper), middle (Middle) and bench (Bench) positions† of a stubble-mulched area.‡

Planting geometry§	Tillers plant^{-1} 28 DAP¶	LAI 42 DAP (kg ha^{-1})	Panicles m^{-2}	Grain (kg ha^{-1})	Harvest index
Upper					
SP-25	2.3a#	1.31a	8.1a	2385c	0.28c
C3-75	0.7b	1.01b	7.7a	2976b	0.36b
C4-100	0.3b	0.87c	6.2b	3563a	0.41a
SP-38	3.1a	1.30a	8.0a	2702bc	0.30c
SP-25-TR	Removed	0.85c	5.4c	2964b	0.39a
Middle					
SP-25	2.0a	1.41a	10.6a	3180c	0.34c
C3-75	1.1b	1.12c	9.5b	4013a	0.41ab
C4-100	0.5c	0.90d	8.1b	3952a	0.44a
SP-38	2.6a	1.37b	10.0a	3610ab	0.38b
SP-25-TR	Removed	0.88d	5.4c	3563bc	0.40b
Bench					
SP-25	2.3a	1.44a	12.0a	4743a	0.41b
C3-75	1.2b	1.18c	9.9bc	4902a	0.46a
C4-100	0.8c	0.93d	8.8c	4810a	0.46a
SP-38	2.9b	1.42b	10.8b	4911a	0.41b
SP-25-TR	Removed	0.91e	5.4c	4247b	0.42b

†Separate but identical experiments were conducted on three positions that had different amounts of stored soil water at time of seeding and different amounts of runoff or run-on during the cropping season.

‡Adapted from Bandaru et al., 2006.

§Planting geometries were SP-25 (plants every 25 cm), C3-75 (clumps of 3 plants every 75 cm), C4-100 (clumps of 4 plants every 100 cm), SP-38 (plants every 38 cm), and SP-25-TR (plants every 25 cm with tillers removed by hand) in 75 cm rows.

¶Days after planting (DAP)

#Means in columns for a position on the benched terrace followed by the same letter are not significantly different according to a protected LSD mean separation (P <0.5 level); each position represents a separate experiment and cannot be compared statistically.

Clumps did not show any yield advantage in this study, and this was not surprising considering the extremely high yield level (Table 4). The C4-100 treatment decreased yield, but the reduction was only 10 to 15%. The C4-100 treatment produced the lowest number of tillers and the relatively low plant population coupled with low tiller formation likely did not produce an adequate number of panicles for maximum yield. The SP-25-TR treatment reduced yields by 25 to 30%, likely due to the low number of panicles that were produced. Observations made during harvest suggested that yields were limited by lack of panicles because they were so large that stalk breakage was common. The fact that clumps depressed sorghum grain yields only about 10% under very favorable growing conditions is important because it indicates minimal downside risk with the use of clumps under dryland conditions even when seasonal precipitation is greater than normal.

Table 4. Mean values of measurements for grain sorghum as affected by five planting geometries in 75-cm rows in experiments at Tribune, KS in 2004[†].

Planting geometry[‡]	Tillers $plant^{-1}$ 28 DAP[§]	Grain (kg ha^{-1})	Harvest index value
Stubble mulched area[¶]			
SP-25	2.3a[#]	6206b	0.43a
C3-75	1.0b	6090b	0.47a
C4-100	1.1b	5691c	0.48a
SP-38	3.1a	6472a	0.43a
SP-25-TR	Removed	4410d	0.43a
No-tilled area[¶]			
SP-25	2.3a	6408b	0.45a
C3-75	1.2b	6426b	0.48a
C4-100	1.0b	6054c	0.48a
SP-38	3.1a	6662a	0.44a
SP-25-TR	Removed	4707d	0.48a

[†] Adapted from Bandaru et al., 2006.
[‡]Planting geometries were SP-25 (plants every 25 cm), C3-75 (clumps of 3 plants every 75 cm), C4-100 (clumps of 4 plants every 100 cm), SP-38 (plants every 38 cm), and SP-25-TR (plants every 25 cm with tillers removed by hand) in 75 cm rows.
[§]DAP = days after planting.
[¶]Separate but identical experiments were conducted on stubble-mulched and no-tilled areas.
[#]Means in columns for a tillage area followed by the same letter are not significantly different according to a protected LSD mean separation ($P < 0.5$ level); each tillage area represents a separate experiment and cannot be compared statistically.

CONCLUSIONS

In the southern Great Plains, dryland grain sorghum is commonly seeded during the wettest period of the year when plant available water is abundant in the soil profile. Bandaru et al. (2006) showed that growing plants in clumps compared to uniformly spaced plants reduced the number of tillers and vegetative growth. This preserved soil water until reproductive and grain filling growth stages, which increased grain yield. There were marked differences in plant architecture of uniformly spaced plants compared to clumped plants. Uniformly spaced plants produced more tillers and the leaves on both the main stalk and tillers grew outward, exposing essentially all of the leaf area to sunlight and wind. In contrast, clumped plants grew upward with the leaves partially shading one another and reducing the effect of wind, thereby reducing water use. The benefit of clumps decreased as grain yields increased, and there was even a slight decrease when yields exceeded 6000 kg ha^{-1}. However, dryland grain sorghum yields seldom reach this level in semiarid regions so growing grain sorghum in clumps appears to be a useful strategy with little downside risk.

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CONTROLLING WATER USE EFFICIENCY WITH IRRIGATION AUTOMATION: CASES FROM DRIP AND CENTER PIVOT IRRIGATION OF CORN AND SOYBEAN

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ABSTRACT

A center pivot was completely automated using the temperature-time-threshold (TTT) method of irrigation scheduling. Methods are described that were used to automatically collect and analyze canopy temperature data and control the moving irrigation system based on the data analysis. Automatic irrigation treatments were compared with manually scheduled irrigation treatments under the same center pivot during the growing seasons of 2004 and 2005. Manual irrigations were scheduled on a weekly basis using the neutron probe to determine the profile water content and the amount of water needed to replenish the profile to field capacity. In both years there was no significant difference between manual and automatic treatments in soybean water use efficiency or irrigation water use efficiency. Using drip irrigation in an earlier study, the automated irrigation method resulted in soybean and corn yields and water use efficiencies that were also not significantly different from those obtained with manual scheduling. However with corn, the automated system responded to crop stress better, prevented yield decline in a droughty year, and showed that water use efficiency could be controlled by varying the system parameters. The automatic irrigation system has the potential to simplify management while maintaining the yields of intensely managed irrigation.

INTRODUCTION

An automated irrigation scheduling and control system that responds to stress indicators from the crop itself has the potential to decrease irrigation management and labor requirements and to increase yields per unit of irrigation water (Evett et al., 2000). Burke (1993) and Burke and Oliver (1993) showed that plant enzymes operate most efficiently in a narrow temperature range termed the thermal kinetic window. Wanjura et al. (1992, 1995) demonstrated that the midpoint of this window, called a canopy temperature threshold, could be used as a criterion for simplifying and automating irrigation scheduling. Upchurch et al. (1996) received U.S. patent no. 5,539,637 for an irrigation management system based on this optimal leaf temperature for enzyme activity and a climate-dependant time threshold. This was termed the temperature-time-threshold (TTT) method of irrigation scheduling. With this method, for every minute that the canopy temperature exceeds the threshold temperature one minute is added to a daily total (Fig. 1, left). If this daily total exceeds the time threshold at the end of the day, then an irrigation of a fixed depth is scheduled. Since humidity can limit evaporative cooling, minutes are not accrued if the wet bulb temperature is greater than the threshold temperature minus two degrees Celsius. We showed that automatic drip irrigation of corn and soybean using the TTT method was more responsive to plant stress and showed the potential to out-yield manual irrigation scheduling based on a 100% replenishment of crop water use as determined by neutron probe soil water content determinations (Evett et al., 1996, 2000).

Later, we showed (Peters and Evett, 2004a) that, to acceptable accuracy for irrigation scheduling, canopy temperatures at other times of day and in other parts of a field, which may be under different stresses, could be modeled relative to a reference diurnal temperature curve using only a one-time-of-day temperature measurement (Fig. 1, right) and the scaling equation:

$$T_{rmt} \quad T_e + \frac{(T_{rmt,t} - T_e)(T_{ref} - T_e)}{T_{ref,t} - T_e} \qquad [1]$$

where T_{rmt} is the calculated canopy temperature at the remote location, T_e is the early morning (pre-dawn) temperature, T_{ref} is the canopy temperature from the reference location at the same time interval as T_{rmt}, $T_{rmt,t}$ is the one-time-of-day canopy temperature measurement at the remote location at any daylight time t, and $T_{ref,t}$ is the measured reference temperature from the time that the remote temperature measurement was taken (t). We applied this method to center pivot irrigation where canopy temperatures were sensed at one time of day from the moving center pivot lateral (Peters and Evett, 2004b,c) and demonstrated that soybean yield and water use efficiency values were not significantly different from those achieved using the best scientific irrigation scheduling method, which was based on soil water balance and time consuming and expensive weekly measurements with a neutron probe.

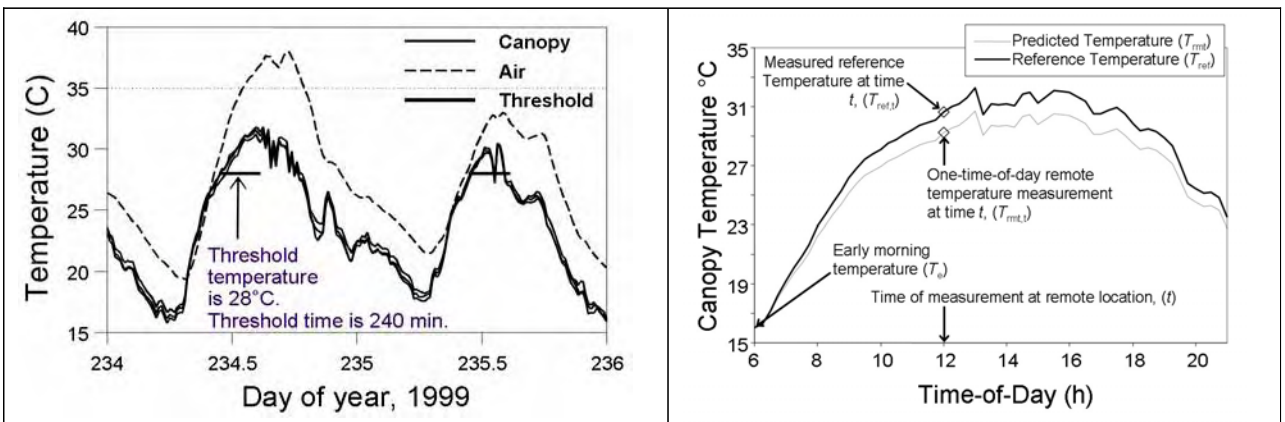

Figure 1. (**Left**) Canopy temperatures of three replicate plots on corn in 1999 (Evett et al., 2000) compared with air temperature. Also shown are horizontal bars drawn at the threshold temperature of 28°C and over the length of the threshold time (240-min). Because the canopy was above the threshold temperature for more than the threshold time on day 234, irrigation occurred in the evening of that day, but not in the evening of day 235. (**Right**) Diagram of the terms used in the scaled method (Equation 1). Time t might be any daylight time at which a canopy temperature ($T_{rmt,t}$) was measured at a remote location in the field. A contemporaneous temperature ($T_{ref,t}$) from the reference temperature data is then used in equation 1 along with the common pre-dawn minimum temperature (T_e) and each value in the reference temperature data (T_{ref}) to predict corresponding temperatures at the remote location for daylight hours (T_{rmt}).

For site specific irrigation to be practical on a large scale, there is a need to develop inexpensive, real-time sensing of the soil and/or plant status integrated with communications networks and control and decision support systems (e.g. Evans et al., 2000). The need for proper decision-support systems for implementing precision decisions was reiterated by McBratney et al. (2005) who stated that there was insufficient recognition of temporal variation as well as spatial variation. We developed a real-time canopy temperature monitoring system integrated with a decision support system to apply the TTT method to center pivot irrigation control and automation (Peters and Evett, 2005a,b). The system used wireless data transmission between dataloggers and the base station computer, which served as a supervisory control and data acquisition (SCADA) system hub, and which transmitted control signals to the center pivot control panel by radio.

The purpose of this paper is to present results from TTT automated center pivot irrigation of soybean and compare them with results from previous studies of the TTT system using drip irrigation.

MATERIALS AND METHODS

Experiments were conducted under a three-tower, 127-m long research center pivot located at the USDA-ARS Conservation and Production Research Laboratory in Bushland, Texas (35° 11' N, 102° 06' W, 1170 m elev. above MSL). Soybeans were grown in 2004 and 2005 on a Pullman fine, mixed, superactive, thermic Torrertic Paleustoll. Experimental treatments were applied to alternative halves of the field each year to allow the other half's soil water content differences from the previous year's experiment to be minimized by growing a wheat cover crop. Crops were planted in concentric circles out from the center point (Fig. 2). Radially, four different water amount treatments were randomized within two blocks (100%, 66% and 33% of projected irrigation needs, and a dry-land, or no-irrigation treatment). Each drop was pressure regulated to 6 psi. Irrigation rate was controlled radially by nozzle sizing and, in the direction of travel, by lateral speed. Drops were spaced every other furrow (1.52 m) and fitted with low energy precision application (LEPA) drag socks. Furrows were dammed/diked to limit runon and runoff. Along the arc of the irrigated half circle there were, alternately, three blocks each of the automatically controlled (via the TTT method) treatments, and the manually scheduled treatments, which were irrigated to replace soil water deficiency as determined by neutron probe (NP). The combination of radial and arc-wise blocking effectively controlled for differences in soil properties underneath the pivot. Typically, statistical analysis shows no block effect, resulting in six replications of each treatment (irrigation amount and method). Irrigation amounts for the automatic and manual scheduling methods could be different. Irrigation frequency for either method could be up to three times per week. Two additional crop rows were planted around the outside and inside edges of the pivot to reduce border effects. Agronomic practices common in the region for high yields were applied.

The pivot movement and positioning were controlled remotely by a computer located in an off-site building, communicating through two different 900-MHz radios (Fig. 2). One radio was used by the center pivot remote control system to communicate with the pivot through a second radio mounted at the pivot center point, thus allowing system status checks and control. The second system consisted of a Campbell Scientific[1] RF400 radio that communicated to similar radios connected to dataloggers mounted on the pivot and in the field.

One center-pivot-mounted datalogger collected data from 16 infrared thermocouple thermometers (IRTC) that were attached to the trusses of the pivot on the leading side of the

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

pivot (Fig. 2). The pivot was allowed to irrigate in only one direction so that the sensors would not view wet canopy. The IRTCs were oriented so that they pointed parallel to the center pivot lateral (perpendicular to crop rows) towards a spot in the middle of each concentric irrigation treatment plot. In order to minimize sensor angle related effects, two IRTCs were aimed at approximately the same spot from either side of each plot, and the average of these two readings for each plot was used (Wanjura et al., 1995). The IRTCS were connected to a multiplexer (Campbell Scientific AM25T) at the second tower, which in turn was connected to a datalogger placed at the third and last tower. The IRTCs were sensed for canopy temperature on 10-s intervals; and the one minute averages were recorded. A second datalogger and radio provided interface to a GPS unit mounted on the last tower.

Sixteen IRTCs were mounted in stationary locations in the field and connected to a separate datalogger (Fig. 2). Each IRTC was mounted in the nadir position over the crop row close enough to the canopy that soil was not included in the field-of-view. These IRTCs were adjusted up with the changing height of the canopy. One IRTC was mounted in each irrigation level of both the automatic and manual treatments. These IRTCs were similarly connected through a multiplexer (Campbell Scientific AM25T) to a datalogger that recorded the five-minute averages of each of the IRTC readings collected on 10-s intervals.

Each IRTC was calibrated using a black body (Omega Black Point, model BB701) before the season began. Using the calibration, each IRTC was individually corrected by the data analysis software running on the control computer. The IRTCs in stationary positions in the field were Exergen model IRt/c.2-T-80 with a 2:1 field of view, which are relatively insensitive to sensor body temperature. In 2004, IRTCs on the center pivot lateral were narrow field of view (10:1) (Exergen model IRt/c.JR-10). In 2005, these were replaced with type T IRTCs (IRt/c.2-T-80).

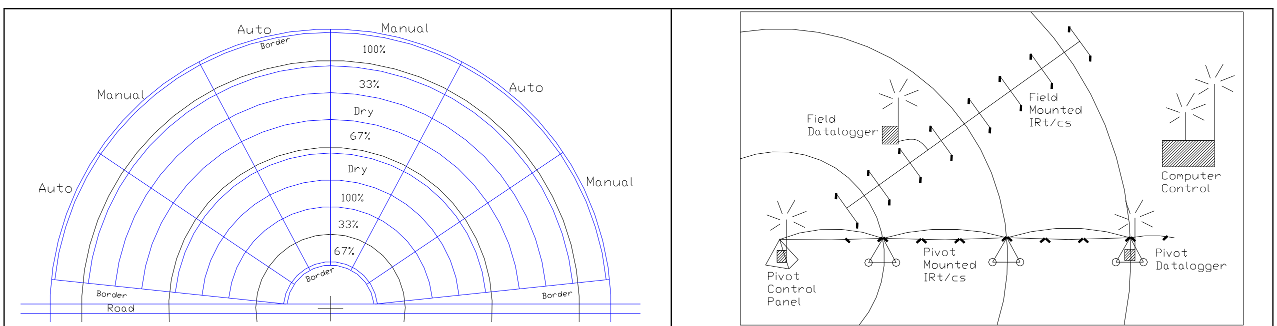

Figure 2. (Left) Automated center pivot irrigation experiment plot plan divided into six “pie slices” labeled Auto for automatically irrigated and Manual for manually irrigated. Irrigation amounts were 100% of the amount determined by each of the two irrigation scheduling methods used in the arcs labeled 100%. In the arcs labeled 67% and 33%, the irrigation amounts were 67% and 33% of the amount applied in 100% arcs. (Right) Automatic center pivot control diagram showing locations of radio antennas, dataloggers and sensors.

During an automatic irrigation event, the pivot stopped at the edge of each arc-wise block (pie slice), paused 10 minutes to drain, and then ran dry over the manual irrigation treatment. It then pressured up again for the next automatic irrigation treatment and continued on in this fashion until all of the automatic irrigation segments were irrigated. An application depth of 20 mm was applied at each automatic irrigation event. This was equivalent to the maximum, two-day crop water use rate for the region. After irrigating the last automatic plot, the pivot continued on around dry to its starting point. During a manual irrigation event, the pivot performed similarly except it irrigated only the manual irrigation blocks at manually set application depths based on that for the 100% treatment, which was based on the soil water deficit as determined by weekly NP readings in 100% treatment plots. In order to both manually and automatically control the same pivot, automatic irrigations were only allowed on even days of the year, and manual irrigations were only allowed on odd days of the year.

The off-site control computer was programmed to call the pivot-mounted datalogger and the pivot control panel every minute to retrieve data and status reports. Software written in Visual Basic reviewed the status reports every minute to determine whether the pivot had crossed a plot boundary. If it had, new instructions were sent to the pivot depending on its location and the subprogram (automatic or manual) that was running at the time. The control computer was linked via wireless Ethernet to a computer in the laboratory through which manual irrigation settings were entered, and system status was checked. Center pivot lateral position was obtained by a combination of pivot control panel resolver angle reports and a GPS system mounted on the pivot end tower (Peters and Evett, 2005a,b).

The field datalogger was polled only once a day soon after midnight. At this time the previous day's data were analyzed to determine the next day's strategy. If the pivot did not move during the previous day, the temperature curve collected by the pivot-mounted IRTCs was used to determine whether irrigation was required. If the pivot *did* move during the previous day then a subroutine was called that scaled one time-of-day temperature measurements and made decisions based on the results. The two canopy temperature measurements from the field-mounted IRTCs in the 100%, automatic treatments were averaged and used as the reference curve for scaling the one time-of-day measurement into a diurnal curve (Eq. 1).

To establish the crop stand, the plots were uniformly irrigated using standard scheduling methods until the crop had grown such that the soil between the rows was not visible when viewed at a 45° angle from the pivot IRTCs. At the end of the season the dry yield was determined by harvesting a 3.48-m^2 sample near the center of each plot. The total dry biomass was measured, as well as the dry grain yield and average seed weight. Total water use was determined by soil water balance (e.g. Evett, 2002). Water use efficiency (*WUE*) and irrigation water use efficiency (*IWUE*) were calculated per Burt et al. (1997) and Howell (2002).

The data were analyzed using SAS (SAS Institute, Inc., Cary, NC) with a procedure for mixed models (Proc Mixed) with the Tukey-Kramer method for adjusting for multiplicity and are given in Tables 1 and 2.

RESULTS AND DISCUSSION

The model IRt/c.JR-10 IRTCs used in 2004 on the center pivot lateral were very sensitive to the sensor body temperature. Type T IRTCs used at stationary locations in the field had previously been shown to be relatively insensitive to sensor body temperature. It was assumed that this would be true for the model IRt/c.JR-10 sensors as well. Thus, all sensors were calibrated independently in the laboratory under practically isothermal conditions; and the errors due to differences between canopy temperature and sensor body temperature were not noticed until after the season was effectively over. This resulted in canopy temperature measurements from the pivot-mounted IRTCs that were three to five degrees Celsius lower than actual. Efforts to calibrate the model IRt/c.JR-10 sensors with sensor body temperature included in the calibration showed that the response was hysteretic so that no dependable calibration could be established. Although the manufacturer replaced these sensors at virtually no cost, the TTT irrigation control in 2004 was based on canopy temperature values that were cooler than actual, resulting in deficit irrigation of even the 100% TTT plots.

The 2004 pivot IRTC measured temperatures were compared to the field IRTC data from times when the pivot was located in approximately the same location. It was found that the pivot mounted IRTCs varied linearly with the more correct field IRTCs. Regression was used to obtain the equation:

$$T_{corrected} \quad 0.7641 \cdot T_{pivot} + 9.1713 \qquad [2]$$

This equation was used to obtain corrected ($T_{corrected}$) canopy temperatures using the pivot temperatures (T_{pivot}) ($r^2 = 0.9731$).

To evaluate the effect that the errors had on the irrigation experiment, the corrected temperatures were analyzed to find what the irrigation decisions would have been if the temperatures had been correct. The results showed that, in five different instances throughout the irrigation season, automatic irrigations should have occurred but didn't due to the lower than actual reported temperatures. The temperature threshold was effectively set at 30 ˚C instead of the 27 ˚C for soybeans that is specified by theory. When tested, there was no difference in the irrigation decisions made by the uncorrected data with a 27°C temperature threshold and the corrected temperatures with a 30°C temperature threshold. A different IRTC was used in 2005 as described above and the problem was corrected for the 2005 season.

In 2004 the manual irrigation treatment yielded significantly more than the automatic irrigation treatment ($Pr > |t| = 0.035$) with an average difference of 0.025 kg/m^2 (Table 1). We believe that this was mainly due to the sensor inaccuracy, which was equivalent to the temperature threshold being set three degrees Celsius greater than it should have been. Although not significantly different, the manual treatments also showed numerically larger WUE and IWUE. For this first season there were no significant differences between the automatic and the manual treatments for any variable (yield, bean mass, etc.) within an irrigation level, with the exception of yield at the 67% irrigation level.

In 2005, with the IRTC issue corrected, the automatic treatment yielded more than the manual irrigation treatment (Table 2). Although the difference was not significant, differences in the treatments could be seen in the field. Because the automatic system makes irrigation management easier, a non-significant difference is viewed as a positive result. In fact, yields from the manual and automatic treatments were not significantly different from each other at any of the irrigation levels in 2005. The automatic treatment resulted in slightly smaller, though not significantly different, total water and irrigation water use efficiencies.

Yields were in the range reported by Evett et al. (2000) for three years of automatically drip irrigated soybean, and by Eck et al. (1987) for three years of fully furrow irrigated soybean. Water use efficiencies were larger than those reported by Evett et al. (2000), which ranged from 0.25 to 0.51 kg m^{-3} for drip irrigated soybean at the same location. They were also larger than values ranging from 0.05 to 0.61 kg m^{-3} reported by Eck et al. (1987). Contrary to results of Evett et al. (2000) and Eck et al. (1987), water use efficiency in 2005 was increased by deficit irrigation, though not in 2004. Results of Evett et al. (2000) showed that water use efficiency of soybean is relatively insensitive to irrigation level (Figure 3, right). By contrast, water use efficiency of grain corn is very sensitive to irrigation level; and it was shown by Evett et al. (2001) that water use efficiency could be controlled using the TTT irrigation automation system with drip irrigation (Figure 3, left). Future studies will elucidate whether corn WUE can also be controlled with the automated center pivot system. Differences in water use across years are partially due to weather differences.

Table 1. Results from 2004 by treatment (automatic vs. manual), irrigation level (100%, 66%, 33%, and dry), and the cross between the two. Numbers in a column followed by the same letter are not significantly different at the 0.05 probability level.

		Dry Yield (kg m^{-2})	Total Water Use (mm)	Water Use Efficiency (kg m^{-3})	Irrigation Water Use Efficiency (kg m^{-3})
Method	Manual	0.295 a	455 a	0.63 a	0.96 a
	Auto	0.270 b	435 b	0.60 a	0.91 a
Irrigation Level	100%	0.400 a	600 a	0.67 a	0.78 c
	67%	0.345 b	502 b	0.69 a	0.93 b
	33%	0.256 c	392 c	0.65 a	1.10 a
	Dry	0.130 d	285 d	0.46 b	
Treatment by Irrigation Level	Manual 100%	0.411 a	620 a	0.66 ab	0.76 c
	Auto 100%	0.389 a	580 b	0.67 ab	0.81 c
	Manual 67%	0.374 a	517 c	0.72 a	0.98 abc
	Auto 67%	0.317 b	488 d	0.65 ab	0.87 bc
	Manual 33%	0.271 c	396 e	0.68 ab	1.15 a
	Auto 33%	0.240 c	387 e	0.62 b	1.05 ab
	Manual Dry	0.125 d	285 f	0.44 c	
	Auto Dry	0.134 d	285 f	0.47 c	

Table 2. Results from 2005 by treatment (automatic vs. manual), irrigation level (100%, 66%, 33%, and dry), and the cross between the two. Numbers in a column followed by the same letter are not significantly different at the 0.05 probability level.

		Dry Yield (kg/m^2)	Total Water Use (mm)	Water Use Efficiency (kg/m^3)	Irrigation Water Use Efficiency (kg/m^3)
Method	Manual	0.272 a	218 b	1.30 a	0.77 a
	Auto	0.289 a	254 a	1.18 a	0.73 a
Irrigation Level	100%	0.383 a	351 a	1.10 a	0.77 a
	67%	0.321 b	273 b	1.18 a	0.80 a
	33%	0.239 c	193 c	1.25 a	0.69 a
	Dry	0.178 d	127 d	1.43 a	
Treatment by Irrigation Level	Manual 100%	0.374 a	323 b	1.16 b	0.84 a
	Auto 100%	0.391 a	379 a	1.03 b	0.71 a
	Manual 67%	0.307 b	254 c	1.21 b	0.82 a
	Auto 67%	0.335 b	292 b	1.15 b	0.78 a
	Manual 33%	0.229 c	180 d	1.28 ab	0.66 a
	Auto 33%	0.249 c	207 d	1.21 ab	0.72 a
	Manual Dry	0.177 d	116 e	1.54 a	
	Auto Dry	0.180 d	137 e	1.33 ab	

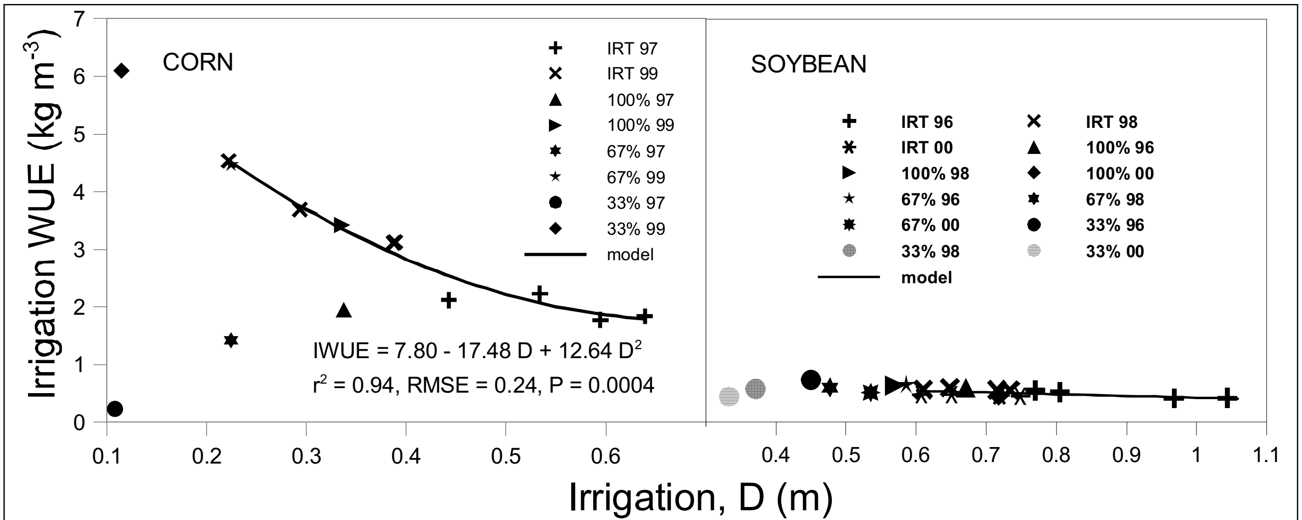

Figure 3. Corn (left) and soybean (right) irrigation water use efficiencies vs. irrigation depth (D, m) for automatic and manual drip irrigation treatments. The solid line is fitted to data from the TTT automated irrigation treatments. Years are given as two digits at the end of each label: 96 for 1996, 97 for 1997, 98 for 1998, 99 for 1999, and 00 for 2000. Labels with IRT are the TTT automation treatments. Labels with percentages are the manual irrigation treatments. This is different from the center pivot irrigation experiments, for which both manual and automated treatments were described in terms of percent of full irrigation determined for each method of scheduling.

CONCLUSIONS

Soybean yield and water use efficiency from a center pivot irrigation system configured to automatically irrigate based on crop stress signals were compared with those from manually scheduled irrigations over two growing seasons in 2004 and 2005. In 2004, incorrect canopy temperatures were recorded by the pivot-mounted infrared thermometers. This resulted in the equivalent of the threshold temperature being set at 30˚ C instead of the prescribed 27˚ C. Therefore, the automatic irrigations ran less often than they should have in 2004. Because of this, the manual treatments yielded significantly more than the automatic treatments. However, during the following season the difference between the manual and automatic irrigation treatments was not significant, with the automatic treatment yielding slightly more than the manual treatment and using slightly more water. There were no significant differences in water use efficiency in either year. It is notable that the manual irrigation scheduling used here, usually referred to as scientific irrigation scheduling, relies on use of the highly accurate neutron probe. This device is seldom used by irrigation managers due to requirements for licensing, training, and constant control of the device, which contains a radioactive sealed source and must be kept in doubly locked storage when not in use. The measurements needed for the manual irrigation scheduling took approximately four hours each week. The automatic irrigation system saves management time and decreases decision making; so a non-significant difference is viewed as a positive result. We believe that the costs and simplicity of methods presented here may become attractive to producers when available in a turn-key commercial package. This is especially true since the methods have the potential to simplify management and reduce labor costs while maintaining or increasing yields compared with intensively and scientifically managed manual irrigation scheduling.

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CONSERVATION TILLAGE AND WATER MANAGEMENT I: QUANTIFYING CROP WATER USE IN CONSERVATION TILLAGE SYSTEMS

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ABSTRACT

Conservation tillage systems purportedly have greater plant available water than conventional tillage systems. However, this conclusion is often based on measurements of soil responses instead of direct measurements of crop water use. In order to fully characterize crop response to a conservation tillage system, we monitored detailed physiological response to strip tillage (ST) and compared it to responses in a conventional tillage (CT) system in a peanut-cotton rotation. In 2003, 2004, and 2005, crop water use via stem flow collars, root growth via rhizotrons, and canopy infrared surface temperature were correlated with measurements of soil moisture and temperature in both ST and CT systems. Further, crop phenological development was monitored throughout the season and integrated water-use efficiency was evaluated through the use of carbon isotope discrimination. Yield and crop quality were also evaluated for both peanuts and cotton. Tillage system had a significant effect on almost every crop response parameter measured, except yield. Plant sap flow was significantly altered by tillage and showed a lowered water use for ST plants. Root growth was significantly greater in the ST system and appeared to be influenced by the previous cover crop's rooting pattern. Reproductive phenology was not significantly affected by ST in the peanut crop which was contrary to grower expectation. Soil moisture patterns were similar to previous studies indicating greater availability in the ST system. This study adds important information about plant response to the growing body of information about the benefits and problems in conservation tillage systems.

CONSERVATION TILLAGE AND WATER MANAGEMENT II: THE EFFECT OF DECREASED IRRIGATION ON CROP YIELD AND PROFITABILITY IN CONSERVATION TILLAGE SYSTEMS

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ABSTRACT

The interaction between reduced irrigation capacity and tillage, including the possible conservation of water with reduced tillage, is of vital interest to growers. A field study was initiated in 2002 to determine crop response under a simulated reduction in irrigation. Three tillage systems were replicated three times each in one of four irrigation levels (100% of a recommended amount, 66%, 33%, and 0% or dryland). Irrigation was based on the Irrigator Pro software model for each crop. Tillage systems were conventional tillage, wide-strip tillage, and narrow-strip tillage. Beginning in 2005, the narrow-strip tillage treatments were converted to a strict no-till system. The test area was planted in triplicate, in a peanut-cotton-corn rotation, with each crop being present each year. Yield of all three crops was highly dependent on seasonal rainfall and degree day accumulation; however, peanut yield was equivalent to the 100% treatment with one-third less irrigation applied in three of four years, regardless of tillage treatment. Corn yield was equal to the 100% level with one-third less water in one season, and two-thirds less in 2004. Cotton yields were equivalent regardless of irrigation treatment or year. All crops responded positively to conservation tillage, with corn yielding a 36 bushel/acre average increase for either type of conservation tillage system versus conventional. Peanut and cotton yielded greater under conservation systems, though not always significant for that year. All crops yielded significantly greater under conservation tillage systems in the 0% (dryland) irrigation system, suggesting that non-irrigated farms may see the most benefit from conservation tillage practices. Net returns, an indicator of farm profitability, were positive each year only in the conservation tillage treatments, regardless of irrigation.

THE ECONOMICS OF COVER CROP BIOMASS FOR CORN AND COTTON

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ABSTRACT

The inclusion of cover crops into cropping systems brings both direct and indirect costs and benefits to the farm. A myriad of studies have examined the economic benefits of cover crops in multiple cropping systems by comparing them to systems without cover crops. To date, economic research pertaining to the economic impact of the level of cover crop biomass has yet to be examined. Thus, the purpose of this paper was to assess the economic impact of different amounts of biomass associated with growing high residue cover crops in a corn-cotton conservation tillage system. An experiment examining planting and termination dates of cover crops and its effects on cover crop biomass, cash crop yields and weed suppression in corn-cotton conservation systems was conducted at two sites in Alabama and one site in Florida. A mathematical model incorporating the direct and indirect effects of cover crops, such as weed suppression and provision of nitrogen to the soil, was estimated using the experimental data. Findings suggest that rye and crimson clover cover crops used in a conservation tillage system can, in fact, be profitable to a farmer if managed properly and if economically viable levels of biomass are obtained from the cover crops. Taking into account potential cost savings, the minimum amount of cover crop biomass needed to be profitable for rye prior to cotton was 4,897 lbs per acre and for crimson clover prior to corn was 2,680 lbs per acre.

INTRODUCTION

Most cotton (*Gossypium hirsutum)* and corn (*Zea Mays* L.) producers in the Southeast have customarily grown their crops utilizing conventional tillage methods. However, as a result of soil degradation and other problems caused by conventional tillage, many farmers have shifted their practices to include conservation tillage systems such as no-till or reduced tillage along with the addition of a winter cover crop.

The inclusion of cover crops in cropping systems brings both direct and indirect costs and benefits. Cover crops can help alleviate drought stress by increasing infiltration rates and soil moisture content. In addition, cover crops can improve soil quality by helping to relieve soil compaction, improve soil organic matter and reduce soil erosion (Reeves, 1994; Sustainable Agriculture Network, 1998). Other benefits can include weed suppression, protecting water quality, increasing nutrient cycling efficiency, and potentially improving cash crop productivity. Costs of using cover crops can include increased direct costs for planting and management, loss in crop revenue if cover crops interfere with cash crop production (e.g. hair-pinning), slow soil warming, and difficulties in predicting N mineralization (Snapp et al., 2005). All of these elements have the potential to increase or decrease yields and the profitability of crop enterprises.

Many studies have examined the costs and benefits of cover crops. However, the purpose of this paper is to assess the economic impact of the amount of biomass or residue associated with growing high residue cover crops in conservation tillage systems. Mathematical models were developed to quantify the amount of rye (*Secale cereale* L.) and crimson clover (*Trifolium Incarnatum* L.) biomass required for cotton and corn enterprises to be economically viable when a cover crop is planted. In addition, economically optimal planting and termination dates for these cover crops were determined.

MATERIALS AND METHODS

The Experiment and Data

An ongoing corn-cotton conservation tillage system experiment examining different planting and termination dates for winter cover crops was established at two locations in Alabama and one location in Florida, beginning in 2003. For the purpose of this paper, only the 2005 data from the experimental site at the E.V. Smith Research and Extension Center near Shorter, AL was used. This portion of the experiment is located on a Coastal Plain soil type (sandy loam), which required in-row sub-soiling prior to planting to disrupt soil compaction with minimal disturbance of the soil surface. The cropping system was a corn-cotton rotation with winter cover crops planted and terminated prior to the cash crop. Rye was planted preceding cotton; and crimson clover was planted preceding corn, both with a no-till grain drill. Five planting dates were examined for each cover crop based on the first average frost date of the year. The planting dates were: 4 weeks prior to average frost, 2 weeks prior to average frost, at average frost, 2 weeks after average frost, and 4 weeks after average frost. A mechanical roller with crimping bars was used in combination with herbicides to terminate the cover crops. Four different termination dates where examined prior to spring planting. The termination dates were 4, 3, 2, and 1 week(s) prior to spring planting. All planting and termination dates were subject to weather conditions, therefore, some dates varied slightly. The experimental set-up was as a strip plot design with planting dates along vertical strips and termination dates along horizontal strips across three replications for both corn and cotton. Each plot was 4-rows in width and both corn and cotton were present each year.

Cover crop biomass samples were taken, at termination of the cover crop, within a ¼ m^2 area randomly chosen inside each plot. Weed biomass samples were taken in a ¼ m^2 area randomly chosen within each plot 3 to 4 weeks after planting of the cash crop. Cash crop plant stands were taken along 10 ft. sections randomly chosen from the rows within the plots. Percent of ground cover provided by residue was measured using digital photographs of a ¼ m^2 area within each plot overlaid with three randomly generated dot screens for each treatment. Each dot intersecting residue in the photograph was then counted and the total number of dots for each dot screen was averaged to determine the percentage of cover (Morrison, et. al.). Yield data was obtained from harvesting the center two rows of each plot with a plot combine and a 2-row cotton picker. The bags were then weighed from every plot of each crop and the yield data was generated from the weights.

Economic Methodology

The primary objective of most farming operations is to maximize profit. Thus, for simplicity, we assume producers are profit maximizers and are risk-neutral. In addition, stochastic conditions, such as weather, are assumed to be known a priori. Based on these assumptions, a farmer who considers planting a winter cover crop will plant that cover if the gain in revenue from planting and managing the cover to achieve a level of biomass *r* is greater than or equal to the cost of the cover crop minus savings. That is, if:

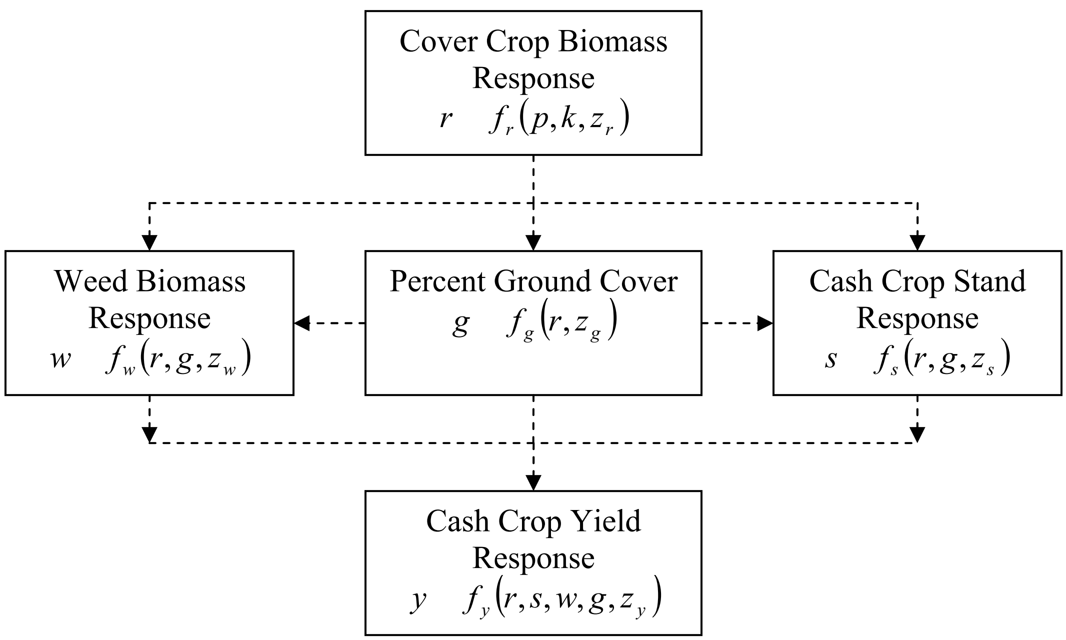
$$p \cdot \Delta y(r) \geq c(r) \qquad (1)$$

where, p is the price of the cash crop, $\Delta y(r)$ is the change in cash crop yield for a given level of r, r is cover crop biomass, and $c(r)$ is a cost function that captures the cost of and potential savings from using a winter cover crop for a given level of biomass r.[2]

Empirical Model

To estimate $\Delta y(r)$ and incorporate potential indirect effects on cash crop yields from increased levels of biomass (r), the cash crop production model presented in Figure 1 was estimated based on the experimental set-up and data available. The weed response (w), percent ground cover (g), and cash crop stand (s) response functions where included to incorporate the potential indirect effects that different levels of cover crop biomass may have on cash crop yields. The rye and clover biomass response functions were based on plant dates (p) and termination dates (k) of the cover crops.

Initially, to estimate the cash crop yield response function, weed biomass, cash crop stand, and percent ground cover response functions were examined with different functional forms. These included linear, semi-log, quadratic, higher-order polynomial expansions, and translog (Chambers, 1988). The models with the best adjusted R^2 and mean-square errors where chosen



Note: z_i, $i = r,w,g,s,y$ are other relevant variables for the respective response function.

Figure 1. Cash Crop Production Model.

to use for further analysis. Models were estimated in SAS using the MIXED procedure to account for random effects due to experimental replications (Little et al., 1996). The functional

[2] Condition (1) is equivalent to the condition that the marginal revenue from obtaining a specified level of cover crop biomass be greater than or equal to the marginal cost.

form for the percent ground cover function was based on the function used by Steiner et al (2000), and was estimated is SAS using the NLMIXED procedure following a similar procedure used by Knezevic, et al. (2002) to estimate critical periods for weed control. The cover crop biomass response functions were estimated in SAS using the MIXED procedure as ANOVA models with fixed effects for plant date/kill date combinations and random effects for replications. The functional forms used for the economic analyses in the paper for each of the cash crop models are presented in Table 1.

Given that $\Delta y \quad \partial y \quad \frac{\partial f_y}{\partial r}\partial r$, condition (1) can be rewritten to incorporate the cash crop production model in figure 1, because cash crop yield can be made to be explicitly a function of *r* by substituting the weed biomass, percent ground cover, and cash crop stand response functions into the cash crop yield response function. Then:

$$\frac{\partial y}{\partial r} \quad \frac{\partial f_y}{\partial_r} + \frac{\partial f_y}{\partial_s}\left[\frac{\partial f_s}{\partial r} + \frac{\partial f_s}{\partial g}\frac{\partial f_g}{\partial r}\right] + \frac{\partial f_y}{\partial w}\left[\frac{\partial f_w}{\partial r} + \frac{\partial f_w}{\partial g}\frac{\partial f_g}{\partial r}\right] + \frac{\partial f_y}{\partial g}\frac{\partial f_g}{\partial r}, \qquad (2)$$

given z_i, $i \quad r, w, g, s, y$ are strictly exogenous to the system.[3] Condition (2) was used to derive revenue curves with MATLAB for each cash crop (see figures 2 and 3). These revenue curves were then used for economic analyses and determining economically viable levels of cover crop biomass using condition (1). The cost function, $c(r)$ is a fixed amount, given the level of biomass produced was determined by different planting and termination dates of the cover crop, which did not change the cost of using a winter cover crop. This is not likely always the case given different levels of nitrogen and/or seeding rates may have achieved the same objective and would have been variable. The cost function includes cost savings from potential reduced use of herbicide due to weed suppression and fertilizers for the cash crop due to the nitrogen equivalence of legumes.

RESULTS AND DISCUSSION

The functional forms and estimates for each of the response functions for both the corn and cotton models are provided in Table 1.[4] The functional forms varied for each response function from the translog the for cotton yield response function, higher order polynomial functions for weed biomass, and linear or quadratic for the rest. R^2 values ranged from 0.20-0.60 and mean square error estimates were the lowest for the models examined. Using the response functions in table 1, crop revenue curves, equal to $p \cdot \Delta y$, were derived using condition (2) (see in figures 2 and 3).

[3] Given a second order translog function was used for the cash crop yield response for the cotton model, $\frac{\partial y}{\partial r} \quad y\frac{\partial \ln(y)}{\partial r}$.

[4] The results for the rye biomass response functions are not presented due to space limitations, but are available for the authors upon request.

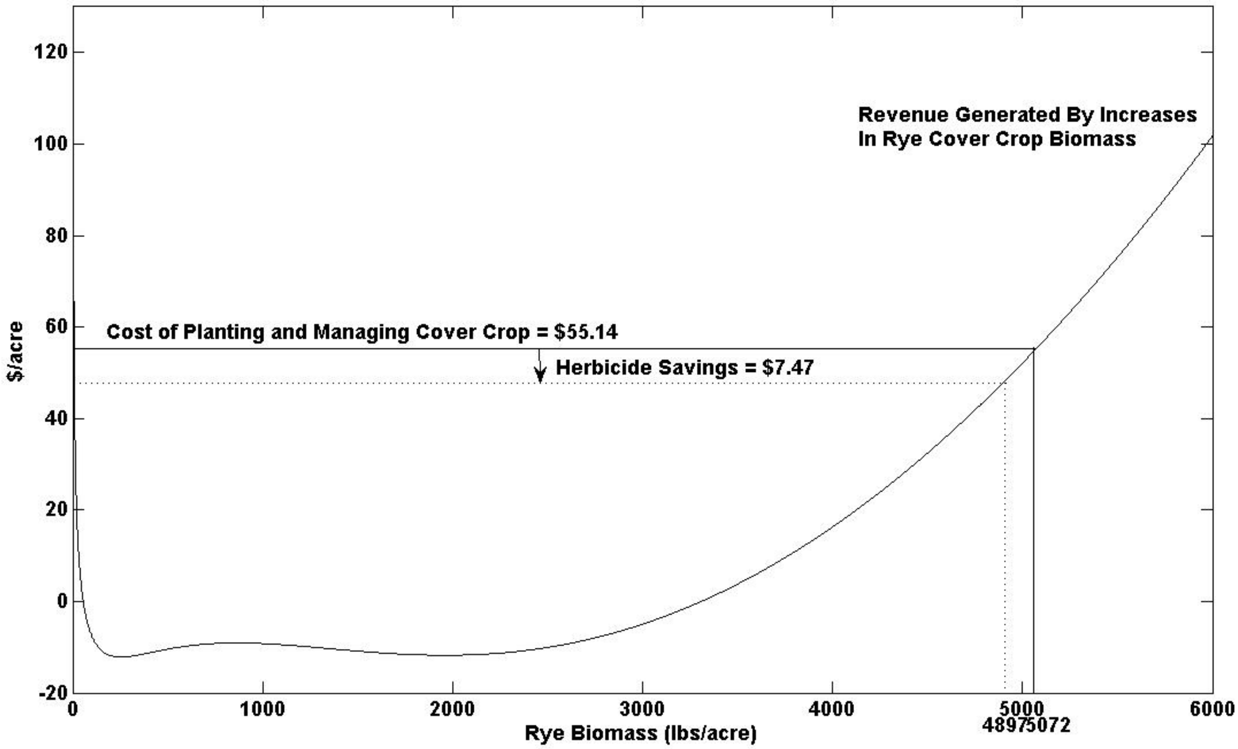


Figure 2: Cotton Revenue Curve for Different Levels of Rye Biomass.

Figure 2 provides a graphical representation of the crop revenue curve for cotton. If only the cost of planting and managing the cover crop is considered, condition (1) is satisfied at equality when 5072 lbs of rye biomass per acre are produced. That is, the change in revenue from 5072 lbs of rye biomass per acre is equal to the cost of planting and managing the rye cover crop. This is the minimum amount of cover crop biomass needed to make it economically viable to plant. If we take into account the weed suppression benefits of the cover crop and forego using a pre-emergence herbicide, then cost savings in the amount of $7.47 per acre can be realized, effectively reducing the economic costs of the cover crop. Taking account of this savings reduces the minimum amount of biomass needed to 4,897 lbs per acre.

Figure 3 provides a graphical representation of the crop revenue curve for corn. The figure shows that condition (1) is met with equality when 4,968 lbs. of crimson clover biomass per acre is produced. Again, this is a minimum for economic viability of using the cover crop. By taking into account pre-emergence herbicide savings, the economic costs of the cover crop can be reduced by $7.47 requiring that only 4,029 lbs. of crimson clover biomass per acre be produced. For simplicity, we assumed that the nitrogen equivalence provided by the crimson clover was linearly related to the amount of biomass produced. At 5,000 lbs of clover biomass per acre, N equivalence was conservatively assumed to be 60 lbs per acre, equal to $22.20 in N savings for the proceeding cash crop. Taking the cost savings of the N equivalence into account reduces the minimum amount of crimson clover biomass needed to 2680 lbs per acre.

Figure 4 illustrates the optimal planting and termination dates of rye and crimson clover for achieving maximum levels of biomass. Surface plots were estimated using SAS. Using the estimated cover crop biomass functions, we determined economically viable planting dates and

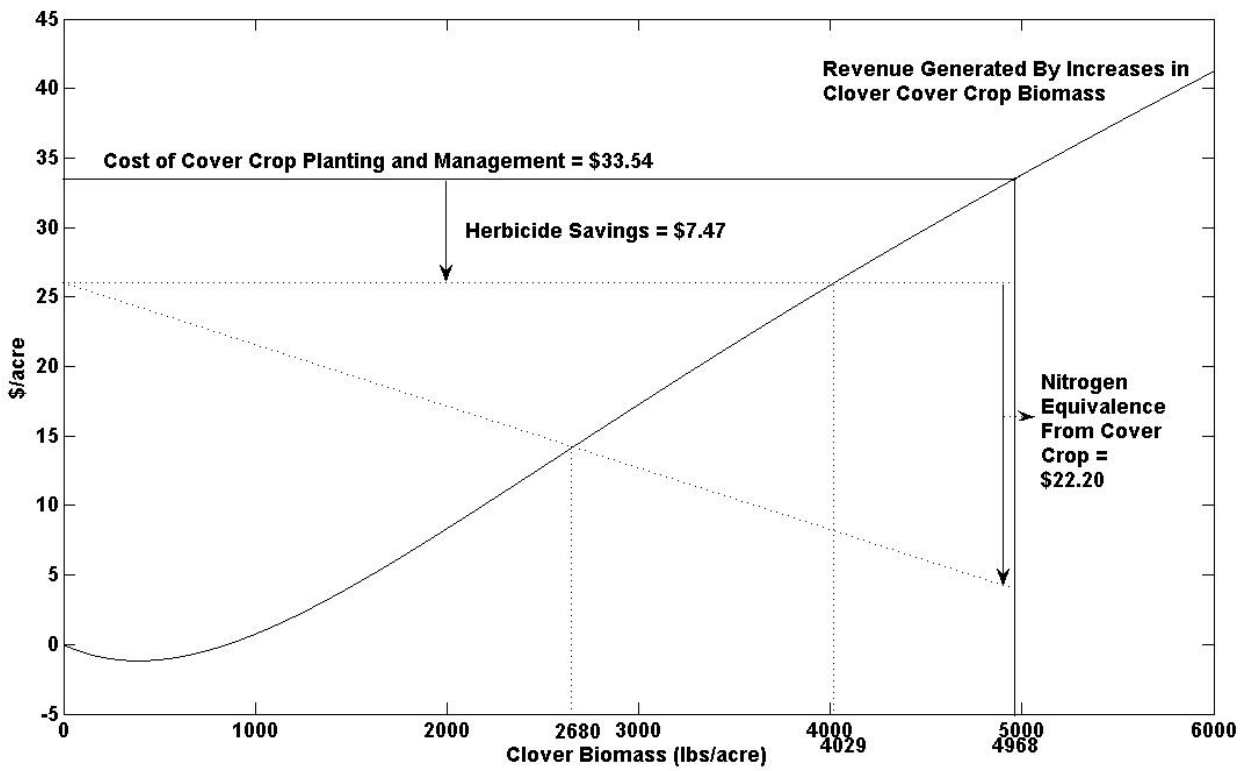
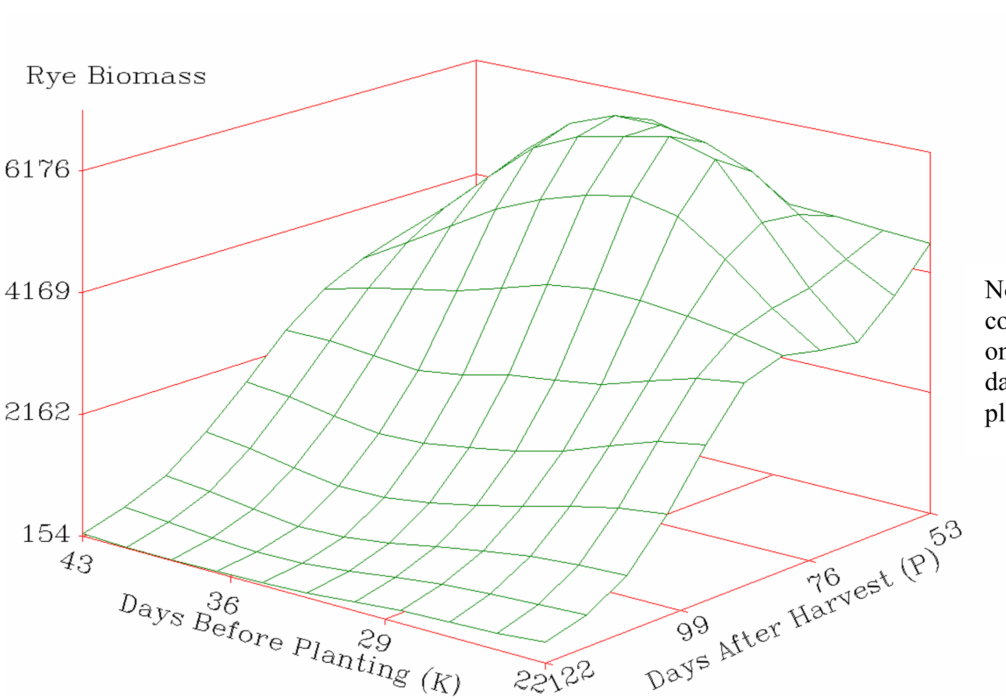


Figure 3: Corn Revenue Curve for Different Levels of Clover Biomass.



Note: Harvest date corresponds to corn harvest on 08/16/2004 and planting date corresponds to cotton planting on 05/02/2005.

Figure 4: Rye Biomass Response Surface to Plant and Termination Date.

termination dates for rye and crimson clover in central Alabama. In order to achieve profitable levels of rye biomass, rye needs to be planted approximately 9-10 weeks after the corn harvest (*p*2) and terminated 4 weeks before cotton is planted (*k*3). Crimson clover needs to be planted approximately 4 weeks after cotton is harvested (*p*2). The termination dates were found to be insignificant for crimson clover, therefore any of the termination dates would suffice.

CONCLUSIONS

The inclusion of cover crops into cropping systems brings both direct and indirect costs and benefits to the farm. The purpose of this paper was to assess the economic impact of different levels of biomass associated with growing high residue cover crops used as an element of a conservation tillage system. The data suggests that rye and crimson clover cover crops used in a conservation tillage system can, in fact, be profitable to a farmer if managed properly and if economically viable levels of biomass are obtained from the cover crops.

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Table 1. Estimated Response Functions for Cash Crop Production Models

Corn		Cotton	
Response	**Functional Form**	**Response**	**Functional Form**
Yield[1]	$y = 53.00 - 0.15w + 16.09s + 0.02y_{-1} + 0.0027w^2$	Yield[1]	$\ln(y) = 10.12 - 0.15\ln(r) - 2.03\ln(w) + 0.70\ln(r_{-1}) + 0.02\ln(w)^2 + 0.12\ln(s)^2 + 0.02\ln(r)\ln(r_{-1}) + 0.02\ln(w)\ln(r_{-1}) + 0.32\ln(w)\ln(y_{-1}) - 0.18\ln(r_{-1})\ln(y_{-1})$
Plant Stand	$s = 2.03 + 0.00005r - 0.32g$	Plant Stand	$s = 4.33 - 0.00029r - 0.00000004r^2 + 0.000019rg^2$
Weed Biomass	$w = 42.66 - 0.02r + 109.03g$	Weed Biomass	$w = 11930 - 2484.28\ln(r) - 19099g + 2934.24g^2 + 23.70\ln(r)^3 - 3.33g^3 + 5216.52\ln(r)g - 460.13\ln(r)^2g$
Percent Cover	$g = 1 - \exp(-0.85 - 0.00061r)$	Percent Cover	$g = 1 - \exp(-1.48 - 0.00049r)$

Note: The ANOVA table for the cover crop biomass response function is not shown, but is available from the authors upon request. Graphical representations are presented in Figure 4.

[1] The variable y_{-1} represents crop yields from the previous year. For corn, this would be prior cotton yield; and for cotton, this would be prior corn yield, due to the two-year cotton-corn rotation used in the experiment. Likewise, the variable r_{-1} is cover crop biomass from the previous year, which would be rye if clover is planted before corn and clover if rye is planted before cotton.

THREE ALTERNATIVE NITROGEN MANAGEMENT STRATEGIES FOR CEREAL GRAIN PRODUCTION

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ABSTRACT

The rising cost of oil has increased the awareness of agricultural producers to nitrogen (N) inputs. The challenge of making a correct fertilizer recommendation is complicated by the dependence on unpredictable temporal variability. High N rates are wasted in years of drought while crops may become more N deficient in years of ample rain. Researchers at Oklahoma State University have developed multiple strategies to precisely prescribe N rates in-season. The strategies range from simple mid-season visual evaluation to a sensor based N rate recommendation. The N-Rich Strip is a strip through a field where N has been applied pre-plant at a level so that no N deficiency can develop during the growing season. When no differences exist mid-season between the N Rich Strip and the farmer practice, the added need for fertilizer N is unlikely. Alternatively, the need for added N can be determined using these same 2 strips and a computed response index. The Ramp Strip consists of 16 different N rates from 0 up to an N Rich rate. This allows producers to walk the Ramp Strip and locate the optimum rate, or the point at which there is no increase in biomass or greenness. The Sensor Based Nitrogen Rate Calculator employees the N-Rich Strip and the GreenSeeker™ hand held optical sensor measurements to determine an exact N rate based on predicted yield.

SUMMARY

Knowing that the world nitrogen use efficiency hovers near 33% in cereal crops, the scientific community has been exploring methods to improve fertilization practices for agricultural crops. However, with the continued increasing cost of petroleum the desire to improve N management has moved beyond academia.

With the benefit of multiple long term fertility trials across the state OSU researchers have studied many interactions between N fertilizer and grain yield. One such interaction was the relationship between the yield of the plot with the highest yield level and the check plot, which never receives fertilizer N. The analysis of over 60 site-years showed that the response to fertilizer N, in terms of grain yield, has ranged from 0 to 4 times the average amount over all years. This large range in yield difference and the wide range in the demand for fertilizer N indicates that some years the crop will not respond to fertilizer N (those years where yields were equal), and other years where fertilizer N is in great demand (those years in which the high N plots are 2 to 4 more times greater in yield). From this data the concept of the response index (RI) was proposed. The RI is simply the ratio between the yield levels of an area with high N levels and an area with low N levels. The RI represents the percentage increase in yield that resulted from additional N.

The N-Rich Strip (NRS) was developed to better account for temporal variability and its influence on the demand for mid-season N. The NRS is an area in a field with a pre-plant N rate that can ensure N deficiencies will not develop at any point in the growing cycle of the crop. The remainder of the field receives a low pre-plant N rate. The NRS serves as an indicator of how the crop will respond to additional fertilizer N mid-season. Through a simple "yes the strip is visible" or "no the strip is not visible" evaluation a producer can determine if top-dress N is needed (yes/no). A visible strip indicates that the crop is taking advantage of the additional N fertilizer applied in the strip. However, it should be noted that the NRS alone can not give the producer any recommendation for the top-dress N rate.

An improvement on the NRS concept is the Ramp Strip (RS). The RS is similar to the NRS in that it is applied in addition to the pre-plant rate. The RS however is not just a single N rate, but a series of 16 N rates. The RS applicator begins fertilization at the highest rate and changes N-rate every 10 ft along the path of the applicator until it reaches 0 and rates start increasing until the initial rate is reached. The total length of the RS is 320 ft. By walking through the area of the RS and visually identifying the point at which the size and color of the crop no longer improves, a producer can make a mid-season top-dress N rate recommendation. This is a very hands-on visual approach that enables the producer to determine the top-dress rate for each field in which the RS is applied.

Through the use of a hand held Green Seeker™ Optical Sensor and the NRS or RS, producers can make a very accurate top-dress N application that is tailored to the field, while accounting for the conditions between planting and top-dress. Oklahoma State University researchers have shown that the potential yield of winter wheat can be estimated with the use of a ground based optical sensor. A large library of sensor and yield data has been compiled to form a yield prediction curve. This curve is updated annually and is available for the public to view at http://nue.okstate.edu/Index_Predicting_Yield.htm. The ability to predict yield allows for mid-season fertilizer N rate determination, tailored to an individual field requirement. The prescribed rate is calculated by the nitrogen fertilization optimization algorithm (NFOA). The NFOA utilizes sensor readings from the N-rich strip and from an area in the field representing the farmer's practice. With these sensor readings, the yield of the two areas is predicted using the yield prediction curve. From the difference in the two yields, an N rate is determined, using the assumption that the difference yield potential is only created by the additional N present in the NRS. A sensor based nitrogen rate calculator (SBNRC) is located at http://www.soiltesting.okstate.edu/SBNRC/SBNRC.php.

PERENNIAL GRASSES - A KEY TO IMPROVING CONSERVATION TILLAGE

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ABSTRACT

Before heavy mechanization and intensive cultivation, perennial grasses and forest land covered the U.S. Farmers were diversified and livestock was a necessary part of life for transportation, tillage and travel. Perennial grasses were used for livestock feed and grain was grown to supply feed for animals and any additional was sold to neighbors. After WWII, farms became mechanized and livestock numbers diminished along with perennial grass pastures. Mechanization brought concentrated areas of grain production and loss of pastures and hay fields. Improvements in plant breeding, fertilizer and pesticide technology resulted in expanded acreages of annual crops using intensive tillage. Extensive areas of tillage resulted in water and wind erosion with loss of productivity which is now being addressed by NRCS, universities and other cooperating agencies and partners through conservation tillage and related management. However, recent systems research utilizing conservation tillage has shown that economics, soil and water quality, and the environment can be further enhanced by introducing perennial grasses back into cropping systems. While conservation tillage has resulted in many benefits, farmers are still struggling with low prices and relatively small yield increases with new technology. A tri-state research project with perennial grasses grown in rotation with crops has shown higher yields (50% higher peanut yields as compared to conservation tillage with annual cover crops), increased infiltration rates (more than 5 times faster), less soil compaction if perennial grass is fall killed vs. spring, and a more economically viable cropping system. Bahiagrass killed in the fall allowed degradation of the root system through the winter resulting in as high of yields as doing tillage in the spring to plant peanut in. Adding nitrogen to help degrade spring killed bahiagrass gave as high of yields as fall killed bahiagrass but at an additional cost. Penetrometer measurements showed less compaction in April from fall kill vs. spring kill in the compaction layer. The system needs further refining for different areas of the country and different cropping systems. However, the concept is sound and is being moved onto farms for demonstration and verification.

INTRODUCTION

New technology in agriculture continues to be introduced and widely adopted by growers. Conservation tillage efforts, likewise, began in the 1960's and were hard to adapt on most farms due to lack of adequate weed control options. However, better equipment and weed control options started to become available in the late 70's and early 80's and the conservation tillage revolution began. Since the mid 90's, Roundup Ready crops became available and conservation tillage became widely accepted across the U.S. Research has shown that conservation tillage may increase soil organic matter, water infiltration, and water holding capacity, while reducing erosion, fuel and labor. The development of precision planters, subsoilers, and varieties resistant to herbicides and insects has enabled widespread adoption of conservation tillage practices in many farming systems. Research from South America began to show the potential to couple perennial grasses in rotation with row crops using conservation tillage for maximum benefit to farms (Reeves, 1997). Conservation tillage techniques are still not widely used for peanut production in the SE and have had a slower adoption rate than for most of the row crops. Reports from various researchers have indicated that yields of peanuts may be lower using conservation tillage techniques. However, lower yields are often the result of not killing out the cover crops soon enough (Wright, et. al, 2005). Many techniques have had to be worked out to make the system work.

In the Southeast, much of the farmland suffers from a natural compaction layer starting at 15-20 cm depth and continuing to 30-35 cm (Kashirad et al., 1967). This results in a shallow root system which confines root development to a small soil volume which is a small reservoir for both water and nutrients and consequently has dramatic effects on crop management and yield. Annual cover crops fail to develop deep root systems, and often are susceptible to short periods of moisture stress under the sandy conditions typical of the southeast. These crops then have no effect on the compaction layer during their life cycle or for on the following crops. Perennial grasses such as bahiagrass and Bermuda grass, which are adapted to the southeast, develop a deep root system which penetrates through the compaction layer (Elkins et al., 1977). When the roots die, they decay and leave root channels which positively impacts soil structure, water infiltration and available water (Elkins et al. 1977; Wright et al., 2004). Long and Elkins (1983) compared cotton following 3 years of bahiagrass sod with continuous cotton and found a seven fold increase in pore sizes greater than 1.0 mm in the dense soil layer below the plow depth. These pores are large enough for roots of the subsequent crop to follow through the compaction layer as well as earth worms.

Cultivation and continuous cropping of some of the best soils in the Midwest has resulted in losing ¼ to ¾ of the SOM that was present 100 years ago (Magruder, Sanborn, and Morrow plots). Many of these long term fertility sites had a rapid decrease in SOM until the 1940’s and 50’s when fertilizer use started to become a normal practice resulting in more biomass being produced and returned to the soil. Continuous row cropping has continued to degrade these soils. The Southeast has higher temperatures that can degrade organic matter faster than the Midwest. It is known that rotation with perennial sod crops will increase soil carbon, water infiltration, improve soil structure, and decrease erosion to a higher level than the winter annual cover crops which have been shown to be better than summer annuals. Winter annual cover crops do not do much to enhance soil quality because of their short duration and fast degradation. Living roots have a tremendous impact on soil quality with annual crops only having active roots for about 3 to 4 months each year. Much of the research in the 20th century has looked at cover crops as green manure crops to be turned under for nitrogen benefit or nematode suppression. Perennial grasses all over the world have been shown to have a major impact on yield. Florida farmers will testify that peanut, watermelon, and soybean will all yield substantially higher after bahiagrass. With economic conditions of rising labor and fuel costs expected to continue indefinitely, growing continuous annual crops can result in a decrease of SOM as well as a buildup of nematodes and diseases (Dickson and Hewlett, 1989), and compaction of the soil so roots cannot explore large areas for water and nutrients. Rotation is always at the top of the list as an important component of producing crops profitably (Wright et al., 2004). The U.S. Geological Survey has reported that 63% of North America that was previously in native grasslands is now cultivated. The reason for this is that most of these soils were highly productive and high in SOM when initially cultivated. Even though perennial grasses contribute little to the immediately available nitrogen pool, it does add significantly to the organic base and long-term nitrogen pool as well as well as helping reduce pests normally found in annual grass or legume crops (Boman et.al., 1996, Elkins et. al. 1977). Areas with long growing seasons can have two to three crops planted each year adding to the organic matter base of the soil (Wright, et. al., 1998). Benefits of sod prior to row crop production can result in dramatic increases in yield at a lower cost of production with less pesticide use and less negative environmental impact than trying to alter all of these factors with chemicals and tillage tools. Recent research indicates that conservation tillage techniques can be altered to use with perennial grasses as well as annual grasses. The objective of this part of the research was to determine if bahiagrass could be managed in a way to get high yields for the following peanut crop without tillage.

EXPERIMENTAL PROCEDURES

The multi-state project examining bahiagrass in rotation with peanut and cotton has been underway since 2000 in Florida and 2001 in Alabama and Georgia. Each site has the basic rotation of 2 years of bahiagrass followed by peanut followed by cotton. Winter grazing or cover crops are planted behind each of the row crops and behind first year bahiagrass at times. The basic design of the study is shown at the site at Marianna, FL under a center pivot irrigation system (Fig. 1). The system rotates each year. Winter grazing is planted after harvest of cotton and peanut each year. Data collected has included water infiltration, soil carbon, soil fertility, bulk density, weed population, earthworm numbers, penetrometer measurements, soil moisture measurements, yields and grades of crops, cattle weight gain, and various other measurements.

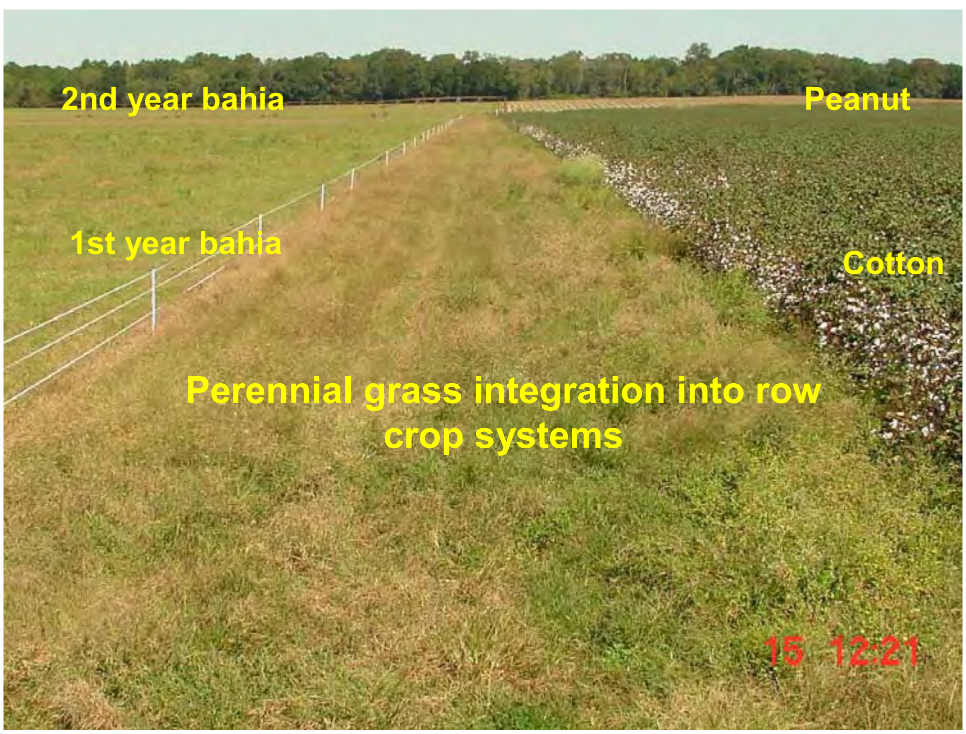

Figure1. Cotton-peanut rotation with bahiagrass with one quarter of the pivot in cotton, peanut, 1 year old bahiagrass, and 2 year old bahiagrass, respectively.

RESULTS

One of the biggest concerns of producers using bahiagrass in rotation with peanut is that of getting good stands using minimum tillage when planting directly into killed bahiagrass sod. When the grass is initially killed, there is a high C:N ratio. This results in nitrogen being tied up and slower decay of the roots and other plant tissue. Decayed root channels from bahiagrass are one of the main passage ways for the subsequent crop roots to get through the compaction layer. We know from previous data that cotton roots exploit the channels and developed a more extensive rooting system in the second year after bahiagrass, which utilize more N across a wider soil profile. Higher root biomass, root area and root length were observed in the bahiagrass rotated cotton following peanut.

Peanut land had typically been plowed for the last 50 years. Most of the information was for growers to turn peanut land so that disease organisms would be buried. This concept seemed reasonable until the early 80's when research showed that strip tilled peanuts actually had less white mold and other diseases than where ground was turned. This went against all prevailing recommendations and has taken a long time to overcome in the peanut industry. However, recent research by many researchers (Jordan, et. al., 2004) has continues to show that peanut diseases are less with strip tillage. However, while bahiagrass is the favored crop to follow with peanut, there are few areas where bahiagrass or other perennial grasses are abundant enough to have many acres following it. Most growers consider it too hard to plant into bahiagrass and that some tillage needs to be done to obtain good yields. Tillage and time of kill were compared at Headland, AL and Marianna, FL to determine if peanuts can be planted after bahiagrass with minimum tillage. At Marianna strip till was compared to strip till plus 40 lbs/A of N to help decompose the plant residue, chisel plow, disk, paratill and turned. Table 1 below shows that there was no significant difference between chisel plowed, disked, and turned and strip till with nitrogen added for decomposition. Strip till alone and paratill had lower yields when bahiagrass was killed in the spring and had little time to decompose.

Table 1. Influence of Tillage on Peanuts Planted into Spring Killed Bahiagrass (FL)

Tillage Treatment	Yield lb/A
Chisel plowed	4445 a
Disked	4280 a
Paratilled	3622 b
Striptilled+ 40 lbs. N	3905 ab
Striptilled	3413 b
Turned	4267 a

Table 2 below shows that there was no difference in yield when bahiagrass was fall killed between strip till and turned as was the case with spring kill. The extra time between killing bahiagrass and planting allows the bahiagrass roots to decompose and soil becomes mellower allowing easier root penetration and higher water infiltration through root channels.

Figure 2 below shows the difference killing bahiagrass in the fall vs. spring makes on penetrometer readings in April just prior to planting peanuts. Soils are less compacted from about 6" deep down to almost 18 inches deep where the level comes back together. This has big implications for managing the perennial grass crop in such a way that allows for minimum tillage. Readings will be followed to determine when spring kill meshes with fall kill plots.

Table 2. Tillage influence on peanut yield in <u>fall killed</u> bahiagrass either turned or striptilled (AL)

-	Yield lb/A	TSWV Incidence	White Mold
Turned Bahia	5,950 a	22.2 a	4.6 ab
Striptill Bahia	5,830 a	10.0 b	3.8 b
Turned Cotton	5,320 b	20.4 a	3.2 b
Striptill Cotton	5,160 b	10.2 b	6.6 a
LSD	271	7.7	2.6

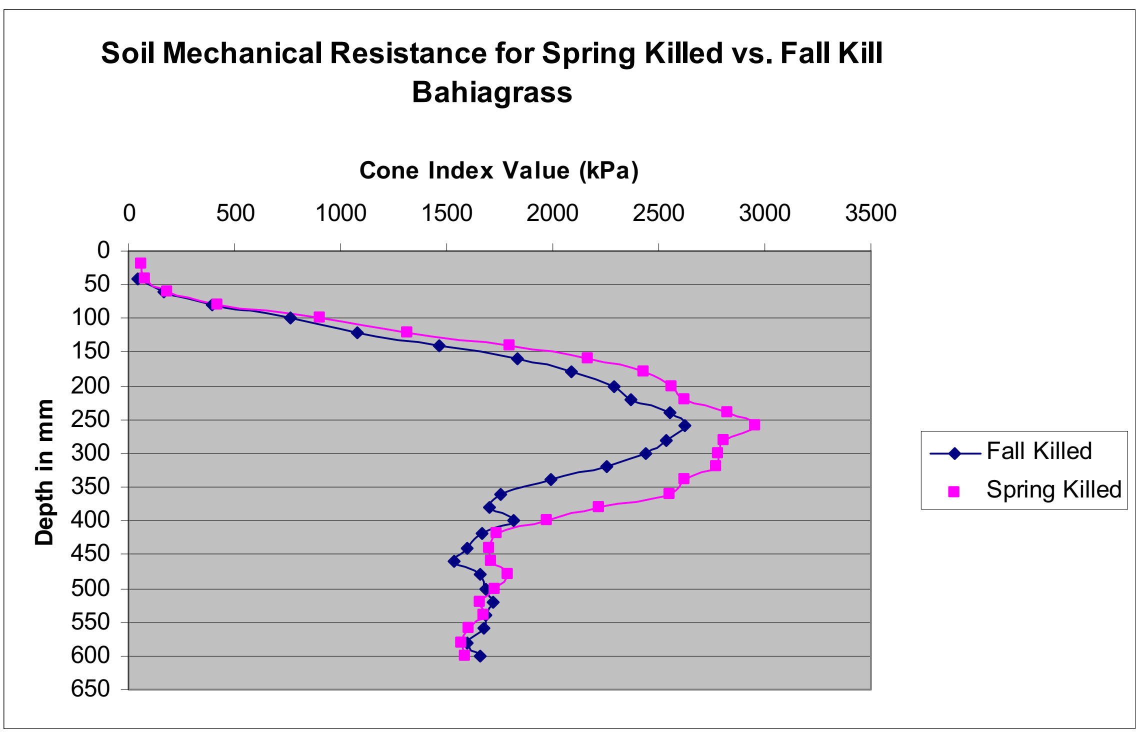

Figure 2. Influence of kill date of bahiagrass on penetrometer readings prior to peanut planting.

The bahiagrass rotated soils had less soil mechanical resistance compared to both cotton and peanuts in the conventional plots. So not only does fall killing help prepare an even better seedbed than with spring kill but it adds and extra dimension over annual cover crops. High mechanical resistance impedes root growth and subsequently reduces yield and retards water movement through the soil profile, thereby increasing the chances of water as runoff.

Fall killing of bahiagrass contributed to the positive aspects of a healthy soil which in turn resulted in healthier and more vigorously growing plants which were better able to withstand stress conditions. Bahiagrass can be managed in such a way to allow strip tillage planting to make it much more economical to grow peanuts. This system is being refined for different areas of the country and different cropping systems and is adding value to conservation tillage planting methods.

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IN-ROW SUBSOILING SOUTHEASTERN SOILS TO REDUCE COMPACTION AND IMPROVE CROP YIELDS

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ABSTRACT

In-row subsoiling has been used in the southern United States as a standard production practice to reduce the ill effects of soil compaction. Much of the subsoiling literature from the southern U.S. indicates that significant increases in productivity are found when in-row subsoiling is used, with the most success being found on sandier soils. However, the cost of this operation is relatively expensive and significant gains in crop yield must be obtained to pay for the tillage practice. Much can also be done to reduce the cost of the in-row subsoiling operation. A number of research studies are presented that indicate various methods that can be used to reduce the cost of in-row subsoiling. These methods include: proper selection of subsoiler shanks, appropriate selection of subsoiler depth, appropriate selection of soil moisture for subsoiling, reducing frequency of subsoiling, and consideration of other methods of compaction reduction, including the use of a cover crop. Use of these methods should allow in-row subsoiling to continue to be a valuable part of conservation agricultural systems.

INTRODUCTION

Soil compaction was only widely recognized as a possible limitation to crop yields in the early 1900's when large agricultural vehicles began to be used for agricultural production and compaction was more easily visualized due to vehicle rutting. Producers began to notice that reduced crop growth was sometimes found in the rutted areas of the field. Reduced infiltration, increased ponding on the soil surface, reduced crop growth, and reduced production was often found in the ruts left from previous passes of tractors or implements. Thus, one of the two causes of soil compaction was diagnosed, i.e. vehicle traffic.

A second cause of soil compaction that was not as easily visualized was a hardpan that can limit rooting and crop yields. Hardpans often have two causes: (1) repeated interaction with tillage equipment (typically discs or rotary tillers sometimes used for years at the same depth), and (2) naturally occurring layers that are caused by interactions of small and large soil particles tending to completely eliminate porosity.

Tillage was first used and continues to be the most common method used to alleviate soil compaction. Disrupting the compacted soil profile often provides immediate visual relief to rutting. However, in many soil types and climatic regions, the damage caused by these tillage events probably outweighed the benefits associated with this process. Deep tillage (often referred to as subsoiling), while adequately disrupting compacted soil conditions, may excessively disturb the soil surface. The subsoiling process may leave soil unprotected by crop residue and susceptible to rainfall that causes runoff and erosion.

Subsoiling is defined as tillage below depths of 35 cm (ASAE Standards, 1999). Soils compacted from traffic or with naturally occurring soil compaction often benefit greatly from subsoiling with larger pores being created that increase rooting and infiltration. The ability of a soil to benefit from subsoiling depends upon many factors including soil type, soil management, vehicle management, etc. Much research has been conducted that has shown evidence about the overall benefit of subsoiling. However, some research has also been conducted that has shown no overall positive benefits to crop productivity. Reasons for discrepancies in these research results on subsoiling consist of differences in equipment, different climatic regions, cropping systems, and soil types.

The combination of subsoiling and modern conservation tillage systems that emphasize large amounts of crop residues on the soil surface has allowed subsoiling to be conducted without increased runoff or soil erosion. Conservation systems emphasize maximizing crop residue on the soil surface at the time after subsoiling has been conducted. Maximizing the amount of crop residue on the soil surface includes eliminating surface tillage and maximizing cover crop growth. In conservation systems, subsoiling is often conducted only in the row area instead of broadcast over the entire field. It is then referred to as in-row subsoiling or strip-tillage. If appropriate measures are taken to minimize surface disturbance caused by subsoiling, in-row subsoiling can be a valuable resource to combat soil compaction.

Therefore, the objective of this report is to examine the pertinent literature on subsoiling that has been conducted in the Southeastern U.S. and to point to opportunities to increase the effectiveness of subsoiling while minimizing the cost of the operation.

IN-ROW SUBSOILING BENEFITS FOR SOILS AND CROPS

Campbell et al. (1974) studied the effect of subsoiling to a 0.38 m depth in sandy loam soils in South Carolina. They found that subsoiling adequately disrupted the A2 horizon, reduced soil strength, increased infiltration, and increased rooting depth. Reicosky et al. (1977) noted several studies that pointed to increased crop yields and reduced soil strength owing to subsoiling. However, most of these studies gave little cropping information and it is assumed that conventional tillage practices were employed. They also noted some soils in the Southeast that might contain toxic levels of soluble aluminum in the acid subsoils would not benefit from deep tillage as deeper rooting would not prove beneficial. Deep placement of lime might be useful to overcome this soil limitation.

Threadgill (1982) conducted a study over 4 years on a sandy loam soil in Georgia that evaluated the long-term effects of soil strength reduction caused by subsoiling to a depth of 0.36-0.38 m. He concluded that soil strength was reduced for one year but was not detected after the second year. He advocated the use of a controlled-traffic system as a method of increasing the longevity of reduced soil strength.

Box and Langdale (1984) evaluated the effect of subsoiling in a sandy loam soil in Georgia. Subsoiling was conducted with points which were 6.4 cm wide and at a depth of 0.36 m. In-row subsoiling and irrigation treatments were found to significantly increase grain yields. However, the effect of irrigation was much greater as it provided a 56% increase in yield while in-row subsoiling provided a 10% increase in yield.

Busscher et al. (1986) also studied the longevity of subsoiling on a loamy sand soil in South Carolina. A non-parabolic angled forward shank that was 20-mm wide and had a 65-cm wide point was used to disrupt soil compaction down to depths of 0.5-0.6 m. One year following subsoiling, the evidence of the previous year's tillage was found, but the soil strength had increased to levels of 1.5-2.5 MPa which were root-limiting. They advised that annual subsoiling was a mainstay of all cropping systems in the Southeastern Coastal Plain.

Touchton et al. (1986) found that in a two-year study in Alabama, in-row subsoiling gave different results on two soil types. On a sandy loam soil, in-row subsoiling was conducted prior to planting by pulling a shank through a soil which had a root-restricting hardpan at a 0.2-m depth. In-row subsoiling was conducted at a depth of 0.3 m. On a silt loam soil, which had no hardpan, in-row subsoiling was conducted at a 0.200-m depth prior to planting. Results on the sandy loam soil showed that in-row subsoiling produced the highest cotton yields for both years of the study while results for the silt loam soil only showed significantly higher yields for in-row subsoiling for one year of the study.

In a later study, Busscher et al. (1988) studied in-row subsoiling on a loamy sand in South Carolina for two years. They used three subsoilers to unspecified depths: Brown-Harden Super Seeder[1] (Ozark, AL), Tye Paratill™ (currently manufactured by Bigham Brothers Inc., Lubbock, TX), and Kelly Manufacturing Company subsoiler (KMC; Tifton, GA). Soil strength was evaluated with and without surface tillage. All three implements effectively disrupted compacted subsoil but a reduced stand establishment (67%) was found for the non surface-tilled treatments. The narrower KMC subsoiler provided a narrower zone of disruption because the shank was 32 mm wide with a 32-mm wide point. The wider shank of the Super-Seeder (50 mm) and wider point (73-mm) provided a larger disrupted area and overall lower soil strength.

Clark et al. (1993) evaluated the use of a Paratill™ on a clay soil in Georgia. Grain sorghum was no-till planted into wheat residue each year of a two-year study. Six shanks with equal spacing of 61 cm were pulled approximately 0.3 m deep. Soil strength was found to increase significantly in the 0.14-0.21-m depth range as the frequency of the use of the Paratill™ also increased. This result further indicates that this operation may need to be performed in this soil on an annual basis.

Mullins et al. (1997) evaluated the effect of in-row subsoiling on a silt loam soil in northern Alabama, a sandy loam soil and a sandy clay loam in central Alabama. Subsoiling was conducted with a deep fertilizer applicator described by Tupper and Pringle (1986) to a depth of 0.38 m. In-row subsoiling caused a 22% increase in cotton yield over the three-years of the study for the sandy loam soil. In all other soil types, no significant benefit of subsoiling was found on crop production.

Smith (1995) used a controlled-traffic system to evaluate the effect of subsoiling in the fall of the year in a clay soil in Mississippi. Subsoiling was conducted after harvest with a parabolic

[1]The use of company names or tradenames does not indicate endorsement by USDA-ARS.

subsoiler to a depth of 40 cm on 50-cm centers. Row spacing of cotton was 1 m. When irrigation was not present, yield increases averaged 15%. When irrigation was present, yield increases averaged 8%. Using soybeans instead of cotton in this same experiment, Wesley and Smith (1991) found dramatically increased yields of 73-132% as compared to non-irrigated check treatments.

Busscher and Bauer (2003) studied the relationship between soil strength and cotton yield in a controlled traffic system on a loamy sand in South Carolina. Subsoiling was conducted with a KMC subsoiler to a depth of 0.4 m. This shank was 2.5 cm wide and was angled forward by 44°. Soil strength was reduced by subsoiling and this coincided with an increase in root growth. However, cotton yield was not influenced by subsoiling. The positive effects of a rye cover crop were also noted even though increased yields did not result.

Raper et al. (1994) used soil strength to evaluate the effects of subsoiling and controlled traffic on a sandy loam soil in Alabama five years after the experiment was initiated. One of the initial tillage treatments consisted of using a Deere & Co. (Moline, IL) V-frame subsoiler operating on 0.25 m centers to completely disrupt the soil profile down to a depth of 0.5 m. Another tillage treatment consisted of using a KMC in-row subsoiler to a depth of 0.4 m prior to planting. Traffic was eliminated on half of the plots using an experimental wide-frame tractive vehicle which could span a distance of 6 m. Results from this study showed that when in-row subsoiling was used on an annual basis, recompaction caused by traffic was not found. The advantages normally attributed to controlled traffic did not materialize due to the annual disruption of in-row subsoiling. Another study that was conducted using the same tillage treatments (Raper et al., 1998) concluded that when traffic was not controlled, the plots that received the initial complete disruption treatment with the V-frame subsoiler recompacted similar to plots that had never been subsoiled.

Schwab et al. (2002) conducted an experiment on a silt loam soil in Alabama to evaluate non-version subsoiling. Subsoiling was conducted with a Paratill™ to a depth of 0.45 m or a KMC subsoiler to a depth of 0.43 m. Results from this experiment indicated that non-inversion subsoiling or in-row subsoiling conducted in the fall of the year resulted in the highest seed cotton yields; 16% greater than conventional tillage and 10% greater than strict no-tillage. Significant compaction reduction was also found with these two subsoiling treatments thus contributing to the increased cotton yields.

Truman et al. (2003) evaluated rainfall infiltration and runoff on the same plots that Schwab et al. (2002) used on the silt loam soil in Alabama. They conducted rainfall simulation experiments during fall and summer months and measured infiltration and runoff at the end of 1 and 2 hour time periods. They concluded that no-till /Paratill™/rye plots had 34% to tenfold less runoff than from other tillage systems, while conventional-till plots had 1.5 to 5.4-fold times more soil loss than from other tillage systems. Subsoiling as conducted with the Paratill™ had more influence on runoff and soil loss than did surface cover in these soils. They recommended that a no-till system combined with the use of the Paratill™ in the fall and a rye cover was the best system to increase infiltration and plant available water and reduce runoff and soil loss for the Tennessee Valley region.

Self-Davis et al. (1996) conducted one of the few studies involving subsoiling in pastures. They evaluated the use of a Paratill™ and an Aer-way (Wylie, TX) pasture renovator in a study in Alabama on a sandy loam soil. Tillage was conducted down to a depth of 0.32 m with the Paratill™. These methods of renovation tillage effectively loosened the compacted soil and caused an increase in dry matter production, but recompaction by cattle traffic caused the bulk density to return to values similar to those measured prior to renovation treatments.

Baumhardt and Jones (2002) conducted a study on a semiarid clay loam soil in Texas where they evaluated the effect of non-inversion subsoiling on soil strength. They found decreased cone index and bulk density. Stubble-mulch tillage conducted following Paratill™ subsoiling diminished the benefits afforded to cone index and bulk density in this study.

One of the major reasons to subsoil is to extend rooting depth into the soil profile where soil moisture is more readily available. However, if moisture is made available to the plants by other means (irrigation or frequent rainfall) it is possible that subsoiling will have little effect. This hypothesis was verified in a study conducted by Camp and Sadler (2002) examining a sandy loam Coastal Plains soil. They found that irrigation increased corn yields all years between 8-135% while subsoiling increased yield in only two years by 4-6%.

Coates (1997) also studied the effects of subsoiling and irrigation in a silt loam soil in Arizona. Subsoiling was conducted with a triplex subsoiler following a cotton stalk puller. Neither plant counts nor crop yields were affected by subsoiling when the field was irrigated.

INCREASING EFFECTIVENESS AND REDUCING COSTS OF IN-ROW SUBSOILING

As illustrated by the previous studies, subsoiling is a valuable tillage practice that has proven effective to reduce soil compaction, increase infiltration, reduce runoff, and increase crop yields on some soil types. These benefits are usually afforded to soil and plants managed in conventional or conservation systems. However, the use of subsoiling in conservation systems requires that extra measures be taken to reduce soil disturbance and maximize residue coverage. The choice of shank and choice of tillage depth may prove of extreme importance in making decisions about whether or not subsoiling is a viable option for conservation systems. Particularly with higher fuel prices that producers must now pay, the cost of subsoiling should be minimized using every method available.

Reducing energy through shank selection

The shape and use of subsoiler shanks can vary greatly for conservation systems. Nichols and Reaves (Nichols and Reaves, 1958) studied several shapes of subsoilers in the soil bins of the USDA-ARS National Soil Dynamics Laboratory (NSDL) in Alabama. The shape of the subsoilers ranged from a straight configuration to a deeply curved configuration. Their research indicated that subsoilers with the most curvature required the least amount of energy. They also indicated similar amounts of soil breakup for all tool shapes. However, other experiments in sandy loam soils (Upadhyaya et al., 1984) found that straight shanks mounted at an inclination to the vertical gave reduced draft measurements compared to a curved subsoiler.

One limitation that curved shanks have is that they are designed to operate at a single depth while inclined shanks are equally effective at all depths (Gill and Vanden Berg, 1966). Considering the concept of site-specific subsoiling which may require subsoilers to operate at different depths, Raper (2005) conducted an experiment to compare straight and curved subsoilers operating at depths of 0.23, 0.30, and 0.38 m in a sandy loam soil and a clay loam soil in the soil bins of the NSDL. He determined that the angled shank took 7-16% less force in the sandy loam soil and 7-14% less force in the clay loam soil.

Raper (2002) compared several shanks in the sandy loam soil and clay loam soil bins at the NSDL in Alabama to evaluate surface and belowground disturbance as well as differences in draft and vertical forces. Seven shanks were tested: (1) Deere and Co. straight shank (32 mm thick) and is currently used on the John Deere 955 Row Crop Ripper with a narrow point of 70 mm, (2) same Deere and Co. shank with a wide 178 mm point, (3) a KMC shank with an angle of 45°, (4) a KMC shank with a more passive angle of 15° degrees, (5) a KMC shank with an angle of 45° and a flexible wing attached to the rear of the shank, (6) a Paratill™, (7) a Terratill™™, and (8) a Worksaver TerraMax™ (Litchfield, IL). The first five shanks were straight but angled with the horizontal while the last three shanks were of bentleg design. The tillage depth was 0.33 m for all shanks. The results surprisingly showed that the bentleg shanks had the lowest draft requirements with the KMC shank at a 45° also performing quite well. The largest belowground disruption was caused by the Deere shank with the wide point. The minimum aboveground disruption was caused by the Paratill™ and Terramax™ shanks.

As a follow up experiment, Raper (2004) conducted an experiment in a loamy sand soil using three shanks, the Paratill™, the Terramax™, and the KMC 45° subsoiler. Depths of subsoiling were 0.2, 0.3, and 0.4 m. The results from this experiment showed that near the soil surface, the KMC subsoiler reduced bulk density better than the other shanks while at deeper depths, the Paratill™ excelled in loosening the soil profile. Reduced subsoiling forces were found for reduced depths of subsoiling but no differences in draft were found for the different implements. Greater surface disruption was found for the KMC subsoiler. Increased belowground disruption was found with the Paratill™ than with the Terramax™ or the KMC subsoiler.

Reducing energy through reducing tillage depth

Another aspect of subsoiling is to target the depth of subsoiling to the depth of compaction. Subsoiling at depths greater than necessary requires significant additional tillage energy and may reduce crop yields while covering excessive amounts of crop residue remaining on the soil surface. Also, loosening the soil to greater depths than necessary can promote future deeper compaction resulting from vehicle traffic.

Raper et al. (2000a) conducted an experiment that examined subsoiling depth, when subsoiling was conducted, and the use of a cover crop to combat compaction in a silt loam soil in Alabama. Preliminary soil strength measurements determined that the depth of the root-impeding layer was found at depths of 0.1-0.15 m. Therefore, shallow subsoiling was conducted just below the root-impeding layer with an experimental Yetter (Colchester, IL) implement to a depth of 0.18 m. A deeper subsoiling depth was also conducted to a depth of 0.33 m. Subsoiling treatments were conducted either in autumn after harvest or in the spring prior to planting. Half of the plots also were planted in a rye cover crop with the main cash crop being cotton. Results from this experiment showed that soil strength was reduced by the subsoiling treatments to their depth of operation. Spring subsoiling was most effective in reducing soil compaction throughout the growing season as compared to subsoiling conducted almost 12 months earlier. They found that subsoiling conducted to a depth of 0.18 m took 50% less energy than subsoiling conducted to a depth of 0.33 m. They also found that in 3 of the 4 years of the experiment, the highest yields in the plots were found with the shallow subsoiling treatment combined with the use of a cover crop. The concept of only supplying the necessary depth of subsoiling to the depth of compaction proved to be the best solution for obtaining maximum yields in this soil type.

In some cases, totally eliminating the use of a subsoiler may prove to be the best option. In the same experiment as previously discussed, Raper et al. (2000b), found that one of the most significant results of this experiment was that the use of a cover crop almost eliminated excessive soil strength in the soil profile during the growing season and increased cotton yields compared to no-tillage. Increased soil moisture was found in the plots with cover crops due to increased infiltration and proper termination of cover crop growth in the spring prior to planting. Even though significant soil compaction was measured prior to starting the study, the use of a subsoiler proved to not significantly increase yields over the use of a cover crop.

In a different soil type with an extremely variable soil, Raper et al. (2005a) conducted an experiment in a field located in southern Alabama over four years to evaluate whether the concept of site-specific subsoiling (tilling just deep enough to eliminate the hardpan layer) would reduce tillage draft and energy requirements and/or reduce crop yields. An initial set of soil strength measurements indicated that the depth of hardpan present in this field was extremely variable, but could be split into three distinct depth ranges; 0.15-0.25 m, 0.25-0.35 m, and 0.35-0.45 m. Subsoiling treatments were conducted using a John Deere 955 Row Crop Ripper equipped with 7-cm wide LASERRIP™ Ripper Points. A cover crop was also used to determine if similar benefits found in the silt loam soil in north Alabama would also be found in central Alabama on the Coastal Plains soil. Results from this study showed that similar corn yields were produced by site-specific subsoiling and by uniform deep subsoiling. Both of these subsoiling treatments yielded greater than the no subsoiling treatment. The cover crop did not affect corn yield. In the shallow (0.25 m) and medium (0.35 m) hardpan soil condition, draft force was reduced by 55% and 28%, respectively, using site-specific subsoiling compared to uniform deep subsoiling at 0.45 m. In the shallow (0.25 m) and medium (0.35 m) hardpan soil condition, drawbar power was reduced by 47% and 17%, respectively, by site-specific subsoiling as compared to uniform deep subsoiling at 0.45 m. Site-specific subsoiling also reduced estimated fuel use by 43% for the 0.25-m hardpan depth plots and 24% for the 0.35-m hardpan depth plots.

Reducing energy through timing of subsoiling

Soil strength varies considerably with moisture content. Likewise, the energy required for subsoiling also varies substantially with varying moisture content. Targeting the moisture content when soil strength is minimal could provide for decreased subsoiling energy.

Raper and Sharma (2004) evaluated the effect of moisture content on subsoiling energy and soil disruption on a sandy loam soil in a soil bin in Alabama. Subsoiling was conducted with two different shanks: a Deere and Co. straight shank used on the John Deere 955 row crop ripper and a Deere minimum-tillage shank used on the John Deere 2100 minimum-till ripper. The depth of operation was 0.33 m. Results from this experiment showed that the draft and vertical subsoiling forces obtained from the 'very dry' soil condition were the largest. However, this 'very dry' soil condition also produced he largest amount of above-ground disruption. The optimum soil condition for subsoiling occurred at the next soil moisture condition, which was dry but was not hydroscopic in nature. At the 'dry' soil moisture level, the draft forces were reduced by 25-32% which were not statistically different than any of the other soil moisture levels except for the 'very dry' soil moisture condition. The above-ground disruption was also reduced by 13% at this 'dry' soil condition as compared to the 'very dry' soil moisture level. The minimum-tillage subsoiler shank was found to require on average 33% increased draft force over the straight shank. However, the minimum-tillage shank was also found to reduce surface disturbance on average by 13%.

Reducing energy through reduced frequency of use

Currently, subsoiling is practiced on a routine basis throughout the world. Many soils respond positively to subsoiling, with yield improvements normally being found. Tillage tools used for subsoiling vary widely and result in differences in residue remaining on the soil surface, draft force requirements, and belowground soil disruption.

Raper et al. (2005b) compared four subsoiler treatments in a 4-year experiment in a silt loam soil in Alabama. The subsoil treatments compared were (1) no-till, (2) KMC in-row subsoiler, (3) Paratill™, and (4) Terratill™. The Paratill™ and Terratill™ were manufactured by Bigham Brothers Inc. (Lubbock, TX). The depth of subsoiling was set to be 0.33 m because the depth of compaction was found at a slightly shallower depth of 0.30 m. Autumn subsoiling was conducted in varied years to allow comparisons to be made between none, annual, biennial, and triennial treatments all in the same year. A rye cover crop was also used for all plots due the tremendous success realized in previous experiments with this cropping practice. Results showed that annual subsoiling reduced bulk density and draft force as compared to all other treatments. The KMC subsoiler required the minimum draft force, followed by the Paratill™ and the Terratill™. The KMC subsoiler also maintained the loosest soil environment for the longest period of time with the Paratill™ reconsolidating within 3 years to bulk density values similar to no-till. Cotton yields did not show any improvement from any of the three subsoiling treatments with optimum yields being produced with no subsoiling and a rye cover crop.

These results verify the results of Threadgill (1982) and Busscher et al. (1986) which advocated subsoiling on an annual basis to remove soil compaction and to improve crop yields. However, using a cover crop may replace the need for in-row subsoiling on a silt loam soil if compaction is effectively managed.

SUMMARY

The literature is replete with studies that indicate that in-row subsoiling is a valuable production practice that can loosen compacted soil profiles, increase infiltration, reduce runoff, and in most cases also increase crop yield. However, subsoiling does require a significant amount of energy to disrupt compacted soil profiles. Every opportunity should be used to examine where savings can be found during the subsoiling operation. Several methods can be employed to reduce the amount of energy required to subsoil in conservation systems. These include the following:

- Selecting inclined shanks or bentleg shanks that minimize energy requirements while minimally disturbing the soil surface and are equally efficient at various depths of operation.
- Only subsoil to the depth necessary to remove soil compaction. Subsoiling deeper than necessary wastes energy while potentially reducing your crop's yield.
- Adjusting subsoiling depth based on the soil's needs. Southeastern U.S. fields are especially variable and knowledge about the field's variability can allow shallower subsoiling depths to be used in certain areas of the field.
- Consider whether subsoiling can be totally eliminated due to the use of a cover crop which can increase soil moisture to the point that excessive soil strength is not a problem.
- Subsoil only when the soil is not in an extremely dry state. This prevents excessive energy requirements and surface soil disruption.
- Reduce frequency of subsoiling in soils where annual subsoiling is not required. Adoption of other conservation strategies can assist with increasing the length of time between subsoiling.

Even though it is possible to subsoil a field to remove compaction, care should be exercised before this potentially expensive operation is performed. Once soil is subsoiled, it easily recompacts if traffic is applied in the same area. Research indicates that two passes of a tractor in the subsoiled area will cause the soil to return to its previous state prior to subsoiling (Blackwell et al., 1989). If traffic is controlled, however, the benefits of subsoiling can be long-lasting and beneficial.

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INTEGRATING GRAZING BEEF CATTLE AND CROP PRODUCTION IN THE SOUTHERN HIGH PLAINS

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ABSTRACT

Agricultural intensification during the past century resulted in specialization of crop and livestock in monoculture systems that captured economies of scale and contributed to increased production. Today, concerns are growing over the ability to maintain long-term intensive monoculture agriculture. Increasingly, these systems are recognized as extracting non-sustainable environmental costs. Such systems are more vulnerable to issues of biosecurity and create dependence on costly infrastructure. Integrating grazing livestock with cropping systems can improve system resilience, diversify income, and decrease dependence on non-renewable resources and energy. The Texas High Plains exemplifies these challenges where cotton (*Gossypium hirsutum* L.) and cattle in monoculture systems represent major agricultural enterprises. Agriculture here is dependent on water extracted from the Ogallala at rates that have exceeded recharge for many years. The decline in water resources, escalating energy costs, and anticipated changes in farm programs are driving dramatic changes in this region. In 1998, long-term systems research was initiated to compare the cotton monoculture typical of the region with an integrated cotton-beef cattle system. At the end of five years, the integrated system lowered irrigation water applied by 23%, decreased nitrogen fertilizer by 40%, and improved profitability by about 90%. Additional benefits were increased soil organic carbon, improved soil microbial activity, decreased soil erosion, improved plant growth, and diversification of income sources. Increasing cotton yields through improved genetics and management can increase profitability in the short term but longer term sustainability of the natural resource base depends on benefits captured by the integrated system.

SUMMARY

Use of land is intensifying as global populations continue to increase and demands for food, feed grains, and fiber expands. With this global increase in need for food and feed production, crop farming intrudes increasingly into traditional grazing lands resulting in over grazing of remaining lands and increasing pressure on natural resources. Declining water resources, soil fertility, air quality, wildlife habitat, and loss of resilience of ecosystems are becoming critical issues.

Worldwide, a key feature of agricultural intensification has been specialization in crop and livestock production, resulting in fewer crop and/or livestock species that are maintained together. Agriculture in the 21st century will increasingly be asked to continue providing an abundant supply of safe and wholesome food and fiber at a reasonable cost and which is environmentally benign and assures the future economic and social sustainability of rural areas. The most scientifically sound and objective way to accomplish this will be by fully exploiting the many advantages and benefits of production systems which are well integrated and are diverse. The concept of integrated systems must be viewed not only on an individual farming entity basis but from a landscape perspective where the mosaic of crop and livestock systems contribute to the diversification of the regional system as well.

The Texas High Plains exemplifies the challenges and opportunities of agricultural production, natural resource management, and economic stability. In 1998, a long-term comparison of two irrigated systems began that includes an integrated crop-livestock system and a cotton monoculture typical of the region. A primary objective of this research is to identify agricultural strategies that conserve water resources and to provide economic viability through inclusion of the grazing animal within the cropping system. Begun in 1997, two large-scale replicated systems compare water use, productivity, and economics of a cotton monoculture and an integrated 3-paddock system that includes cotton in a 2-paddock rotation with grazed wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.) and the perennial 'WW-B. Dahl' old world bluestem [*Bothriochloa bladhii* (Retz) S.T. Blake]) in the third paddock for grazing and seed production. Angus crossbred beef steers (*Bos taurus* L.; initial BW 249 kg; SD= 26 kg) sequence graze dormant bluestem, rye, wheat, and spring-growth of bluestem from January to mid-July when they enter the feedyard for finishing. Both systems are irrigated by a subsurface drip system (Netafim, Tel Aviv, Israel 64922).

Over the first five years of this research, the integrated system used 23% less irrigation water, 40% less nitrogen fertilizer, and fewer other chemical inputs than the monoculture cotton. Cotton yields in both systems averaged about 1050 kg ha^{-1}. Steers gained about 0.82 kg d^{-1} from January to July when they then entered the feedyard for finishing. Cattle gained about 1.6 kg d^{-1} during the 125-d finishing period and 54% graded USDA Choice. Profitability was 90% greater for the integrated system at this yield level and with a 90-m pumping depth for irrigation water, the actual depth to water at the research site and a representative depth for the region. Income sources were diversified in the integrated system to include cattle, cotton, grass seed, and potentially hay and small grains. In the continuous cotton system, alternative crop strategies were severely limited in the event of a crop failure due to time and herbicides already applied.

With the decline in water resources in this region, alternative strategies are essential if productivity of crops and livestock are sustained. This will likely require a return of significant areas to dryland systems. As the world's attention focuses increasingly on the need for a safe, economical, and adequate food supply for a growing global population, there must be equal concern for the sustainability of that food production and the protection of our natural resources and environment. The grazing animal will likely play a key role in achieving these objectives and contributing to resilience of these ecosystems. The Texas High Plains is but a case study for the challenges that are unfolding across this country and around the world.

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CORN, COTTON AND SOYBEAN RESPONSE TO REDUCED TILLAGE STALE SEEDBED SYSTEMS

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ABSTRACT

Studies were conducted to evaluate cotton yield response to tillage systems; and corn and soybean yield response to rotation and tillage. A three-year (2003-2005) tillage study on a Leeper silty clay loam soil in North Mississippi indicated differences between tillage systems but no tillage by year interaction for yield, plant height and number of nodes. No-till had less mid-season height and fewer nodes per plant than the early spring Prepmaster® bed system, fall bed-roller, fall Paratill® (10-12 inch depth under-row tillage) + bed-roller and alternating years of fall bed-roller and fall paratill + bed-roller. The fall applied bed-roller and spring applied Prepmaster stale seedbed system yields were 21 to 24% higher than no-till and equal to the Paratill treatments. A 5-year (2001-2005) study on a Blackland prairie clay soil (Catalpa silty clay loam) indicated no-till corn following no-till soybeans showed a rotation yield response 3 of 5 years with a 5-year average of 21%. There was no added corn yield response from tillage applied to the previous soybean crop. After the first two years (2001 and 2003), subsequent years (2003-2005) showed that no-till yield in both continuous soybeans and in a rotation with no-till corn were equivalent to the fall applied chisel-harrow (one-pass operation) reduced tillage stale seedbed system. However, the fall applied chisel-harrow system for the first 2 years averaged 13% and 20% more yield than no-till with continuous soybean and in rotation with no-till corn, respectively.

INTRODUCTION

Previous corn and cotton research on a silty clay loam soil in North Mississippi indicated deep under the row tillage in a reduced tillage stale seedbed system improved yield and profitability (Buehring et al., 1999a; Buehring et al., 1999b; Buehring et al., 2004). On a Blackland prairie clay soil, narrow soybeans in continuous monoculture and in rotation with corn showed a positive yield response to a fall applied reduced tillage stale seedbed system (Buehring et al., 1999c). No-till corn in the rotation with no-till soybean produced yield equal to conventional tillage corn. More recent cotton and corn research indicated no yield response to deep under the row tillage (Buehring et al., 2005; Dobbs et al., 2004). Our objectives in these studies were to evaluate: cotton growth and yield response to one-pass minimum tillage raised stale seedbed systems in comparison to raised stale seedbed systems with deep under the row tillage; and soybean and corn yield response to rotation and a fall applied reduced tillage stale seedbed system.

MATERIALS AND METHODS

Cotton Tillage Systems

The study was conducted on a Leeper silty clay loam soil as a randomized complete block design with 4 replications. Plot size was 4 rows (38-inch) by 500 ft long. All tillage treatments (fall bed-roller, fall paratill + bed-roller) except the Prepmaster® were applied in January 2003 (due to wet fall in 2002), October 2003 and November 2004. The Prepmaster treatment was applied in late March or early April of each year where stalks had been mowed the previous fall.

The Paratill implement, manufactured by Bigham Brothers, Lubbock, Texas, has an offset shank which lifts the soil under the row as it passes through the soil profile. Prepmaster is a pre-plant herbicide incorporator implement manufactured by Bigham Brothers, Lubbock, Texas. This implement was equipped with 16 inch wide sweeps positioned on the center of the row, a 9 inch wide buster sweep, rolling cutter bar, rolling basket and smooth metal roller. This implement was operated at 6 to 7 mph and formed a wide smooth surface bed height of 4 to 6 inches.

Recommended agronomic practices were used in the study for a 2 bale/acre cotton yield goal. Delta and Pineland Company Suregrow SG 215BR variety was planted no-till on all plots in late April or early May. Potassium and phosphorus fertilizers were applied based on soil test recommendation. Nitrogen fertilizer at 90 lb N/acre as a UAN (32%N) solution, was applied with a colter-knife system that placed the fertilizer approximately 6 inches from the row and 2 inches deep. The nitrogen fertilizer was applied to cotton in the pinhead square stage of growth. Pentia (mepiquat pentaborate) applications were made each year as needed to control rank growth.

The center 2 rows of the study were harvested in mid to late September with a 2-row spindle picker equipped for plot harvest. Grab samples were pulled from the seed cotton samples of each plot. The seed cotton samples were ginned with an 8-saw laboratory gin (no dryer, seed cotton cleaners, or lint cleaners) to determine percent lint turnout.

Data collected were: plant stands 5 weeks after planting (WAP); mid-season plant height and nodes/plant 11 WAP; seed cotton yield; percent lint turnout; and lint yield. The data were subjected to SAS mixed procedure analysis with year as main plot and tillage treatment as subplots (Littell et al. 1996). Means were separated using Fisher's Protected LSD calculated at the 5% significance level.

Corn-Soybean Rotation Tillage Systems

The study was conducted as a randomized complete block design with 4 replications in 20 ft wide by 60 ft long plots. The corn and soybean tillage and rotation systems are listed in Table 2 and 3, respectively. The reduced tillage (FCH) stale seedbed system was applied in the fall of each year with a high clearance chisel plow equipped with coulters in front of each chisel shank and a chain harrow attached to the rear of the chisel plow. All treatments were planted with a no-till planter equipped with residue movers and coulters.

Roundup WEATHERMAX (glyphosate) + Clarity (dicamba) at 1.0 + 0.25 lb ai/acre were applied in March of each year as a burndown to the entire study area. The Roundup Ready corn was planted no-till in late March or early April of each year at 28,000 seed/acre. Roundup Ready Maturity Group V soybean was also planted no-till in late April of each year. Both corn and soybeans were planted in 30 inch rows in 2000-2004 and 38 inch rows in 2005. Recommended agronomic practices were used for a yield goal of 150 bu/acre for corn and 50 bu/acre for soybeans.

The center 2 rows in each corn and soybean plot were harvested with a plot combine for grain yield. Corn and soybean grain yields were adjusted to 15 and 13% seed moisture, respectively. The data were subjected to Analysis of Variance procedure and means were separated using Fisher Protected LSD calculated at the 5% significance level.

RESULTS AND DISCUSSION

Cotton Tillage System

The environmental growing seasons were highly variable but the study mean lint yield was 1071 lb/acre. Since there was no year by tillage system interaction for mid-season plant height, nodes per plant, plant population and lint yield, the data was pooled over years and analyzed.

End of each growing season bed height measurements indicated 1 to 2 inches for continuous no-till and 4 to 6 inches for all other raised bed systems in 2003-2005 (data not shown). Tillage systems had no effect on population and percent lint turnout (data not shown).

Tillage systems showed differences for mid-season plant height, mid-season nodes per plant and lint yield (Table 1). Prepmaster, fall bed-roller, fall paratill + bed-roller and alternating years of fall bed-roller and fall paratill + bed-roller systems showed more mid-season growth (nodes/plant and plant height at 11 WAP) and 21 to 25% more lint yield than continuous no-till cotton. There were no yield differences among the raised bed systems which had some tillage. These results differed from reports (Stevens, et al., 1992; Triplett et al., 1996; Hutchinson et al., 1990) that after 2 years of no-till production on silt loam soils cotton yields were equal or greater than conventional tillage. The difference in no-till yield responses may be related to soil texture differences between the silt loam soil and the silty clay loam soil.

The spring one-pass (late March/early April) Prepmaster and the fall bed-roller tillage systems produced yield equal to the annual fall paratill + bed-roller or alternating years of fall bed-roller + fall paratill + bed-roller. This was in contrast to earlier research which showed a positive yield and profitable response to deep under the row tillage (Buehring et al., 1999a; Buehring, et al., 2004). However, the results are in agreement with more recent research that showed no yield response to deep under the row tillage for cotton (Buehring, et al., 2005). The contrasting results suggest that with less tillage in recent years, soil changes may have occurred which negated the positive benefit of deep under row tillage.

Corn-Soybean Rotation Tillage Systems

Corn study mean yield ranged from 124.4 in 2003 to 164.0 bu/acre for 2005 (Table 2). Three (2001, 2003, 2004) of 5 years, corn showed a positive yield response to rotation with a 5-year average increase of 21%. In the rotation, tillage with the previous soybean crop did not improve no-till corn yield. These results are in agreement with previous research that no-till corn showed yield equivalent to corn with conventional tillage on a Blackland prairie clay soil (Buehring et al., 1999c). However, the results are in contrast with Hairston et al. (1984) research reported that conventional tillage corn on a Blackland prairie clay soil produced higher yield than no-till.

The soybean study mean yields ranged from 40.5 in 2001 to 54.3 bu/acre in 2004 (Table 3). In the continuous monoculture, the FCH stale seedbed system only produced higher yield than no-till in 2002. However, in the rotation, FCH produced 8.3 and 9.6 bu/A higher yield than no-till soybeans in 2001 and 2002. Subsequent years 2003, 2004 and 2005, showed no yield differences between FCH and no-till in both continuous soybean and in rotation with corn. These results differ from research report by Hairston et. al., (1984) that on a Blackland prairie clay soil, conventional tillage soybean produced higher yield than no-till. However, these results agreed with previous research (Buehring et al., 1999c) on a Blackland prairie clay soil which indicated in continuous soybean and in a corn-soybean rotation FCH only produced higher yield than no-till soybeans in year one of a 3 year study. These results also are similar to reports (Stevens, et al., 1992, Hutchinson et al., 1990; Triplett et al., 1996) with cotton that after 2 years of no-till production on silt loam soils, cotton yields were equal or higher than conventional tillage.

When expressed as a percentage of yield averaged over years 2001 and 2002, and 2003-2005, FCH showed 9% and 13% higher yield for the rotation than continuous soybean, respectively, (Table 4). This is in contrast to no-till which showed a rotation advantage of 1% averaged for 2001 and 2002 and an 8% average advantage for 2003-2005.

Compared to no-till in continuous soybean, FCH showed 13% greater yield average for 2001-2002 but averaged 3% less yield than no-till for 2003-2005. In the corn-soybean rotation, FCH showed a 20% greater yield average than no-till for 2001-2002 with only a 2% greater yield average than no-till for 2003-2005.

CONCLUSIONS

Cotton Tillage Systems
A fall applied bed-roller or spring applied Prepmaster bed systems will produce yield equal to deep under the row tillage and 21 to 24% higher yield than no-till. Deep under row tillage may not be necessary on the silty clay loam soils of North Mississippi.

Corn-Soybean Rotation Tillage Systems
The rotation of no-till corn with no-till soybeans can improve corn yield as much as 21%. In a continuous soybean monoculture and rotation with corn, no-till may show as much as a 13% and 20% respectively, lower yield than FCH the first 2 years with no difference in subsequent years. Due to the potential 13 to 20% yield loss the first 2 years, the adoption of the no-till soybean production on the Blackland prairie clay soils of North and East Mississippi will be limited. However, FCH as a one-pass stale seedbed system offers an alternative to no-till or conventional tillage.

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Table 1. Three year (2003-2005) average tillage system effect on mid-season nodes per plant and plant height, and lint yield on a Leeper silty clay loam soil, Verona, MS.

Tillage System	Tillage Time	Plant height 11 WAP	Nodes per plant 11 WAP	Lint lb/acre
1. Prepmaster	Spring	34	12.0	1122
2. Fall bed-roller	Fall	35	12.4	1094
3. Fall paratill + bed-roller	Fall	35	12.2	1098
4. Fall bed-roller 2002 fb fall paratill + bed-roller 2003 fb fall bed-roller 2004	Fall	36	12.4	1134
5. No-till	---------	29	11.2	905
Mean		34	12.0	1071
LSD 0.05		2	0.6	54

Table 2. Corn yield response to tillage and rotation on a Blackland prairie clay soil in 2001-2005, Verona, MS.

	------------------Yield bu/acre-----------------					
Rotation/tillage systems	2001	2002	2003	2004	2005	5 yr Mean
I. Continuous corn						
1. No-till (NT)	105.3	151.8	94.2	107.4	156.3	123.0
II. Corn rotated after soybeans						
2. NT corn after NT soybean (Bn)	148.2	163.0	139.7	132.7	163.6	149.4
3. NT corn after fall colter-chisel-harrow (FCH) Bn	153.9	158.3	139.3	135.9	172.1	151.9
Mean	135.8	157.7	124.4	125.3	164.0	141.4
LSD (.05)	12.2	NS	33.9	11.0	12.6	
% CV	9.2	3.5	16.2	5.5	4.7	

Table 3. Soybean yield response to tillage and rotation on a Blackland prairie clay soil in 2001-2005, Verona, MS.

	------------------Yield bu/acre------------------					
Rotation/tillage systems	2001	2002	2003	2004	2005	5 yr Mean
I. Continuous soybean						
1. No-till (NT)	38.1	37.6	38.6	53.4	42.2	42.0
2. Fall colter-chisel-harrow (FCH)	41.0	45.8	36.0	52.2	42.7	43.5
II. Soybeans rotated after corn						
3. NT Bn after NT corn	37.2	39.0	41.9	55.2	48.4	44.3
4. FCH Bn after NT corn	45.5	49.4	44.5	56.5	48.3	48.8
Mean	40.5	43.0	40.3	54.3	45.4	44.7
LSD (.05)	5.2	4.8	5.2	NS	4.5	
% CV	8.4	3.5	8.7	7.7	6.4	

Table 4. Soybean percent yield response as influenced by tillage system and rotation, 2001-2005, Verona, MS.

	2001-2002	2003-2005	5 year Av
Tillage System	----------------% Rotation yld > continuous----------------		
FCH	9	13	11
No-till	1	8	5
Production System	--------------% FCH yield > no-tillage--------------		
Continuous Soybean	13	-3	4
Soybean – corn rotation	20	2	9

HYBRID, ROW PATTERN, AND PLANT POPULATION COMPARISONS FOR CONSERVATION TILLAGE CORN PRODUCTION

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ABSTRACT

Corn (*Zea mays* L.) produced in narrow rows can increase yields and result in a quicker canopy closure. Costly equipment modifications make narrow rows impractical, but a twin row configuration may boost production with fewer equipment modifications. We compared yield, leaf area index, and weed biomass, for a conventional and a glyphosate-tolerant hybrid across three plant populations (low 16,000-18,000; medium 24,000-26,000; high 32,000-34,000 plants ac^{-1}) in two row patterns (single vs. twin) at four locations during the 2005 growing season. The experimental design was a RCB (r = 4) with a split-split plot restriction on randomization, where hybrids were assigned to main plots, row patterns to subplots and plant populations to sub-subplots. There was a noticeable and statistically significant interaction between hybrid and population at three out of four locations. The conventional hybrid yielded 15% (138 vs. 117 bu ac^{-1}), 12% (158 vs. 139 bu ac^{-1}), and 16% (138 vs. 117 bu ac^{-1}) higher than the glyphosate-tolerant hybrid at the medium population. Row spacing had little effect on yields. Corn yields did not always increase with increased populations. Row spacing had no effect on weed biomass; however populations had a small effect. At two locations leaf area index values of the twin row pattern were 13% (3.1 vs. 2.7 ft^2 ft^{-2}) and 10% (3.3 vs. 3.0 ft^2 ft^{-2}) higher than the standard row pattern. Leaf area index generally increased with increased plant populations and twin row configurations. Twin row corn resulted in a faster canopy closure, but corn yields were not increased by row pattern.

INTRODUCTION

Weeds compete with crops for moisture, light, and nutrients, which can lead to poor crop development and reduced yields (Dalley et al., 2004). The acreage of transgenic crops, including glyphosate-resistant technology, has increased in recent years (Padgette et al., 1995). Glyphosate allows producers to control broadleaf weeds, and annual and perennial grasses, which eliminates the need for multiple herbicide applications. This technology provides a window for postemergence application, but correct timing is essential to prevent yield loss (Krausz et al., 2001).

In addition to the use of herbicides, narrow row crop production might increase yields and reduce weed populations. Farmers in many areas of the southeastern United States are already using narrow rows for corn, cotton (*Gossypium hirsutum* L.), and soybeans (*Glycine max* L.) (Karlen et al., 1987). Decreased space between rows allows the crop to utilize sunlight more efficiently (Bullock et al., 1998). Yield increases in soybeans have been attributed to more efficient interception of sunlight and increased rates of photosynthesis attributable to an increased leaf area index (Lambert and Lowenberg-DeBoer, 2001).

While yields may increase, some cases have shown that the increase is insignificant compared to the cost of conversion (Lambert and Lowenberg-DeBoer, 2001). An alternative to planting narrow rows, while maintaining many of the benefits, is twin rows. Unlike narrow rows, which are planted in uniform spaces, twin rows are 7.5" to 8" rows centered on traditional row spacings (Hurt et al., 2003). A wide variety of crops, including corn, cotton, and peanuts (*Arachis hypogea* L.) are now under research in twin-row production systems (Lanier et al., 2004). While increased leaf area index in twin rows may not occur as quickly as narrow rows, they do provide more rapid canopy closure than conventional single spaced rows (Hauser and Buchanan, 1981). From an economical standpoint, twin rows may provide a decrease in cost per acre, since they can be harvested with the same equipment used to harvest conventional rows. The objective of this study was to examine the effects of hybrid, row pattern, and plant population on leaf area index, weed biomass, and corn grain yield.

MATERIALS AND METHODS

This study was conducted during the 2005 growing season at the Gulf Coast Research and Extension Center (GCS) in Fairhope, AL on a Malbis sandy loam (fine-loamy, kaolinitic, thermic Typic Kandiudult); the West Florida Research and Education Center (JAY) in Jay, FL on a Red Bay sandy loam (fine-loamy, kaolinitic, thermic, Rhodic Kandiudult); the Tennessee Valley Research and Extension Center (TVS) in Belle Mina, AL on a Decatur silt loam (fine, kaolinitic, thermic Rhodic Paleudult); and the Wiregrass Research and Extension Center (WGS) in Headland, AL on a Dothan sandy loam (fine-loamy, kaolinitic, thermic Plinthic Kandiudult). The experimental design was a RCB (r=4) with a split-split plot restriction on randomization. Conventional (CN) or glyphosate tolerant (GT) hybrids were assigned to main plots, twin or single row pattern to sub plots, and low (16,000-18,000 plants ac^{-1}), medium (24,000-2,6000 plants ac^{-1}), or high (32,000-34,000 plants ac^{-1}) population to sub-sub plots. Sub-sub plot dimensions for GCS and TVS were 50' long by 10' wide. Single rows were spaced 30" apart and twin rows were spaced 7.5" apart on 30" in centers. Plot dimensions for JAY and WGS were 50' long by 12' wide. Single rows were spaced 36" apart and twin row were spaced 7.5" apart on 36" centers.

All four locations utilized a conservation system that included a rye (*Secale cereale* L.) cover crop planted in October or November of 2004. Cover crops were terminated with glyphosate prior to planting and plots in-row sub-soiled. Dates that correspond to specific planting, spraying, harvesting, and sampling times for each location are summarized in Table 1. Atrazine and metolachlor were applied to CN treatments prior to plant emergence. Post-emergence applications of atrazine for the CN variety were used as needed until theV7 growth stage. Glyphosate was applied to GT plots within three weeks of planting at GCS and WGS, and approximately 6 weeks after planting at JAY and TVS.

Weed biomass samples were taken prior to any post-emergent herbicide applications at all locations. Three samples were randomly collected from each plot under yield rows using a 2.69 ft^2 square. Samples were grouped by plot and oven dried at 131°F for 48 hours, prior to weighing. Leaf area index readings were taken at three different times prior to canopy closure. Samples were taken using a LI-COR 2000 Plant Canopy Analyzer (LI-COR, Inc., Lincoln, Nebraska). Corn was harvested during August or September of 2005 using a mechanical combine except for Jay, FL, where 10 ft sections were harvested at 2 different locations within each plot due to severe lodging damage caused by Hurricane Dennis.

Leaf area index, weed biomass, and grain yield were subjected to mixed models analysis of variance as implemented in the SAS® procedure MIXED (http://support.sas.com/onlinedoc/913/docMainpage.jsp). Data were analyzed with location as a fixed effect in the model, and there were significant location × treatment interactions for all response variables. Therefore, data were analyzed by location. Fixed effects, and interactions were considered different if P > F was equal to or less than 0.1.

RESULTS AND DISCUSSION

No difference was observed between hybrids for leaf area index when averaged across row patterns and plant populations. At WGS and TVS, the twin row pattern provided a greater leaf area than the single row pattern when averaged across hybrids and plant populations (Figure 1). At all four locations, leaf area was highest in the highest plant populations when averaged across hybrids and row patterns (Table 2). A significant interaction between row pattern and plant population was observed at WGS, when averaged across hybrids. The twin row pattern produced a higher leaf area (3.67 vs. 3.28 ft^2 ft^{-2}) at the high plant population compared to the single row pattern. This supports previous research stating that a decrease between row widths and increased populations allow the crop to utilize sunlight more efficiently (Bullock et al., 1998).

Significant differences among weed populations were observed across hybrids, when averaged across row patterns and plant populations. At JAY and TVS, less weed biomass was observed in the CN hybrid plots compared to the GT hybrid. Reduced weed biomass can be attributed to the pre-emerge addition of metolachlor on all CN treatments. While some studies have shown effective control of weeds with narrow rows (Forcella, et al. 1992; Teasdale, 1995), no significant differences were observed between row patterns in our study. Previous studies attributed weed control to quicker canopy closure; however, seeding plants in twin row patterns may not provide canopy closure fast enough for effective control during the critical period for weed control. Our study may also underestimate the effect of twin rows since weed populations were very low at all locations during the early growing season.

A significant difference was observed for weed biomass across plant populations. At GCS, the medium population resulted in a lower weed biomass (38.48 vs. 62.08 lbs ac^{-1}) compared to the low population. No difference was observed between the medium and high plant population. Results for plant populations appeared similar at other locations, though not significant. This suggests that planting at low populations increases competition between corn and early season weeds.

At TVS, the CN hybrid yielded (141 vs. 135 bu ac^{-1}) significantly higher than the GT hybrid. Though not significant at other locations, the CN hybrid also yielded higher than the GT hybrid. While weed biomass was reduced during the critical period of control for the CN hybrid, it is doubtful that weed populations affected grain yields.

Grain yield was affected by row pattern at one location when averaged across hybrids and plant populations (Table 3). At JAY, the single rows yielded (128 vs. 119 bu ac^{-1}) significantly higher than twin rows. Grain yields between the twin and single rows varied among the other locations. An interaction was also observed at JAY between row patterns plant population (Table 3). Single rows produced significantly higher yields (143 vs. 117 bu ac^{-1}) than twin rows at the high plant population. A significant interaction between row pattern and plant population was observed at WGS where the twin row pattern yielded higher (145 vs. 125 bu ac^{-1}) than the single row pattern at the high plant population (Table 3).

Grain yields were different across plant populations at all four locations, but the high population did not always result in the highest yields. At TVS, JAY, and GCS differences were only observed between the low and medium populations (Table 4). At WGS, differences were observed between the low and medium, as well as the medium and high plant populations (Table 4). The WGS location was the only location where plots were irrigated (4.5 inches of water over the growing season). This supports previous results indicating available moisture may support higher yields in high plant densities and populations (Lambert and Lowenberg-DeBoer, 2001).

Significant interactions between hybrid and row pattern were observed at two locations when grain yields were averaged across populations (Table 3). At JAY and WGS, the CN hybrid yielded higher than GT hybrid across single rows (Figure 2). No differences were observed between hybrids across twin rows. A significant interaction was also observed between hybrid and plant population at three locations when grain yields were averaged across row patterns. At JAY, TVS, and WGS, the CN hybrid yielded 15% (138 vs. 117 bu ac^{-1}), 12% (158 vs. 139 bu ac^{-1}), and 16% (138 vs. 117 bu ac^{-1}) higher than the GT hybrid at the medium population (Table 5). At WGS, the CN hybrid was significantly higher than the GT hybrid at low plant populations. These reductions in yield associated with the GT hybrid support the yield drag previously reported for transgenic crops (Carey and Kells, 1995).

CONCLUSIONS

The CN hybrid tended to yield as well or higher than the GT hybrid across all four locations. There was some evidence that twin row patterns increase leaf area index; however there was little evidence to support any effect on weed populations or grain yield. It was noted that available moisture might be the controlling factor for increasing grain yield in twin row patterns. Plants seeded at high rates (32,000-34,000 plants ac^{-1}) have the highest leaf area index, while plants seeded at medium rates (24,000-26,000 plants ac^{-1}) appear to have an optimal effect on grain yield. Since early season weed populations were so low, more research is needed to determine if twin row patterns might have more effect on early season weed populations.

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Table1. Dates corresponding to planting, spraying, harvesting, and sampling times for weed biomass and leaf area index measurements during the 2005 growing season at four experimental locations.

		Herbicides				LAI†			
Location	Planting	Application			Weed biomass				Harvest
		Date		Rate		Time 1	Time 2	Time 3	
GCS	3/24/05	3/25/05	Metolaclor (CN)‡	1.5 pt ac^{-1}	4/14/05	5/16/05	5/25/05	6/10/05	8/19/05
		4/15/05	Glyphosate (GT)§	24 oz ac^{-1}					
		5/13/05	Atrazine (CN)	2.0 qt ac^{-1}					
JAY	3/16/05	3/17/05	Metolaclor (CN)	1.0 pt ac^{-1}	4/14/05	5/19/05	5/25/05	6/10/05	8/1/05
		4/15/05	Atrazine (CN)	1.5 qt ac^{-1}					
		5/16/05	Glyphosate (GT)	22 oz ac^{-1}					
TVS	4/15/05	4/15/05	Metolaclor (CN)	1.0 pt ac^{-1}	5/27/05	5/29/05	6/15/05	6/25/05	9/22/05
		4/15/05	Atrazine (CN)	1.8 qt ac^{-1}					
		6/9/05	Glyphosate (GT)	22 oz ac^{-1}					
WGS	3/21/05	3/22/05	Metolaclor (CN)	1.5 pt ac^{-1}	4/11/05	6/1/05	6/6/05	6/13/05	9/12/05
		4/11/05	Atrazine (CN)	2.0 qt ac^{-1}					
		4/15/05	Glyphosate (GT)	32 oz ac^{-1}					

†LAI; Leaf area index
‡CN; Conventional variety
§GT; Glyphosate-tolerant variety

Table 2. Population effect on leaf area index when averaged across hybrid and row pattern for all four locations during the 2005 growing season.

Population	GCS	JAY	TVS	WGS
	---------------------- $ft^2\ ft^{-2}$	----------------------		
Low	1.38c†	1.65c	2.89c	2.15c
Medium	1.78b	1.95b	3.26b	2.41b
High	2.04a	2.15a	3.48a	2.86a

†Means within a location followed by the same letter are not significantly different according to Fisher's Protected LSD at $p \leq 0.10$.

Table 3. Analysis of variance on fixed effects and interactions for grain yield at all locations during the 2005 growing season.

		Analysis of Variance (P>F)			
Fixed effect	df	GCS	JAY	TVS	WGS
Hybrid	1	0.9300†	0.1073	0.0709	0.1081
Row pattern	1	0.1174	0.0820	0.5515	0.2560
Hybrid×Row pattern	1	0.5130	0.0059	0.1308	0.0631
Population	2	0.0004	0.0017	0.0002	0.0001
Hybrid×Population	2	0.6713	0.0561	0.0062	0.0341
Row pattern×Population	2	0.2953	0.0020	0.1932	0.0281
Hybrid×Row pattern×Population	2	0.7166	0.1160	0.7560	0.5667

†Fixed effects and interactions were considered different if P>F was equal to or less than 0.1

Table 4. Population effect on grain yield when averaged across hybrid and row pattern for all four locations during the 2005 season.

Population	GCS	JAY	TVS	WGS
	----------------------	bu ac^{-1}	----------------------	
Low	105b†	114b	118b	113c
Medium	135a	127a	149a	128b
High	134a	129a	148a	150a

†Means within a location followed by the same letter are not significantly different according to Fisher's Protected LSD at $p \leq 0.10$.

Table 5. Grain yields measured for each hybrid and plant population for all four locations during the 2005 growing season.

Population	Hybrid	GCS	JAY	TVS	WGS
		----------------------	bu ac^{-1}	----------------------	
Low	CN†	107a‡	114a	121a	124a
	GT§	103a	114a	115a	101b
Medium	CN	135a	138a	158a	138a
	GT	134a	117b	139b	117b
High	CN	132a	131a	145a	142a
	GT	137a	127a	152a	152a

†CN; conventional variety
§GT; glyphosate-tolerant variety
‡Means within location and population followed by the same letter are not significantly different according to Fisher's Protected LSD at $p \leq 0.10$.

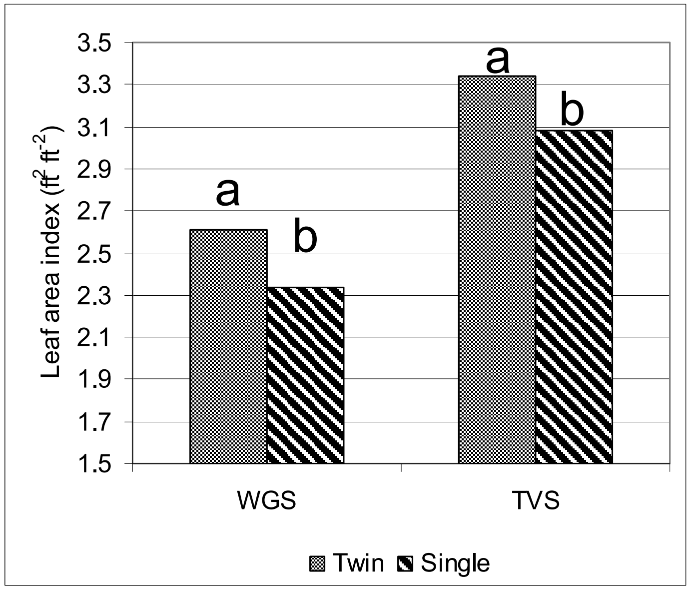

Figure 1. Leaf area index for row patterns at two locations.

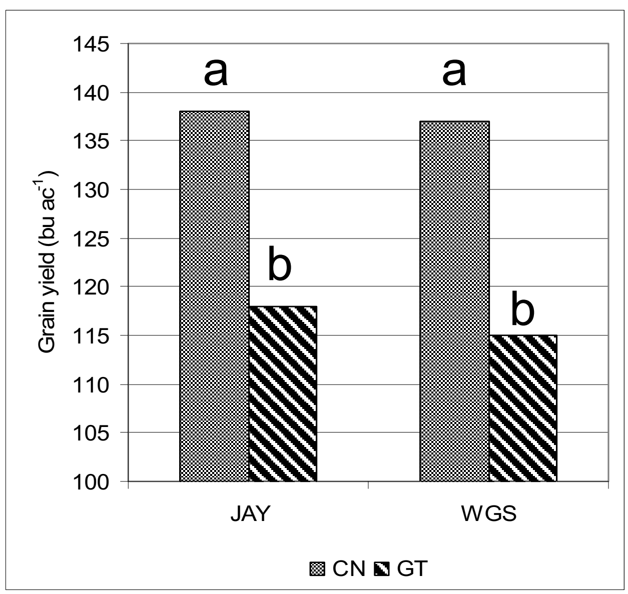

Figure 2. Grain yield for hybrids in single row patterns when averaged across populations at two locations.

FORAGE SORGHUM SILAGE VS CORN SILAGE

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ABSTRACT

Trials were conducted from 1999 to 2005 at the Texas Agricultural Experiment Station, near Bushland, TX, to compare forage sorghum types and varieties for their agronomic characteristics, water use efficiency, standibility, forage and grain yield, and nutritional value. Comparisons were also made to corn varieties planted in an adjacent trial. Forage sorghum yield was similar to that achieved with corn but required considerably less in-season irrigation water. Averaged across all entries, BMR (brown midrib) varieties yielded 10 to 11 percent less in most years than non-BMR varieties, and in one year where weather conditions were hotter and dryer than normal, yield was 26% less. Average in-vitro digestibility of BMR varieties was higher than non-BMR varieties and was similar to that of corn. Lodging on average has not been worse with the BMR varieties, however, a higher percentage of the BMR varieties were observed to have at least some observable lodging compared to the non-BMRs.

INTRODUCTION

In the Texas High Plains the cattle industry is primarily centered on stocker cattle grazing systems and confined cattle feeding. Both of these segments utilize hay and silage in their feeding operations. Additional demand for quality silage is coming from the areas budding dairy industry. Corn silage has long served the region well, producing consistent high quality silage. However, many areas no longer have the irrigation capacity to successfully produce corn silage. Six years of research has shown the potential for replacing corn with lower water requiring forage sorghum. These studies have examined the yield and quality of recently developed BMR (brown midrib), photoperiod sensitive (PS) and conventional forage sorghum varieties. BMR sorghums have less lignin content in the plant making them on average, higher in digestibility than non-BMR sorghums.

METHODS AND MATERIALS

Since 1999 forage sorghum variety trials have been conducted at the Texas Agricultural Experiment Station located at the James E. Bush Farm near Bushland, TX. In these trials, different types and varieties of forage sorghum were compared for their agronomic characteristics, water use efficiency, standibility, forage and grain yield, and nutritional value. Comparisons were also made to corn varieties planted in an adjacent trial.

The varieties were planted in a randomized block design in four row plots planted on 30-inch raised beds. The trials were considered to be fully irrigated with water applied as needed by furrow. Irrigation scheduling was determined by monitoring gypsum blocks placed in the soil at depths of 1, 2, and 3 feet. Moisture blocks were read every two to three days and plots were irrigated when the average of the three moisture blocks fell below 60. Seeding rate was 120,000 seed/acre and fertilizer rate of N and P varied each year depending on soil test analysis. Each variety was harvested when grain reached the soft dough stage. PS varieties were harvested on the last harvest date of the season.

Corn varieties were planted adjacent to the sorghum silage trial for comparison. Maturity of corn varieties ranged from 114 to 119 CRM. Each variety was planted in a 200-ft strip on four 30-inch rows at 34,000 seed/acre. Plots were irrigated based on gypsum block readings at soil depths of 1, 2, and 3 feet. Four samples were collected from each variety plot (strip) for yield and nutrient composition determination when each variety's milkline had advanced 1/2 to 2/3 of the way down the kernel. Details of cultural practices and other study information for each year can be found at http://amarillo.tamu.edu/.

RESULTS AND DISCUSSION

Forage sorghum yields have been similar to that achieved with corn and in most years required at least 40% less irrigation water than fully irrigated corn. PS varieties have been the highest yielding, but produced the lowest quality. On average, the BMR varieties yielded 10 to 11 percent less than non-BMR varieties, with the exception of 2003 when conditions were drier and hotter than normal, BMR varieties yielded 26% less than non-BMR varieties.

Many of the BMR varieties as well as some of the non-BMR varieties have consistently had an in-vitro true digestibility (IVTD) value equal or greater than that of corn. An important point is the variation among the varieties within each type. Despite the average differences for protein, fiber, lignin, and digestibility, there was a great deal of overlap among the BMR and non-BMR varieties. For instance, the average in-vitro digestibility values for BMR and non-BMR were 81.3% and 75.9%, but there were some BMR varieties that were less digestible than the high end of the non-BMR varieties and some non-BMR varieties that were as digestible as the high end of the BMR varieties. So the designation of "BMR" or non-BMR does not necessarily mean an individual variety was better or worse than other alternatives. Although percent ADF and NDF was somewhat higher in the BMR varieties compared to corn, the in-vitro digestibility was similar. It is also important to note that the range in digestibility of the BMR varieties was similar to what was observed in corn

A six year summary of the varieties that were in our trials for at least three years revealed the following: 1) non-BMR forage sorghum varieties averaged 24.1 ton/Ac (65% moisture) of silage with an average % IVTD of 75.9% and 2) BMR forage sorghum varieties averaged 20.7 ton/Ac of silage with an average % IVTD of 81.3%. Each year yield and % IVTD were compared to corn. The average yield of the non-BMR varieties was 100% of the average corn yield and % IVTD was 94.2% of corn. BMR varieties yielded 85.9% of corn with a % IVTD of 100.4% of corn.

Poor standibility is a reason often sited by growers for not growing BMR forage sorghum. Our results have shown that BMR forage sorghums do not necessarily lodge more than non-BMR forage sorghum. When choosing a variety for standibility, the choice of the individual variety is more important than if the variety is a BMR or not.

BIOMASS PRODUCTION AND NUTRIENT UPTAKE OF RYE FOLLOWING PEANUT RESIDUE

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ABSTRACT

Leguminous crops have been utilized in conservation systems to partially meet N requirements of succeeding summer cash crops. This study assessed the N contribution of peanut (*Arachis hypogaea* L.) residues to a subsequent rye (*Secale cereale* L.) cover crop grown in a conservation system on a Dothan sandy loam (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) at Headland, AL during the 2003-2005 growing seasons. Treatments were arranged in a split plot design, with main plots of peanut residue retained or removed from the soil surface, and subplots as N application rates (0, 30, 60 and 90 lb ac^{-1}) applied in fall. Peanut residue did not affect rye biomass yields, N content, C/N ratio, or N, P, K and Ca uptake. Additional N increased rye biomass, N, P, K, and Ca uptakes, although the highest N rate did not maximize these observed variables. Our results indicate that peanut residue does not contribute significant amounts of N to a rye cover crop grown as part of a conservation system, but retaining peanut residue on the soil surface can improve soil physical properties of the typically degraded southeastern soils.

INTRODUCTION

In the Southeast, legume crop residues have been extensively evaluated in conservation tillage systems to improve crop production and enhance soil physical characteristics (Mitchell and Teel, 1977; Touchton et al., 1984; Hargrove, 1986; Oyer and Touchton, 1990). Typically, legumes are planted after harvest in the fall and terminated in the spring. A summer crop is planted into the residue. A major benefit usually associated with legumes is the potential reduction in N fertilizer expenses for subsequent cash crops.

Nitrogen fixed by legumes in symbiosis with *Rhizobium* bacteria contributes to succeeding non-fixing crops upon decomposition of legume top and root material (Bruulsema and Christie, 1987; Touchton et al., 1984). Winter annual legumes, such as crimson clover (*Trifolium incarnatum* L.) and hairy vetch (*Vicia villosa* Roth.), are utilized as N sources for summer crops (Touchton et al., 1984; Brown et al., 1985; Reeves, 1994). Balkcom and Reeves (2005) also showed how sunn hemp, a summer legume, could be utilized to decrease corn N requirements. In addition, summer cash legumes have also been examined as an N source for subsequent crops. Researchers in the U.S. Corn Belt have found that alfalfa (*Medicago sativa* L.) and soybean (*Glycine max* L.), can decrease the fertilizer N requirements of a succeeding corn (*Zea mays* L.) crop (Bruulsema and Christie, 1987; Bundy et al., 1993; Morris et al., 1993). Although peanut is a legume that is widely grown in the Southeast, no previous research has examined the N contribution of peanut residues to a cover crop utilized in a conservation system. Therefore, our objective was to compare the N response of rye in a conservation tillage system following the removal and retention of peanut residue.

MATERIALS AND METHODS

This experiment was established in October 2002 at the Wiregrass Research and Extension Center in Headland, AL on a Dothan sandy loam. The experimental area rotated to a different location each year to utilize peanut residue from the previous peanut crop, but remained on a Dothan sandy loam. Treatments were arranged with a split-plot structure in a randomized complete block design with four replications. Main plots consisted of the retention or removal of peanut residue from the soil surface following mechanical harvest of peanut pods. Peanut residue was removed by mechanically raking into windrows and baling the peanut residue. The average peanut biomass was estimated by weighing the baled residue. A subsample of the residue was dried at 131°F for 72 h and ground to pass a 2-mm screen with a Wiley mill (Thomas Scientific, Swedesboro, NJ) then further ground to pass a 1-mm screen with a Cyclone grinder (Thomas Scientific, Swedesboro, NJ). The peanut residue was analyzed for total N by dry combustion on a LECO CN-2000 analyzer (Leco Corp., St. Joseph, MI). A rye cover crop was drilled at 90 lb ac^{-1} across the experimental area on 20 November 2002, 30 October 2003, and 15 November 2004. Subplot treatments were N rates (0, 30, 60, and 90 lb N ac^{-1}) hand-applied in the fall, as NH_4NO_3, to the cover crop. Nitrogen was applied to the rye cover crop on 21 November 2002, 14 November 2003, and 3 December 2004. Plot dimensions were 24 ft wide (8-36 in. rows) and 40 ft. long.

Rye biomass production was measured the following spring, prior to termination, on 23 April 2003, 8 April 2004, and 11 April 2005 by cutting all the aboveground biomass at the soil surface randomly from each plot within a 2.7 ft^2 area. Samples were dried at 131°F for 72 h, and weighed to determine total biomass production. A subsample of the dried rye biomass from each plot was ground, and analyzed for total N using procedures described above. An additional 0.5 g subsample was digested in a 70:30 mixture of nitric and perchloric acid overnight (Hue and Evans, 1986) and analyzed for total P, K, and Ca using an inductively coupled argon plasma spectrophotometer (Jarrel-Ash Division/Fisher Scientific Co., Waltham, MA).

All response variables were analyzed using the MIXED procedure (Littell et al., 1996) and the LSMEANS PDIFF option to distinguish between treatment means (SAS Inst., 2001). Data were analyzed with year as a fixed effect in the model, and there were significant year X treatment interactions for all response variables. Therefore, data were analyzed within each year, with data and discussion presented by year. Peanut residue and N rate were also considered as fixed effects, while rep and rep X peanut residue were considered random. Single degree-of-freedom contrasts were used to evaluate linear and quadratic effects of N rates on each response variable. If a single degree-of-freedom contrast indicated a significant linear or quadratic response, the specified regression model was fit with the PROC REG procedure (SAS Institute, 2002). Treatment differences were considered significant if $P \leq 0.10$.

RESULTS AND DISCUSSION

Peanut residue biomass and selected nutrient concentrations are shown in Table 1. Variability in nutrient concentrations existed among years, however in 2005 the K concentration averaged 72% lower than concentrations observed during 2003 and 2004. The N concentration averaged 1.4 % across all three years of the experiment. This N concentration was comparable to that reported by Balkcom et al. (2004) for post-harvest peanut residue. Based on the average residue production and N concentration, peanut residue had a total N accumulation of nearly 41 lb ac^{-1}. Since, this N is bound in the organic form, not all the N would be immediately available for plant uptake. Decomposition of the residue by soil microbes is required and what portion of the N the microbes do not use during the decomposition process will be potentially available for plant uptake and/or N loss pathways (i.e. leaching). Although peanut is a legume, the residue had no effect on any of the measured variables during any year of the experiment (Table 2). The lack of response may be attributed to the C/N ratio of residue, which has been shown to indicate the likelihood of N mineralization. Low ratios (i.e. < 20 to 1) result in net N mineralization, while high ratios (i.e. > 30 to 1) result in net immobilization of N (Tisdale et al., 1993).

All observed variables responded to additional N applied in the fall across all years of the experiment with the exception of N concentration and subsequent C/N ratio during the 2003 crop year (Table 2). The response of additional N was linear for all observed variables, except rye biomass yield and K uptake during the 2004 growing season (Table 3). The linear response would indicate that additional N above 90 lb ac^{-1} could have increased rye biomass and subsequent nutrient uptake. However, it is unrealistic to expect growers to apply high rates of an expensive input, like N, to the cover crop, which will not be harvested for grain. The increased response of rye biomass and N uptake to additional N is obvious, but the increased uptake of P, K, and Ca is also related. As additional N is applied to the rye, growth increases and the subsequent uptake of other nutrients is also increased. Therefore, P, K, and Ca uptakes were increased.

Interactions were observed between peanut residue and N rates during the 2005 growing season for N concentration, C/N ratio, and Ca uptake (Fig. 1). The N concentration and C/N ratio are related due to the relatively constant C concentration of plant tissues. Nitrogen concentrations measured in rye plant tissue following peanut residue were generally higher compared to N concentrations measured following no peanut residue. However, at the 30 lb N ac^{-1} rate, N concentration was lower in the rye following peanut residue compared to no peanut residue. The observed low N concentration observed illustrates why the interaction occurred, but no clear explanation exists why the observed N concentration was so low at that N rate. Calcium uptake increased linearly with N rate following peanut residue, but was more erratic across the N rates following no peanut residue.

CONCLUSIONS

Peanut residue did not contribute significant amounts of N to the rye cover crop based on biomass yield over a 3-yr period. As expected, rye did respond positively to additional N applications, but the linear response to many variables indicates that 90 lb N ac^{-1} may not maximize biomass or the subsequent uptake. Although peanut is a legume, it does not appear to supplement any additional N to a rye cover crop following the harvest of peanut. However, since peanut production in the Southeast is generally on highly weathered Ultisols, retention of peanut residue in the field protects the soil surface from erosion and could increase soil organic matter contents, which will improve soil physical and chemical properties.

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Table 1. Peanut residue yield and selected nutrient (C, N, P, K, and Ca) concentrations measured after peanut harvest at the Wiregrass Research and Extension Center in Headland, AL from 2002-2004.

Peanut crop year	Peanut residue yield	C	N	C/N ratio	P	K	Ca
	lb ac^{-1}	---------%---------			-----------------%-----------------		
2002	2820	42.2	1.7	25.3	0.10	1.2	0.83
2003	2880	44.0	1.1	39.6	0.16	1.3	1.2
2004	3000	36.2	1.4	26.6	0.18	0.35	0.97

Table 2. Analysis of variance probabilities following the removal and retention of peanut residues on the soil surface, subsequent N rates, and the interaction between these effects for rye biomass yield, N concentration, N uptake, C/N ratio, P uptake, K uptake and Ca uptake at the Wiregrass Research and Extension Center in Headland, AL from 2003-2005.

Year	Source	df	Rye biomass yield	N concentration	N uptake	C/N ratio	P uptake	K uptake	Ca uptake
	Residue	1	0.5033	0.1534	0.1774	0.4668	0.4879	0.4399	0.4471
2003	N rate	3	0.0002	0.3671	0.0059	0.4721	0.0032	0.0005	0.0005
	Interaction	3	0.1392	0.3962	0.5378	0.2542	0.1512	0.1461	0.2554
	Residue	1	0.6623	0.1077	0.7657	0.2299	0.8014	0.6284	0.9336
2004	N rate	3	0.0000	0.0008	0.0000	0.0053	0.0000	0.0000	0.0001
	Interaction	3	0.4487	0.3251	0.1607	0.7355	0.7291	0.2000	0.3028
	Residue	1	0.5838	0.3391	0.2182	0.2632	0.6410	0.2841	0.6750
2005	N rate	3	0.0008	0.0257	0.0001	0.0131	0.0097	0.0016	0.0015
	Interaction	3	0.1578	0.0541	0.6557	0.0213	0.6197	0.4204	0.0740

Table 3. Regression equations for rye biomass yield, N uptake, P uptake, K uptake and Ca uptake as a function of fertilizer N rate at the Wiregrass Research and Extension Center in Headland, AL from 2003-2005.

Year	Regression equation	R^2	P > F
Rye biomass yield			
2003	$Y = 2969 + 36.3x$	0.77	0.0039
2004	$Y = 3113 + 108.6x - 0.65x^2$	0.91	0.0022
2005	$Y = 4588 + 66.5x$	0.80	0.0028
N uptake			
2003	$Y = 22.4 + 0.38x$	0.79	0.0033
2004	$Y = 15.7 + 0.50x$	0.91	0.0003
2005	$Y = 30.1 + 0.81x$	0.86	0.0008
P uptake			
2003	$Y = 6.4 + 0.05x$	0.79	0.0033
2004	$Y = 4.8 + 0.06x$	0.96	<0.0001
2005	$Y = 8.7 + 0.11x$	0.87	0.0008
K uptake			
2003	$Y = 9.5 + 0.10x$	0.77	0.0041
2004	$Y = 7.3 + 0.20x - 0.001x^2$	0.88	0.0050
2005	$Y = 14.6 + 0.22x$	0.80	0.0027
Ca uptake			
2003	$Y = 12.0 + 0.17x$	0.81	0.0023
2004	$Y = 7.9 + 0.16x$	0.84	0.0014
2005	$Y = 11.5 + 0.18x$	0.67	0.0128

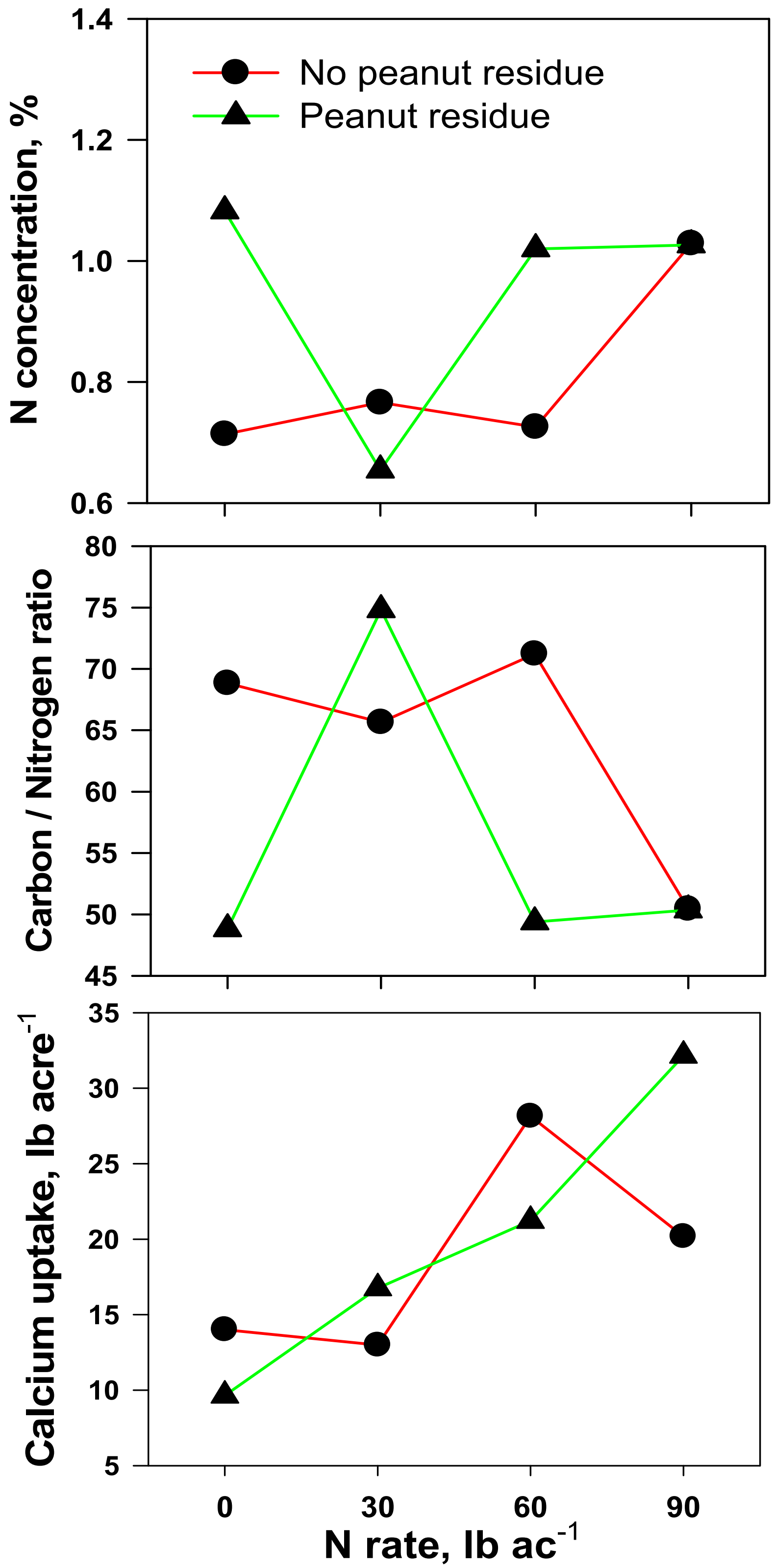

Figure 1. Nitrogen concentration, C/N ratio, and Ca uptake of rye observed following removal and retention of peanut residue during the 2005 crop year at the Wiregrass Research and Extension Center in Headland, AL.

CROP RESPONSE IN A SIX-YEAR SPLIT-FIELD COMPARISON OF CONVENTIONAL AND CONSERVATION TECHNOLOGIES

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ABSTRACT

This research was conducted in an effort to assess, on a field scale, a combination of new crop growing technologies. In 1998, a fourteen acre field containing 7 different soils was divided roughly in half, with half of the field managed with innovative practices and half managed with traditional. Corn was grown in 1999, 2001, and 2003. Cotton was grown in 2000, 2002, 2004, and 2005. The traditional practices included conventional tillage and using broadcast P application. The innovative practices were conservation tillage and site-specific application of P based on grid sampling. Data are presented from 2004 (using a conventional and transgenic cotton cultivar and 2005 (using a common cultivar was grown on both sides of the field). There was considerable within-field variability in both years, and management practices (innovative vs. traditional) did not appear to affect the amount of within-field variability. The innovative practices resulted in seedcotton yield increases over traditional practices of 157 lb/ac in 2004 and 103 lb/ac in 2005, but cotton productivity response to the management practices differed by soil map unit. In both years, cotton grown with the innovative practices had higher yield than cotton grown with traditional practices on the Bonneau sand and Norfolk loamy sand soils but lower yields on the Ocilla sand and Rains sandy loam soils. The overall increase in yield with the innovative practices is in agreement with previous small plot research on conservation tillage management.

PROFITABILITY OF PRODUCTION SYSTEMS WITH COTTON AND PEANUTS INCORPORATING WINTER ANNUAL GRAZING

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ABSTRACT

The use of contracts in livestock production has been widespread since at least the 1950s. Under grazing contracts, cattle owners usually place stocker cattle on pasture owned or leased by a caretaker (e.g. farmer or landowner). It can provide farmers an increase in revenue by utilizing winter cover crops (such as oats and rye) as forages. As crop input costs rise, partially due to higher fuel prices, additional income from diversified sources, such as winter annual grazing, may be of greater importance for profitability of the farming operation. Furthermore, as the cost of planting cover crops in conservation tillage systems increases due to higher input costs, winter annual grazing may provide a means for offsetting that cost, while still maintaining some of the benefit of the cover crop. The purpose of this study is to examine the profitability of integrating winter annual grazing into cotton-peanut cropping systems under different tillage practices and types of forage or cover. Data were obtained from a 3-year field study conducted by Siri-Prieto (2004) initiated in October 2000 at the Alabama Agricultural Experiment Station's Wiregrass Research and Extension Center in the Coastal Plain of southeastern Alabama. Findings suggest that winter annual grazing can be a profitable enterprise, supplementing farmers' income when input costs increase. Furthermore, conservation systems using in-row subsoiling, such as strip-till and para-till, provided the highest return when coupled with winter annual grazing, while strict no-till tended to provide the lowest returns.

A CONSERVATION TILLAGE PROFITABILITY LEARNING TOOL

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ABSTRACT

Many studies have examined the agronomic and economic impact of conservation tillage systems on the primary cash crops in Alabama and Georgia (e.g. corn, cotton, peanuts and soybeans) with mixed results. While some studies purport that conservation tillage systems are agronomically and economically beneficial, others have shown that conservation tillage systems under various circumstances can be detrimental and actually hurt crop yields and lower farm profits. To date, only a limited number of studies have tried to bring much of these results together to examine the impact of conservation tillage systems on corn, cotton, peanuts and soybeans across the Southeast. In an effort to bring the results of past and present agronomic and economic studies together into a decision support tool, the purpose of this project is to construct a conservation tillage profitability learning tool that allows end-users to assess the economic impact of alternative conservation tillage technologies, including cover crops, on different cropping systems in their geographic region of the Southeast. The initial version of the learning tool is a profitability calculator allowing users to examine the profitability of adopting conservation tillage technologies with or without a cover crop in Alabama and Georgia. Data used to construct the tool came from studies published in agronomic and economic journals, as well as research experiments being conducted in both states. Future versions of the learning tool will include information about the benefits and costs of conservation tillage and interactive agronomic components, as well as be expanded to include other states in the Southeast.

WATER BALANCE IN A CECIL SOIL UNDER CONTROLLED IRRIGATION IN LARGE NO-TILL AND CONVENTIONAL TILLAGE PLOTS

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ABSTRACT

There is continuing need for systematic research under site-specific conditions to quantify soil water availability in different soils and tillage practices to help growers make informed decisions. We conducted an irrigation study from June 4 to 7, 2002, on twelve 33 x 100-ft plots on Cecil soil at the USDA-ARS, J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville, GA, to quantify differences in the soil hydrologic balance between no-till (NT) and conventional tillage (CT). The plots had been in either CT or NT for eleven years. We found significant differences in hydrology between CT and NT. Following 2.2 in. of irrigation and 0.5 in. of rainfall on June 4, there was about 38% more drainage from NT. No runoff was recorded. The soil profile retained about 1.7 in. of the water input. Runoff and drainage occurred following 2.6 in. of irrigation and 0.5 in. of rainfall on June 5. Runoff from CT was about 4 times that from NT, while drainage from NT was about double that from CT. Soil water content did not rise much as the soil was close to saturation. For the two days, there was 89% more drainage from NT while runoff was again about 4 times more from CT. In an area where short or longer-term drought is common, this is an important result for growers and water resource planners seeking to improve water use and mitigate drought. The finding has great regional importance since Cecil soils occupy over 50% of the 41 million acre Southern Piedmont.

INTRODUCTION

Cecil and related soils occupy over 50% of the 41 million acre Southern Piedmont in Southeastern United States (Radcliffe and West, 2000). Conventional tillage practices, such as moldboard plowing, chisel plowing and disking, that break soil aggregates and leave little or no residue on the surface, have exacerbated soil degradation problems in these highly erodible soils. In addition to degraded soils, growers in the Southern Piedmont must contend with short-term drought common during critical crop growth periods and periodic multi-year droughts. Similar problems across the country led to concerted efforts to develop alternative tillage and residue management methods to protect the land while providing a technically and economically viable solution for growers. Hence, the conservation tillage revolution was born. Use of conservation tillage with cover crops causes minimal soil disturbance and builds soil organic matter, which helps soil to aggregate and increase biological activity. The net effect, often, is increased infiltration, reduced evaporation, and improved water and nutrient availability (Bradley, 1995; Endale et al., 2002; Fawcett et al., 1994; Golabi et al., 1995; Radcliffe et al., 1988). In the US, conservation tillage use grew to 41% of all cropland by 2004 about 23% of which is no-till (CTIC, 2005).

There is continuing need for systematic research under site-specific conditions to quantify soil water availability in different soils in different tillage practices to help growers make informed decision between tillage choices. Our objective was to quantify differences in runoff and drainage of soil water following two long irrigation events in large plots that have been under either eleven years of no-till (NT) or conventional tillage (CT). The soil belonged to the Cecil series.

MATERIALS AND METHODS

The research was conducted from June 4 to 7, 2002, at the USDA-ARS, J. Phil Campbell Sr. Natural Resource Conservation Center in Watkinsville, GA (83°24' W and 33°54' N). The site consisted of twelve 33-ft x 100-ft plots, with subsurface drainage, located on nearly level (0-2% slope) Cecil sandy loam (fine, kaolinitic, thermic Typic Kanhapludults). Cecil soils are deep, well drained and moderately permeable. When not eroded, they have a sandy loam to sandy clay loam surface texture underlain by clay subsoil on top of a saprolite. Bruce et al. (1983) have described in detail the characteristics of the soil at the site.

The plots have been under CT and NT treatment since 1991 in a randomized complete block (split plot) arrangement with three replications. Main plots were divided into CT and NT. Subplots were divided into two fertilizer treatments. In this paper we discuss the main plot arrangements only. The CT consisted of a 12-in. deep chisel plowing followed by one to two diskings to a depth of 8 in. and a subsequent disking to 3 in. to smooth the seedbed. The only soil disturbance in NT was a coulter disk at planting. For the first five years beginning in 1991, CT plots were fallowed in winter while NT plots were under rye (*Secale cereale* L.). Summer crop was corn (*Zea Mays*). During the following 5 years, cotton (*Gossypium hirsutum* L.) was grown in summer and a rye cover crop in winter on both tillage treatments. Another corn-rye cycle was started in 2001. In 2002 corn was planted on May 22.

In this study eight sets of laterals at 33-ft spacing, each with ten risers and sprinkler heads spaced approximately 30 ft, were used for irrigation. Overall, sprinkler heads were on a triangular grid which was expected to give even distribution of irrigation. A set of seventy rain gauges on an approximately 25 x 44-ft grid were used to measure spatial distribution of irrigation and estimate irrigation for each plot. Plots were irrigated from 10:15 AM to 4:15 PM on June 4. A total of 2.2 in. was applied at constant rate. A 0.52 in. rain fell during the night. On June 5, irrigation lasted from 10:00 AM to 5:00 PM and a total of 2.6 in. was applied at constant rate. A 0.48-in. rain fell during the night. Rain gauges were read approximately hourly during irrigation as well as in the mornings of June 5 and June 6 to determine irrigation and rainfall amount and distribution. The irrigation rates were the maximum the system could deliver for the number of sprinkler heads. The two-year, 24-hour maximum rainfall for the area is approximately 3.75 in. (GSWCC, 2000).

To monitor drainage, five 100-ft long drain lines made of flexible, slotted 4-in. diameter PVC had been installed in each plot at 7.5 ft spacing. Drain lines lie on a 1% grade, 2.5 ft deep at the shallow end. All five lines terminate at a collector drain, which delivers the drainage for measurement to a pair of tipping buckets located in a pit. Polyethylene sheeting installed around each plot to the depth of the drain lines isolates each plot from lateral flow. A 33-ft galvanized metal pan installed at the lower end of each plot collects and directs runoff into a 13-ft flume approach. This approach empties into a 0.6-in. HS type flume where runoff is measured.

A CR10X data logger (Campbell Scientific Inc; Logan, Utah) integrated with appropriate sensors automatically monitored runoff and drainage from a pair of plots. Runoff height was measured in the stilling well of the flume with a 2.5 psi depth sensing transducer (Druck Incorporated, New Fairfield, CT). Standard calibration curves were used to convert depth of flow to rate of flow. For drainage, the tipping buckets were calibrated to tip every 1.1 cubic foot (3 L) and were fitted with an encapsulated reed switch to measure the tips. Actual evaporanspiration was estimated by first calculating potential evapotranspiration by the Penman-Monteith method (Allen, 1994), and then applying a crop coefficient of 0.3 – corn about two weeks old.

The soil water balance was calculated as:

$$\text{Input} - \text{Output} = \text{Sink}$$

The input is the sum of the irrigation and drainage. Runoff, drainage and evapotranspiration make up the output. The sink term would then represent change in soil water storage, percolation and errors in measurement. Occasionally there were leaks around the drainage delivery pipe suggesting erosion of soil around some of the drain lines. Sensors sometime malfunction and estimates from a plot have to be made based on values in others under similar treatment. Occasionally manual checks were made for runoff height and the output from the CR10X adjusted accordingly.

To estimate soil water storage directly and compare it with that obtained from water balance calculations, the following approach was adopted. Soil water was measured at one location in each plot on the morning of June 4 prior to start of irrigation using the TDR-based MoisturePoint system (model MP-917, ESI, Vic., BC, Canada). From this measurement average soil water content for each of the 0-6, 6-12, 12-24, 24-36, 36-48 in. depths was determined. Bruce et al (1983) give extensive data set for the soil at the research site for soil water content by depth measured at soil water potentials varying from 0.005 to 15 bar. By 10:00 AM on June 7, drainage was down to about 1.1 cubic feet per hour (one 3 L tip per hour). So this date and time was taken as the cutoff for water balance calculations – about 40hours after the last irrigation. The soil was very wet following about 5.75 in. of rainfall and irrigation in a period of about 48 hours. We did not take soil water readings. Instead we estimated soil water to be that equivalent at 0.030 bar soil water potential for each depth; i.e. between field capacity and total saturation. The net storage was thus estimated as the difference between the initial soil water content and these values integrated down to 48-in. depth.

Analysis of variance was carried out with the General Linear Models Procedure of SAS (SAS Inst., 1990) by separating the data into three 'events'. The first event was represented by irrigation, rainfall and subsequent change in hydrology on June 4. Similarly the second event was for June 5. Event three was taken as the combined hydrologic event of June 4 and 5.

RESULTS AND DISCUSSION

Consistent with previous studies on these soils (Endale et al, 2002; Radcliffe et al, 1988), there was more runoff and less drainage from CT compared to NT plots (Table 1). On June 4, about

2.2 in. of irrigation was applied in six hours (0.37 in. per hour). About 0.5 in. of rain fell during the night. The rain gauge data indicated that both the irrigation and rainfall had a fairly even distribution across the plots. Potential evapotranspiration was about 0.2 in. per day during the experiment. Actual evapotranspiration was estimated as 0.06 in. per day. There was no runoff but drainage occurred both from the day irrigation and night rainfall. There was about 38% more drainage from NT than CT. The sink term in the water balance calculation was about 1.8 in. for CT and 1.6 in. for NT which are statistically different at $\alpha = 0.1$. The larger value in CT suggests these plots possibly had less soil water than NT plots prior to irrigation (Fig. 1).

The next day, about 2.6 in. of irrigation was applied in seven hours. The rate was thus the same as the previous day and indicates the irrigation system to be fairly reliable. Another 0.5 in. of rain fell during the night. In contrast to the previous day, the sink term was now much smaller (0.35 in. CT; 0.04 in. NT – no statistical difference) indicating the soil was near saturation from the previous day of irrigation and rainfall. As a result there was much runoff and drainage. Runoff from CT was about 4 times that from NT, while drainage from NT was about double that from CT (Table 1). The output term of the water balance was about 14% larger from NT.

For the combined irrigation and rainfall events over the two days, there was 89% more drainage from NT while runoff was again about 4 times more from CT. The mean sink term of the water balance equation was 2.2 in. for CT and 1.6 in. for NT, a 36% difference. The net change in soil water content between start of irrigation on June 4 and 10:00 PM on June 7 estimated according to the details given above was 2.68 in. for CT and 1.32 in. for NT. The differences in value between the two approaches fall within experimental errors – about 10% of input in CT and 5% in NT.

CONCLUSIONS

Results from our study support previous findings that no-till in Cecil soils enhances infiltration and reduces runoff. In an area plagued with common short-term drought during critical crop growth periods and periodic multi-year droughts, this is an important confirmation for growers and water resource planners that this system of cropping ought to be embraced and expanded. The finding has a regional application since Cecil soils occupy over 50% of the 41 million acre Southern Piedmont. Two to four fold differences in runoff and/or drainage between no-till and conventional tillage cropping suggests that significant irrigation water and cost savings could be gained by adopting no-till in croplands under irrigation in the region. The data generated in this research could also be used in testing and validating several hydrologic models, and scale issues. Many models are developed from data generated in small plots. Our data were generated from plots several orders of magnitude larger.

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Table 1. Statistics for soil water balance in CT and NT plots following irrigation on June 4 and 5, 2006.
All values except count are in inches[1].

	INPUT			OUTPUT				SINK	INPUT			OUTPUT				SINK
Stat	R	I	RI	Ro	Drain	ET	RDP	Delta	R	I	RI	Ro	Drain	ET	RDP	Delta
	June 4, 2006 - CT								June 4, 2006 - NT							
Mean	0.52	2.13	2.65	0.00	0.79	0.06	0.85	1.80	0.51	2.19	2.70	0.00	1.09**	0.06	1.15**	1.56*
STDER	0.00	0.05	0.06	0.00	0.05	0.00	0.05	0.06	0.00	0.05	0.05	0.00	0.10	0.00	0.10	0.09
STDEV	0.01	0.13	0.14	0.00	0.11	0.00	0.11	0.15	0.01	0.11	0.11	0.00	0.25	0.00	0.25	0.23
Min	0.50	1.93	2.43	0.00	0.69	0.06	0.74	1.63	0.50	2.05	2.56	0.00	0.82	0.06	0.88	1.22
Max	0.53	2.28	2.80	0.00	0.98	0.06	1.04	1.99	0.53	2.37	2.88	0.00	1.39	0.06	1.45	1.79
Count	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	June 5, 2006 - CT								June 5, 2006 - NT							
Mean	0.48	2.58	3.06	1.45	1.20	0.06	2.71	0.35	0.48	2.66	3.14	0.36***	2.67***	0.06	3.10*	0.04
STDER	0.00	0.06	0.06	0.16	0.13	0.00	0.19	0.22	0.00	0.05	0.05	0.11	0.14	0.00	0.07	0.09
STDEV	0.00	0.14	0.14	0.39	0.31	0.00	0.46	0.54	0.00	0.13	0.13	0.26	0.34	0.00	0.16	0.22
Min	0.48	2.45	2.93	0.81	0.89	0.06	2.19	-0.41	0.48	2.54	3.02	0.03	2.23	0.06	2.92	-0.22
Max	0.48	2.83	3.31	1.80	1.58	0.06	3.40	0.91	0.48	2.89	3.37	0.76	3.12	0.06	3.36	0.45
Count	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	June 4+5, 2006 - CT								June 4+5, 2006 - NT							
Mean	1.00	4.72	5.71	1.45	1.99	0.12	3.56	2.16	0.99	4.85	5.84	0.36***	3.76***	0.12	4.25**	1.59*
STDER	0.00	0.10	0.10	0.16	0.10	0.00	0.18	0.25	0.00	0.09	0.09	0.11	0.19	0.00	0.13	0.14
STDEV	0.01	0.24	0.25	0.39	0.24	0.00	0.45	0.62	0.01	0.22	0.22	0.26	0.47	0.00	0.31	0.35
Min	0.98	4.43	5.42	0.81	1.69	0.12	2.99	1.22	0.98	4.68	5.68	0.03	3.05	0.12	3.93	1.11
Max	1.01	5.11	6.11	1.80	2.28	0.12	4.20	2.9	1.01	5.26	6.25	0.76	4.41	0.12	4.81	2.12
Count	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

[1]Statistically significant difference between CT and NT are indicated as * ($\alpha = 0.1$), ** ($\alpha = 0.05$), and *** ($\alpha = 0.001$) in highlighted cells

INPUT: R-rainfall; I-irrigation; RI-I+R. OUTPUT: Ro-runoff; Drain-drainage; ET-evapotranspiration; RDP-ΣOUTPUT

SINK: Delta-difference between INPUT and OUTPUT

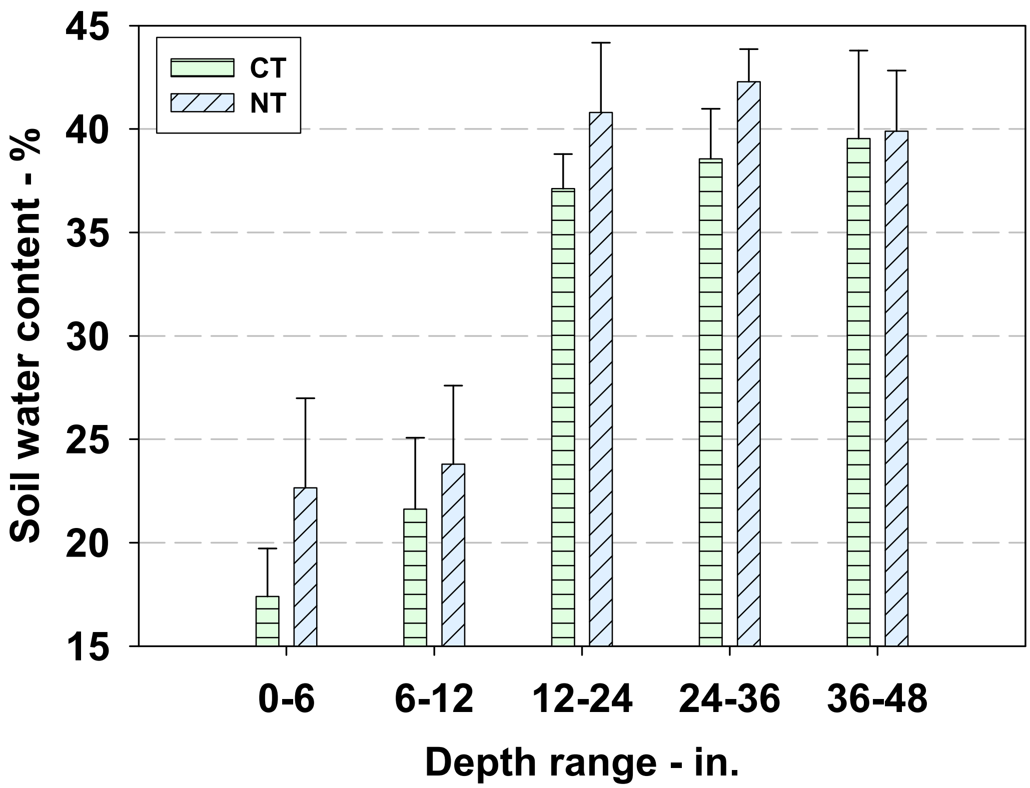

Fig. 1. Mean soil water content in CT and NT plots with standard deviation bars before start of irrigation on June 4, 2002

SOIL MANAGEMENT AND LANDSCAPE EFFECTS ON METHANE, NITROUS OXIDE AND CARBON DIOXIDE FLUXES

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ABSTRACT

Knowledge of interactive effects of agricultural soil management and landscape variability on greenhouse gas emissions is necessary for soil organic carbon sequestration efforts. This study evaluates the effects of tillage, dairy manure and landscape position on nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) emissions from a corn (*Zea may* L.)-cotton (*Gossypium hirsutum* L.) rotation. Gas samples were collected seasonally using a closed chamber method on a field-scale experiment near Shorter, AL, in spring 2004 through winter 2005. Treatments included conservation tillage (CsT) and conventional tillage (CT) with or without dairy manure (DM) application distributed over three landscape positions: drainageway, sideslope, and upland. In spring 2004, tillage, landscape variability, and DM significantly influenced total methane emission (p=0.0361), with DM increasing total methane emission on sideslopes by 20%. Mean CO_2 fluxes were significantly different among treatments (p= 0.0255). Dairy manure decreased CO_2 flux on upland CT and sideslopes CsT treatments by 10% and 20% respectively, while it increased the flux on concave CsT treatment by 20%. In winter 2005, CO_2 flux was in the order upland>sideslope>drainageway. Nitrous oxide flux was significantly different among treatments only in spring 2004 (p= 0.0001). Dairy manure increased N_2O flux on upland CT treatment by 10%. Nitrous oxide flux was in the order upland>drainageway>sideslope. Adopting CsT in spring through fall can decrease CO_2 and N_2O emissions in these agricultural systems; however, CsT may increase winter CO_2 fluxes. It is apparent that soil management and landscape position interact to control greenhouse gas emissions from agricultural fields.

TWIN-ROW SPACING DOES NOT AFFECT WEED FREE CRITICAL PERIOD IN CONSERVATION-TILLAGE CORN

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ABSTRACT

The critical period for weed control is the crop growth stage when weeds must be controlled to prevent cash crop yield losses. Field trials were conducted at the E.V. Smith Research and Extension Center near Shorter, AL, in 2004 and 2005 to compare the critical period for weed control in twin (19 cm twin rows centered on 76 cm centers) and wide-row (76 cm) corn (*Zea mays* L.). In both years, the corn variety Dekalb 69-72RR was planted into rye (*Secale cereale* L.) residue utilizing narrow strip tillage (only pneumatic tires following subsoiler shank) and a planter equipped with row cleaners and double-disk openers. A series of treatments with increasing duration of weed interference and weed free periods were implemented within each row spacing. Weeds present in both years of the experiment were carpetweed (*Mollugo verticillata* L.), cutleaf eveningprimrose (*Oenothera laciniata* Hill), large crabgrass [*Digitaria sanguinalis* (L.) Scop.], Palmer amaranth *(Amaranthus palmeri* L.), and purple nutsedge (*Cyperus rotundus* L.). Row spacing did not affect the weed free critical period in conservation tillage corn. The critical weed free periods in 2004 and 2005 were 4.7 and 14.5 days, respectively. Relative yield losses never exceeded 25% in either year in non-treated plots, likely resulting from early season weed suppression provided by the high-residue rye cover during the critical weed free period.

REDUCED TILLAGE RESEARCH WITH PEANUT IN NORTH CAROLINA (1997-2005)

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ABSTRACT

Reduced tillage peanut (*Arachis hypogaea* L.) production continues to gain interest in North Carolina. Forty-one experiments were conduced from 1997 through 2005 to compare peanut yield in conventional tillage systems to yield of peanut strip tilled into stubble from the previous crop or into residue from dessicated small grain. When pooled over all experiments, pod yield in conventional tillage was 130 lb/acre or 3.0% higher when peanut was in strip tillage. Yield varied by less than 5% in 15 of 41 experiments, and in these experiments yield of strip tillage exceeded that of conventional tillage in 60% of experiments. When yield differed by 5 to 10%, yield in strip tillage exceeded that of conventional tillage in 55% of experiments. Yield differences of 10 to 15% were higher in strip tillage in 62% of experiments. However, when yield differences exceeded 15%, yield always favored conventional tillage. These data indicate that strip tillage is increasingly a viable option for peanut growers in North Carolina.

INTRODUCTION

Research indicates that peanut response to reduced tillage can be inconsistent (Baldwin and Hook, 1998; Brandenburg et al., 1998). However, advantages to reduced tillage peanut production exist, and more recently recommendations on reducing tomato spotted wilt of peanut have included planting peanut in reduced tillage systems (Brown et al., 2005; Hurt et al., 2003). Peanut in North Carolina was planted in reduced tillage systems by approximately 23% of farmers during 2004 (Table 1). Determining the impact of tillage on peanut yield continues across the peanut belt, and defining interactions among tillage systems and other production and pest management practices is important in order to develop recommendations for growers, especially for those planting Virginia market types. In 2003 an Advisory Index was developed based on research from 1997 to 2001 to assist growers in deciding whether or not to transition to reduced tillage systems (Jordan et al., 2004b). Objectives of this article are to provide a summary of experiments conducted from 1997-2005 in North Carolina where conventional tillage systems and strip tillage systems were compared and to scrutinize the current Advisory Index developed for transitioning from conventional tillage peanut to reduced tillage peanut.

MATERIALS AND METHODS

Experiments were conducted in North Carolina from 1997 through 2005 at a variety of locations, on several soils, and with various Virginia market type cultivars (Table 2). Although these experiments often had multiple variables, in this article peanut response to tillage systems was pooled over treatment factors to compare general trends. Risk of yield being lower in reduced tillage systems compared with conventional tillage systems was compared for each experiment using the Advisory Index developed in North Carolina for transitioning to reduced tillage peanut production (Jordan et al., 2004b).

RESULTS AND DISCUSSION

When averaged over the 41 experiments, peanut pod yield was 103 lb/acre higher in conventional tillage compared with strip tillage into stubble or dessicated cover crop (Table 2). However, differences in response to tillage were noted when comparing data from 1997-2001 to data from 2002-2005. In the former experiments, yield was 5.0% higher in conventional tillage systems. However, during 2002-2005, yield was 2.3% higher when peanut was planted in reduced tillage. This difference most likely reflects a transition to peanut on coarser-textured soils in the latter data set. Experiments during 2002-2005 were conducted on Norfolk, Goldsboro, and Wanda soil series while experiments during 1997-2001 included these soil series and finer-textured soils such as those from Craven, Perquimans, and Roanoke series. These soils tend to be less amenable to strip tillage peanut production unless beds are established during the fall prior to planting peanut in the spring (Jordan et al., 2002). Although yield differences were often noted at levels higher than 15% (Table 3), many of these experiments were conducted on finer-textured soils. During the period 2002-2005, experiments were conducted on soils that reflect grower plantings under current marketing options. Fewer growers are now planting Virginia market type peanut on finer textured soils due to lower yield potential often associated with digging losses in either conventional or reduced tillage systems. Growers continuing to produce peanut on coarser textured soils may be able to plant in reduced tillage systems without sacrificing yield. Considerable variation in yield was noted among experiments, soil series, and other treatment factors, and results from these individual experiments have been reported elsewhere (Jordan et al., 2001, 2002, 2003, 2004a, 2004b, 2005).

Collectively, results from these experiments indicate that when at least a 5% difference in yield was noted in the moderate risk category, yield favored strip tillage in 11 of 17 experiments (Table 4). These data also indicate that the Advisory Index is too conservative in that growers might receive a yield advantage from strip tillage when in fact the Advisory Index indicates that there is a moderate risk that yield will be lower in strip tillage than in conventional tillage. However, peanut yielded less in strip tillage than conventional tillage in all nine experiments within the high-risk category. When yield differed by less than 5%, yield in strip tillage exceeded that of conventional tillage in 8 of 15 experiments (Table 5). Consequently, it is apparent that the Advisory Index is incorrect in estimating risk of lower yields in strip tillage in many instances.

CONCLUSIONS

Adjustments to the current Advisory Index most likely will involve removal of cover crop and tomato spotted wilt components of the Advisory Index and minimizing points associated with the irrigation component (Table 6). Additionally, point values will be adjusted to minimize bias against strip tillage.

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Table 1. Percentages of North Carolina peanut growers implementing specific tillage practices during 1998 and 2004. Data represent approximately 25% of acreage in North Carolina.

Tillage	1998	2004
Disk	90	78
Chisel	25	23
Moldboard plow	58	17
Field cultivate	75	55
Rip and bed	49	39
Bed	44	35
Reduced tillage	10	23

Table 2. Year, location, soil series, conventional tillage system, seedbed present during strip-till operation, cultivar, actual yield difference, and percent yield difference from 41 trials comparing peanut in conventional tillage to strip tillage in North Carolina during 1997-2005. A positive value for actual and percent yield indicates that peanut yield was higher in conventional tillage systems compared with strip tillage systems.

Year	Location	Soil series†	Tillage‡		Cultivar	Yield difference	
			Conventional	Strip		lb/A	%
1997	Tyner	CLS	D/R-B	Wheat	Multiple§	-327	-8.3
1997	Edenton	RSL	D/C-B	Cotton	Multiple¶	+905	+21.7
1997	Lewiston	NSL	D/R-B	Corn	NC 10C	-458	-9.7
1997	Rock Mount	GLS	D/R-B	Corn	NC 10C	-463	-10.6
1997	Lewiston	NSL	D/R-B	Cereal rye	NC 7	-438	-10.7
1998	Lewiston	NSL	D/C/R-B	Corn	NC 9	-116	-2.9
1998	Edenton	RSL	D/C/B	Cotton	NC 7	+938	+27.1
1998	Edenton	RSL	D/C/B	Corn	NC 7	+148	+4.8
1998	Halifax	NSL	D/C/R-B	Wheat	NC-V 11	+277	+7.2
1998	Lewiston	NSL	D/R/B	Wheat	NC 7	+317	+11.0
1998	Woodland	CrSL	D/C/R-B	Cotton	NC-V 11	+274	+9.4
1999	Woodland	CrSL	D/C/R-B	Cotton	NC-V 11	+1069	+29.9
1999	Scotland Neck	NSL	D/R/B	Wheat	NC-V 11	+729	+14.9
1999	Halifax	NSL	D/C/R-B	Wheat	NC 12C	-192	-4.2
1999	Rocky Mount	GSL	D/R-B	Cotton	VA 98R	+258	+9.5
1999	Edenton	PSL	D/C/R-B	Cotton	NC-V 11	+115	+3.4
1999	Edenton	PSL	D/C/B	Cotton	NC-V 11	+981	+24.3
1999	Lewiston	NSL	D/C/R-B	Corn	NC 9	+614	+17.2
1999	Lewiston	NSL	D/R/B	Cereal rye	NC 7	-258	-6.3
1999	Gatesville	CLS	D/R/B	Cotton	Multiple#	+146	+3.1
1999	Williamston	GLS	D/R/B	Corn	Multiple#	+4	+0.2
1999	Tyner	CSL	D	Cotton	Multiple#	-162	-4.5
1999	Whitakers	GSL	D/R-B	Cotton	Multiple#	-149	-4.1
2000	Woodland	CrSL	D/R-B	Wheat	NC-V 11	+546	+23.2
2000	Lewiston	NSL	D/R-B	Corn	NC 12C	+202	+4.5
2000	Lewiston	NSL	D/R-B	Corn	Multiple††	-258	-6.3
2000	Lewiston	NSL	D/C/R-B	Wheat	NC 12C	+17	+0.5
2000	Rocky Mount	GSL	D/R-B	Cotton	NC-V 11	+273	+7.2
2001	Lewiston	NSL	D/R-B	Corn	Multiple††	+53	+2.0
2001	Lewiston	NSL	D/R-B	Corn	NC 12C	-120	-4.3
2002	Lewiston	NSL	D/R-B	Corn	Multiple‡‡	-715	-14.6
2002	Lewiston	NSL	D/R-B	Crop[g]	NC 12C	-210	-9.2
2002	Rocky Mount	GSL	D/R-B	Cotton	VA 98R	+330	+8.6
2003	Lewiston	NSL	D/R-B	Corn	Multiple‡‡	+517	+11.4
2003	Tyner	WFS	D/R-B	Wheat	Multiple‡‡	-54	-1.0
2003	Rocky Mount	GSL	D/R-B	Wheat	Multiple‡‡	-455	-12.2
2004	Rocky Mount	GSL	D/R-B	Cotton	Multiple‡‡	-90	-2.4

Table 2. (Cont.)

Year	Location	Soil series†	Tillage‡		Cultivar	Yield difference	
			Conventional	Strip		lb/A	%
2004	Lewiston	NSL	D/R-B	Crop§§	NC 12C	-551	-12.4
2004	Rocky Mount	GSL	D/R-B	Cotton	VA 98R	-141	-4.1
2005	Lewiston	NSL	R-B	Crop¶¶	NC-V 11	+468	+16.8
Average (1997-2001)						+164	+5.0
Average (2002-2005)						-68	-2.3
Average (1997-2005)						+103	+3.0

†Abbreviation: CLS, Conetoe loamy sand; CrSL, Craven silt loam; GSL Goldsboro sandy loam; NSL, Norfolk sandy loam; PSL, Perquimans silt loam; RSL, Roanoke silt loam; WFS, Wanda fine sand.
‡Abbreviations: D, disk; C, chisel; R-B, in-row rip and bed; B, bed. In-row sub-soiling was included at all locations except Edenton when strip tilling.
§Averaged over the cultivars NC 7, Gregory, and NC-V 11.
¶Averaged over the cultivars NC 7, VA 93B, and VA-C 92R.
#Averaged over the cultivars Georgia Green, NC 10C, NC-V 11, NC 12C, Perry, and VA 98R.
††Averaged over the cultivars NC-V 11, NC 12C, Perry, and VA98R.
‡‡Averaged over cultivars Gregory and Perry.
§§Averaged over the rotation crops cotton and corn.
¶¶Averaged over the rotation crops corn, cotton, and grain sorghum.

Table 3. Comparison of percent differences in peanut yield between conventional tillage and strip tillage from 41 experiments conducted from 1997-2005 in North Carolina.

Percent difference between conventional and reduced tillage	Number of comparisons falling within a range of percentages	Experiments were yield of conventional tillage exceeded strip tillage	
		Number	%
0-5.0	15	6	40
5.1-10.0	11	5	45
10.1-15.0	8	3	38
15.1-20.0	2	2	100
20.1-25.0	3	3	100
25.1-30.0	2	2	100
>30.1	0	0	0
Total	41	21	51

Table 4. Number of experiments where greater than 5% difference in pod yield was noted when a moderate risk of yield in strip tillage being lower than yield in conventional tillage was projected by the Advisory Index.†

Risk of yield in strip tillage being lower than yield in conventional tillage	Actual yield response (1997-2005)	
	Conventional tillage > Strip tillage	Strip tillage > Conventional tillage
Low risk	0	0
Moderate risk	6	11
High risk	9	0

†Jordan, D., R. Brandenburg, B. Shew, G. Naderman, S. Barnes, and C. Bogle. 2004. Advisory index for transitioning from conventional to reduced tillage peanut production in North Carolina. North Carolina Coop. Ext. Ser. AG-644.

Table 5. Number of experiments where less than 5% difference in pod yield was noted when a moderate risk of yield in strip tillage being lower than yield in conventional tillage was projected by the Advisory Index.†

Risk of yield in strip tillage being lower than yield in conventional tillage	Actual yield response (1997-2005)	
	Conventional tillage > Strip tillage	Strip tillage > Conventional tillage
Moderate risk	7	8

†Jordan, D., R. Brandenburg, B. Shew, G. Naderman, S. Barnes, and C. Bogle. 2004. Advisory index for transitioning from conventional to reduced tillage peanut production in North Carolina. North Carolina Coop. Ext. Ser. AG-644.

Table 6. Preliminary adjustment of current Advisory Index to better reflect results from experiments conducted during 1997-2005.

Current point category (2004-2006)†		Preliminary adjustment of point category	
Peanut variety		*Soil series*	
Virginia market type	5	Craven, Lynchburg, Roanoke	40
Runner market type	0	Goldsboro	20
Irrigation		Norfolk	10
No irrigation	10	Conetoe and Wanda	0
Irrigation	0	*Tillage intensity*	
Soil series		No till into flat ground	40
Craven and Roanoke	40	Strip tillage into crop stubble	10
Goldsboro and Lynchburg	20	Strip tillage into stale seedbeds	0
Norfolk	10		
Conetoe and Wanda	0		
Tillage intensity			
No till into flat ground	40		
Strip tillage into flat ground	20		
Strip tillage into stale seedbeds	0		
Small grain cover			
Not present	5		
Present	0		
History of tomato spotted wilt			
No tomato spotted wilt in the past	10		
Tomato spotted wilt in the past	0		
Risk of yield being lower in reduced tillage compared with conventional tillage		*Risk of yield being lower in reduced tillage compared with conventional tillage*	
Low	30 or less	Low	40 or less
Moderate	35 to 65	Moderate	40 to 50
High	70 or more	High	60 or more

†Jordan, D., R. Brandenburg, B. Shew, G. Naderman, S. Barnes, and C. Bogle. 2004. Advisory index for transitioning from conventional to reduced tillage peanut production in North Carolina. North Carolina Coop. Ext. Ser. AG-644.

SOIL AMENDMENTS TO DECREASE HIGH STRENGTH IN SE COASTAL PLAIN HARDPANS

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ABSTRACT

Southeastern Coastal Plain loamy sands often contain cemented subsurface hard layers that restrict root development. Soil properties are usually improved by tillage but can also be improved by adding soil amendments. Wheat and polyacrylamide (PAM) amendments were mixed into a Norfolk soil, a mix of 90% hard layer soil and 10% Ap horizon to assure microbial activity. Our hypothesis was that incorporation of wheat and PAM would improve soil physical properties, making the soil more amenable to root growth. Treatments contained 1 lb of soil, 6.44 lbs lb^{-1} wheat stubble, and 30 or 120 PPM of PAM; duplicate sets of treatments were incubated for 30 d and 60 d at 10 % (w/w) water content. Treatments were leached with 1.3 pore volumes of water. After leaching and equilibration to stable water contents, soil strengths were measured with a .12-in diameter flat-tipped bench-top penetrometer. PAM formulation of 2.64×10^4 lbs $mole^{-1}$ molecules, anionic, and 35% charge density decreased bulk density when added at the higher rate of 120 PPM of soil. The higher PAM rate also decreased the amount of water that was needed to maintain treatments at 10 %. Both PAM and wheat amendments decreased penetrometer resistances and increased aggregation. Amendments improved soil physical properties, especially when the higher rate of PAM was used and when treatments were allowed to incubate for a longer period of time.

INTRODUCTION

In many southeastern Coastal soils, high strengths can develop in subsurface E horizons. Strengths can reduce or prevent root growth (Blanchar et al., 1978). Typically, strengths are managed by disrupting the E horizon with non-inversion deep tillage that increases root growth and yield (Raper et al., 2000). Unfortunately, over time, tillage effects diminish and yields again decrease as soil strength rebuilds (Arvidsson et al., 2001). In some cases, strength rebuilds over the period of a few years (Munkholm et al., 2001); in other cases, it rebuilds in only one or two seasons (Frederick et al., 1998); and the cycle begins again. As a result, producers in the southeast deep till annually.

Deep tillage costs \$15 to \$25 a^{-1} (Khalilian et al., 2002), plus increases due to high fuel costs. Tillage can be reduced and costs lowered by adding soil amendments such as soil organic matter and PAM. It has been known for a long time that organic matter additions will improve soil tilth (Waksman, 1937) and reduce strength (Free et al., 1947), even for soils such as those found in the Coastal Plain (Ekwue and Stone, 1995). However, organic matter oxidizes rapidly because of high summer temperatures (Wang et al., 2000) and it does not increase over time or it increases only near the surface (Novak et al., 1996).

Another amendment that can reduce deep tillage is polyacrylamide (PAM). It can reduce tillage by increasing soil aggregation which would disrupt the massive structure that causes the hard layer. PAM addition has the added benefit of helping retain organic matter (OM) in the soil by incorporating it into aggregates where it can be protected from decomposition (Goebel et al., 2005; John et al., 2005). In the early 1950's, older PAM formulations were used as soil conditioners (Weeks and Colter, 1952). PAM and other conditioners were found to improve plant growth by reducing soil physical problems, stabilizing aggregates in the surface 12- to 16-in depths. Unfortunately, the older formulations required hundreds of pounds of PAM per acre with multiple spraying and tillage operations. Newer polymer formulations and purity have improved PAMs, making them more effective at lower concentrations. Water soluble PAM was identified as a highly effective erosion-preventing and infiltration-enhancing polymer, when applied at rates of 10 PPM in furrow irrigation water (Sojka and Lentz, 1997; Sojka et al., 1998a; Trout et al., 1995). PAM achieved this result by stabilizing soil surface structure and pore continuity. Since the effect was limited to the surface few millimeters of soil, efficacy was achieved at application rates of 1-2 lbs a^{-1} per irrigation.

We hypothesized that adding low concentrations of a newer PAM formulation to sandy coastal soils could decrease soil strength and bulk density and increase aggregation.

MATERIALS AND METHODS

Soil type

The soil used in the experiment was a mix of 90% of the E horizon and 10% of the Ap horizon (to assure microbial activity) of a Norfolk loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiudult). It was collected from a field 1 mile northwest of Florence, SC and poured through a 0.4-in sieve to remove debris. Norfolk soil formed in coastal marine sediments and had a seasonally high water table at 48- to 72-in depth. Over the years, the soil developed an Ap horizon by being tilled to a depth of about 8 in. Below the plow layer, the soil had an eluviated E horizon that restricted root growth (http://soils.usda.gov/technical/classification/osd/index.html, accessed February 2006). The E horizon extended to a depth of 12 to 18 in overlaying sandy clay loam Bt horizon that extended beyond 24-in depth.

Treatments

Six treatments included all combinations of soil mixed with 2 organic matter levels and three PAM levels. Organic matter treatment levels were 0 and 6.44 lbs lb^{-1} ground wheat stubble. Organic matter and soil C:N ratios were brought to 20:1 by adding nitrogen in the form of NH_4NO_3 in amounts of 0.157 lbs lb^{-1} and 0.456 lbs lb^{-1} for the treatments with no wheat and wheat stubble, respectively. PAM treatment levels were 0 PPM, 30 PPM, and 120 PPM. The PAM formulation was 2.64 x 10^4 lbs $mole^{-1}$ molecules, anionic, and 35% charge density[1] (SNF Inc, Riceboro, GA, USA). Each treatment was replicated three times.

Because the amount of PAM added to the soil was so small and it did not mix well in the dry state, the various treatments were dissolved into 1.5 oz of deionized water and sprayed onto the

[1]Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

soil or soil and ground wheat straw while mixing it on waxed paper. Treatments were based on the dry weight of 1 lb of soil which was packed into 4-in diameter pots with a 20 mesh nylon screen on the bottom to prevent soil from leaking out drain holes. Treatments were packed to a bulk density of 75 lbs ft^{-3} by pouring amended soil into the pots and tapping them on the lab bench until the soil settled to a preset line.

Duplicate sets of treatments were incubated for periods of either 30 or 60 days in a lab that was maintained at 68 to 70 degrees F and ambient humidity. Treatments were maintained at 10 % soil water content on a dry weight basis by weighing and adding water to the pots 2 to 3 times a week.

Measurements

At 28 and 56 days after the beginning of the experiment, pots were leached with 1.3 pore volumes of water. After leaching, pots were drained, covered, and allowed to come to equilibrium before penetrometer resistance (PR) readings were taken to determine soil strength. At 42 and 73 days, penetration resistance was measured on the soil surface with a 0.12-in-diameter, stainless-steel flat-tipped probe. The probe was attached to a strain gauge and a motor geared to penetrate the soil at a constant rate of 0.01 in s^{-1}. Strain gauge output was expressed in millivolts and read at a rate of 100 hz on a CT-23X Micrologger (Campbell Scientific, Inc, Logan, UT, USA) while the probe penetrated the top 0.2 in of the core. Output was uploaded to a desktop computer. After probing to 0.12- to 0.16-in depth, output either reached a plateau or peaked and receded. In either case, the mean of the top ten values was used as the reading for each probing. Three probings were taken on the soil surface half way from the center to the edge of the pot at equally spaced positions around the circumference; data for the three probings were averaged and treated as a single data point. Data were converted from millivoltage to penetration resistance using a previously-developed calibration PR = f(V) with r^2 = 0.99 where PR is probe resistance and V is voltage (Busscher et al., 2000).

At 14, 24, and 53 days, soil bulk densities were calculated from averages of the distance from the top of the pot to the soil surface at three points along the side of the pot and one point in the center of the pot. To determine the volume of soil in a pot, distances along the side of the pot were calibrated against volume of the pot by sealing the drain holes at the bottom and filling the pot with water to several depths, giving a linear relationship Vo = f(d) with r^2 = 0.99 where Vo is volume of the pot filled with water and d is depth of water in the pot. Volumes were combined with known dry weights of each treatment to calculate bulk densities.

At the end of each treatment's incubation period, 30 d or 60 d, aggregate sizes were measured by pushing 0.15 lb of soil through a 0.16-in sieve and placing it into a nest of sieves with openings 0.08 in, 0.04 in, 0.02 in and 0.01 in and shaking the nest with an Octagon Digital Sieve Shaker (Endecotts, Inc., London) using the procedure of Sainju et al. (2003).

Data analysis

Data were analyzed using analysis of variance and Fisher's protected least significant difference mean separation procedure (SAS Institute Inc., 2000). When data were taken over several dates, readings at specific dates were considered main plots with treatments as splits in a split plot design. When readings for the two sets of treatments were considered together, the sets were considered main plots with treatments within sets as splits. Data were tested for significant differences at the 0.05 level.

RESULTS AND DISCUSSION

Bulk density

Bulk densities did not vary between wheat and non-wheat treatments but they did vary with PAM treatment and time of measurement. Bulk densities were lower for the 120-PPM PAM treatments at 84.3 lbs ft^{-3} than for the treatments with no PAM at 85.5 lbs ft^{-3} or the treatments with 30-PPM at 86.2 lbs ft^{-3} (LSD at 5 % = 0.62). The decreased bulk densities were probably caused by the aggregating action of the PAM as seen by Levy and Miller (1999). Bulk densities increased with time (Fig. 1), starting at a packed value of 75 lbs ft^{-3} and increasing to 87 lbs ft^{-3} by the end of the experiment which would be associated with an increase in soil strength (Chan and Sivapragasam, 1996) probably as a result of settling.

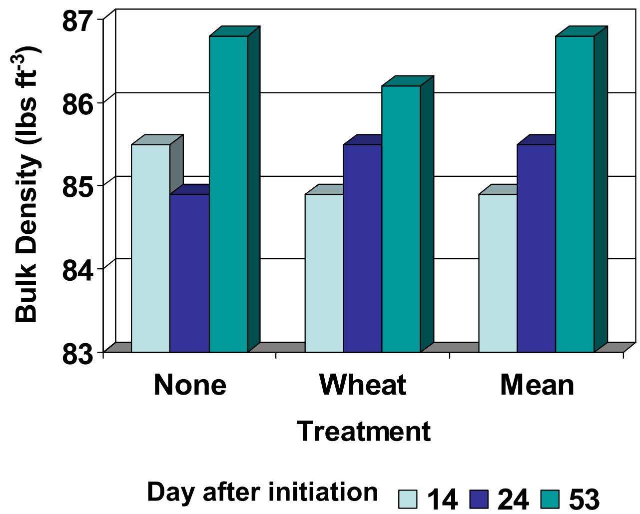

Figure 1. Bulk densities (lbs ft-3) for treatments on 14, 24, and 53 days after beginning of the experiment.

Penetrometer resistance

Penetrometer resistances were taken about two weeks after leaching because pots were too wet to give significant readings before those dates. Penetrometer resistances could also be affected by water content readings if they differed among treatments with wetter soils having naturally lower readings. To allow treatments to come to equilibrium, penetrometer resistance readings were taken after about two weeks of drainage where the pots were covered with plastic wrap. For penetrometer resistance reading taken 42 d after initiation of the experiment, water contents differed for both the wheat and PAM treatments with values of 10.8 % for the wheat treated soil and 10.0 % (LSD at 5 % = 0.3 %) for the treatment with no wheat. Water contents increased with PAM content, having values of 9.7 %, 10.5 %, and 11.1 % for treatments

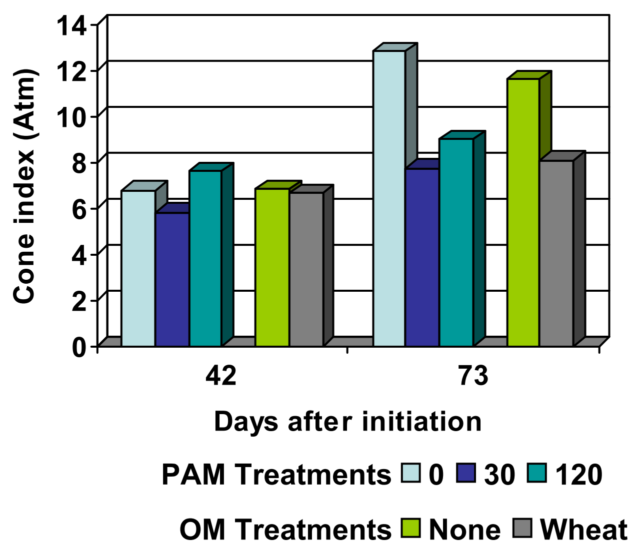

Figure 2. Penetrometer resistances (MPa) for treatments after they were covered and allowed to come to equilibrium for about two weeks.

with 0, 30 mg kg^{-1} and 120 mg kg^{-1} PAM respectively (LSD at 5 % = 0.4 %). For penetrometer resistance readings taken 73 d after initiation of the experiment, water contents were not significantly different among treatments with values ranging from 8.7 to 8.9 %. Water contents would have to be taken into consideration for the first date of penetrometer resistance measurement.

For either measurement date, penetrometer resistance results were the same whether water content was added as a cofactor in the statistical analysis or not, suggesting that the water content differences of 1.1 % or less may not be enough to alter results. Furthermore, regressions of penetrometer resistance with water contents did not reveal any significant relationship, yielding, for example, an r^2 of only 0.01 when the two were related linearly.

For the measurements taken at 42 d, penetrometer resistances were only marginally higher for the treatment without wheat than for the treatment with wheat (Fig. 2). And though they differed for the PAM treatments, there was no trend with amount of PAM. For the measurements taken at 73 d, penetrometer resistances differed among both PAM and wheat treatments; they were both lower than their non-amended counterparts. And though PAM did not show a trend, penetrometer resistances for both treatments were lower than the treatment without PAM. Decreased penetrometer resistances have been related to increased aggregation and PAM amendment by Sojka et al. (1998b). And lower penetrometer resistances for treatments with organic matter added and the associated increase in aggregation have been observed by many researchers (Sanchez et al., 2003; Hamza and Anderson, 2005).

Cumulative water added

The amount of water added to each pot was shown in Fig. 3; it was averaged over the dates when water was added to bring the treatments up to 10 % water content. Water added was analyzed separately for the treatments that ended at 30 d and those that ended at 60 d, though the same results were attained if data for both sets of treatments were analyzed at 30 d. At 30 d, the amount of water added was not significantly different for the wheat treatments and less for the 30 PPM PAM treatment than for the others. At 60 d, less water was added for the treatments with wheat than for the treatments without wheat and less water was added to the treatments with PAM than to those without it. In both cases, treatments with wheat and PAM amendments, less water added implies that PAM and wheat were holding water against evaporation and/or

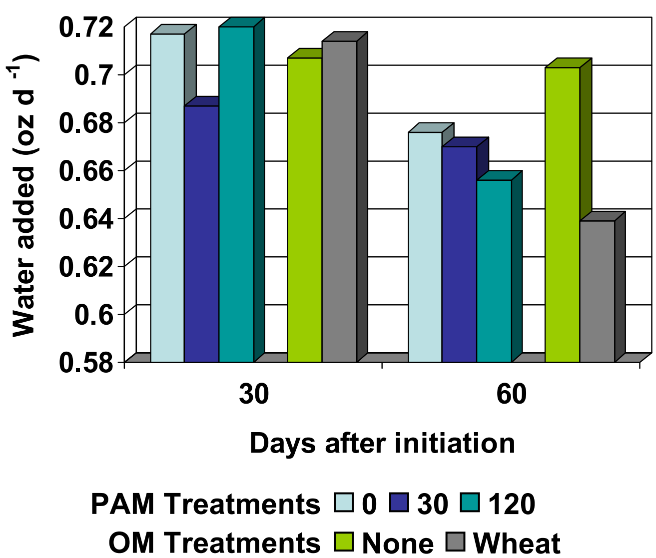

Figure 3. Amount of water added (in oz / g averaged over dates of water addition) throughout the course of the experiment for the treatments that ended on days 30 and 60.

drainage. Though the differences were small, they suggest that the amendments were altering the soil by increasing aggregation, similar to the study of Green et al. (2004) where PAM stabilized aggregation in a crusting/erosion study.

Aggregation

Though aggregates were measured on a nest of sieves, the fractions that remained on the largest sieve and the fraction that fell through the smallest sieve were not analyzed as aggregates but considered respectively as a mix of loose organic matter with aggregates or small aggregates mixed with individual particles. Aggregates analyzed on the other three sieves fell in the size range of 0.08 in to 0.01 in. At 60 d, the smallest size had more aggregates and amounts decreased with increasing size; the smallest size had 5.2 %, next largest 2.3 %, and largest 1.4 % (LSD at 5 % significance = 0.3).

Amount of aggregation increased (Fig. 4) with increasing amounts of PAM as seen by others (Sojka et al., 1998a), though it was only significant for the 120 PPM treatment at 60 d. Treatments amended with wheat had more aggregation than the treatment without it (Krull et al., 2005).

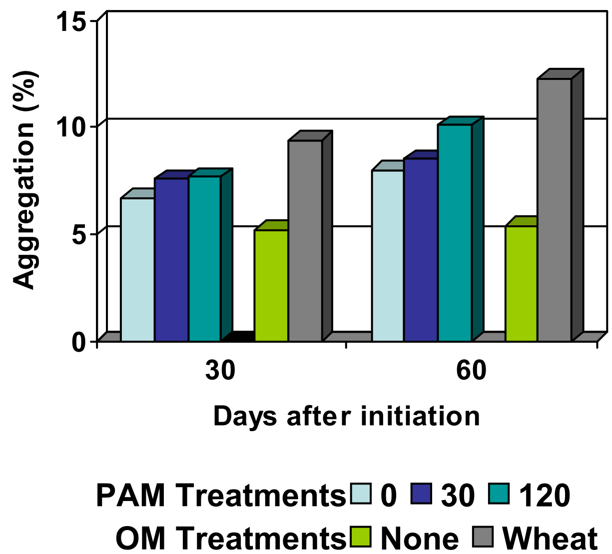

Figure 4. Amount of aggregation (%) developed during the experiment for the treatments that ended on 30 d and 60 d.

CONCLUSIONS

When soils were amended with wheat or with a PAM formulation of 2.64 x 10^4 lbs $mole^{-1}$, anionic, and 35 % charge density at both 30 mg kg^{-1} and 120 mg kg^{-1}, they appeared to have improved aggregation and associated properties. Amended soils needed to have 0.4 to 1.2 oz lb^{-1} less water added to bring them to 10 % indicating that more water was being held in the soil against leaching or evaporation. This suggested that wheat and PAM were increasing aggregation and the aggregates were holding water. When wheat and PAM were added to the soil, penetrometer resistances and bulk densities decreased with amendment which would also be consistent with increased aggregation. Aggregation, as measured by dry sieving, increased when soil was amended with PAM and wheat, though the PAM difference was only significant at the higher amendment level and only at the 60-d measurement.

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PREPLANT HORSEWEED AND RUSSIAN THISTLE CONTROL IN CONSERVATION TILLAGE COTTON

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ABSTRACT

With increasing use of reduced or no-till practices, Russian thistle (*Salsola iberica*) and horseweed (*Conyza canadensis*) are two winter annual weeds that are increasing problems to Texas Southern High Plains producers. Studies were conducted in 2005 at the Texas Agricultural Experiment Station near Lubbock. Treatments evaluated included 2,4-D, Clarity, and Roundup WeatherMax applied at three weed growth stages. Gramoxone Max, Ignite, and ET were compared to Roundup WeatherMax. 2,4-D and Clarity controlled 1 to 3 inch Russian thistle >90%, and were more effective than Roundup WeatherMax. At the 4 to 6 inch and 6 to 12 inch weed stages, control declined with 2,4-D and Clarity while control with Roundup WeatherMax was 97 to 100%. 2,4-D, Clarity, and Roundup WeatherMax controlled 1 to 3 inch horseweed 90 to 92%. Horseweed control declined with both 2,4-D and Clarity as weed size increased; however, Roundup WeatherMax controlled 4 to 6 inch and 6 to 12 inch horseweed 93 and 99%, respectively. Gramoxone Max, ET, and Roundup WeatherMax controlled 4 to 6 inch Russian thistle 97 to 100%. Roundup WeatherMax and Gramoxone Max controlled 4 to 6 inch horseweed 92 to 95% 14 DAT; however, significant regrowth occurred 28 DAT and control declined with Gramoxone Max. Ignite controlled horseweed 77%, while ET was less effective. Studies indicated 2,4-D is an effective option for control of both Russian thistle and horseweed.

EFFECTIVENESS OF DIFFERENT ROLLER DESIGNS ON MANAGING RYE AS A COVER CROP IN NO-TILL COTTON

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ABSTRACT

Rollers may provide a viable alternative to herbicides for terminating cover crops, however, excessive vibration generated and transferred to the tractor hinders adoption of this technology in the U.S. To avoid excessive vibration, producers must limit their operational speed, which increases time and cost of rolling. The effect of speed on rye (Secale cereale L.) termination rate, vibrations and cotton yield was tested for two roller designs during the 2004-2005 growing season. A triple-section roller (4.1 m wide) with long straight bars (straight bar roller) and a smooth roller with an oscillating crimping bar (smooth roller/crimper) were evaluated at speeds of 3.2 and 6.4 km h^{-1}. Cover termination and cotton yield were recorded. In 2004, higher rye termination rates resulted from the straight bar roller (96%) in comparison with the smooth roller/crimper (94%). Three weeks after rolling, both rollers had effectively terminated rye without use of herbicides. The smooth roller/crimper transferred lower vibration levels to the tractor's frame than the straight bar roller at both speeds. No differences in cotton yield were found between roller types, speeds and chemical treatment (glyphosate) except for lower cotton yield recorded for the smooth roller/crimper at the speed of 3.2 km h^{-1}. Cotton yield in 2004 was decreased by hurricane Ivan and these results might not be representative for normal weather conditions. Under typical weather conditions in 2005, higher cotton yield resulted following straight bar roller and glyphosate application, and might be associated with higher soil moisture availability due to faster termination of rye.

INTRODUCTION

Cover crops are a vital part of conservation tillage systems, but they must be managed appropriately to get their full benefit (Brady and Weil, 1999). Benefits include decreased weed pressure caused by alleopathy and mulch effects and improved soil properties. Several studies have identified these benefits, such as increased water infiltration, reduced runoff, reduced soil erosion, and reduced detrimental effects of soil compaction (Kern and Johnson, 1993; McGregor and Mutchler, 1992; Reeves, 1994; Raper et al., 2000a; Raper et al., 2000b).

A report by Conservation Technology Information Center (CTIC) (2003) showed that between 1990 and 2002, Southern U.S. cropland acres planted in conservation systems without surface tillage increased from 5.7.0 million hectares to 7.0 million hectares. This significant increase of 1.3 million hectares (23%) can be attributed to positive benefits of winter cover crops as an integral component of conservation tillage systems.

Most agricultural extension services recommend terminating cover crops at least two weeks prior to planting the cash crop to prevent the cover crop from using valuable soil moisture that could be used by the cash crop. Hargrove and Frye (1987) stated that a termination date at least 14 days before planting of cash crop enabled soil water recharge by planting time. In conservation systems, terminating cover crops three weeks prior to planting the cash crop is a standard recommendation (Ashford and Reeves, 2003).

Terminating cover crops has been historically accomplished by use of herbicides, since spraying is fast, effective, and economical. However, for a cover crop such as rye that is relatively tall and lodges in multiple directions, planting efficiency can be reduced due to a need for frequent stops to clean accumulated cover crop residue from planting units. In addition, non-rolled residue may cause hair-pinning, a condition where residue prevents adequate seed-soil contact.

According to Derpsch et al. (1991), flattening and crimping cover crops by mechanical rollers is widely used in South America, especially in Brazil, to successfully terminate cover crops without herbicides. Because of potential environmental and monetary benefits, this technology is now receiving increased interest in North America. Rollers historically consisted of round drums with equally-spaced straight blunt bars around the drum's perimeter. The function of the bars is to crimp or crush the cover crop stems without cutting them, otherwise, cover crops can re-sprout. Ashford and Reeves (2003) investigated benefits of rolling cover crops in the Southeastern U.S. by comparing cover crop termination rates during a 28-day period using a roller alone and a roller with different herbicides and application rates. They indicated that when rolling was conducted at the appropriate plant growth stage (i.e. soft dough), the roller was equally effective at terminating the cover crop (94%) as chemical herbicides. In addition, Ashford and Reeves (2003) found no significant differences in kill rates between chemical and mechanical termination by the roller between 14 and 28 days prior to planting, and rye mortality above 90% was sufficient to begin planting of cash crop due to accelerated cover crop senescence. Another important aspect of rolling cover crops is that a flat residue mat is created that lies in the direction of travel. This allows farmers to use planters for cash crop operating in parallel to the rolled cover crop direction, which has been successful in obtaining proper plant establishment.

Some North American producers have reported problems with roller/crimper implements on-farm (personal communications). The main complaint has been the excessive vibration generated by the rollers. Vibration is a form of wasted energy and undesirable in many cases. This is particularly true in machinery where vibration generates noise, degrades parts, and transmits unwanted forces and movements that create potential sources of discomfort, annoyance, and even physical damage to people and structures adjacent to the source of the vibration. Research shows that vibrations generated by agricultural equipment have detrimental effects on operator's health including increased heart rate, headache, stomach pain, lower back pain, and spinal degeneration with long exposure to vibrations (Bovenzi, 1996; Toren et al., 2002; Muzammil et al., 2004). International Standard Office (ISO, 1997) developed vibration limits that are harmful to the human body. Vibration levels from 1.25 to 2.0 m sec^{-2} are classified as "very uncomfortable" and vibrations above 2.0 m sec^{-2} are considered "extremely uncomfortable". Australian Standards developed limits for 8-hours human exposure to vibrations; for comfort limit, fatigue limit, and health limit (detrimental effect) vibrations levels should be 0.1 m sec^{-2}, 0.315 m sec^{-2}, and 0.63 m sec^{-2}, respectively (Mabbott, 2001).

The most effective method of alleviating roller/crimper vibration has been to reduce travel speed, but this is not desirable or economical. Most producers find this to be an unacceptable solution due to the much higher operating speeds utilized for spraying herbicides onto cover crops. Therefore, the objectives of this study were to:

1. Determine the effectiveness of two different roller designs in terminating cover crops as compared to chemical termination.
2. Determine the effect of operating speed on termination rates for different roller types.
3. Determine vibration levels generated by different roller designs at different operating speeds.
4. Determine operating speed and roller type effects on cotton yield.

MATERIALS AND METHODS

In 2004 and 2005, field experiments were conducted at the Alabama Agricultural Experiment Station's E.V. Smith Research Station near Shorter, Alabama on a Compass loamy sand soil (thermic Plinthic Paleudults). Rye was planted in fall 2003 and in 2004. In 2004, treatments were applied in mid-April when the cover crop was in the soft dough growth stage (Nelson et al., 1995) which is a desirable growth stage for mechanical termination.

Treatments

In spring 2004, two different roller designs of 4.1-m width were used at two operating speeds. The two different designs were: (1) straight bar roller and (2) smooth roller/crimper. Termination rates by rollers were compared to (3) rolling + chemical treatment. In spring 2005, a third design was added. In addition to rollers described for use in 2004, a modified cam mechanism to oscillate the crimping bar was used with the smooth roller/crimper design. In 2005, soil moisture content was also measured at treatment application, and 1, 2, and 3 weeks after application.

The first roller was a three-piece assembly (Fig. 1a) constructed by Bigham Brothers, Inc.[1] (Lubbock, TX). The second roller was a three-piece assembly prototype of the smooth roller/crimper developed and fabricated at the USDA-ARS-NSDL (Fig. 1b).

Figure 1. Three-section roller types: (a) Straight bar roller, and (b) Smooth roller/crimper.

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

A completely randomized block design was used with four replications. Each plot was 15-m long and 4.1-m wide to plant 4 rows of cotton. Before treatment application, the height and the biomass of rye were measured. The two operating speeds used for the experiment were 3.2 and 6.4 km h^{-1}. The 6.4 km h^{-1} speed was chosen to match speeds commonly used by tractors in field chemical applications. Rolling direction was parallel both to rye rows and cotton planting direction. Rye injury, based on visual desiccation, was estimated on a scale of 0 (no injury symptoms) to 100 (complete death of all plants) a method commonly used in weed science (Frans et al., 1986), and was evaluated on a weekly basis at one, two, and three weeks after rolling treatments. Accelerometers from Crossbow Technology Inc. (San Jose, CA) were mounted on the tractor's frame to measure vibration levels to which the driver was subjected (Fig. 2a) and on the roller's frame to measure vibration due to roller motion (Fig. 2b). Vibration data from accelerometers was recorded through the use of a custom data acquisition system and a laptop computer. Percentage of rye mortality data were transformed using an arcsine square-root transformation method (Steel and Torrie, 1980), but this transformation did not result in a change in the analysis of variance. Thus, non-transformed means are presented. For vibration analysis, original vibration data were used. Treatment means were separated by the Fisher's protected least significant difference test at the 0.10 probability level. Data were separately analyzed after the first, the second, and the third weeks using SAS (Statistical Analysis Software) ANOVA Analyst's linear model.

Cotton was planted using a 4-row John Deere Vacuum Max planter after rye was terminated and with soil moisture condition adequate to plant cotton seeds. A two-row John Deere 9920 cotton picker was used for field harvesting of the seed cotton. The two middle rows from each four row plot were harvested and bagged in the field. Bags were then weighed in order to determine the seed cotton yield. The cotton variety planted for both 2004 and 2005 was Stoneville 5242BR.

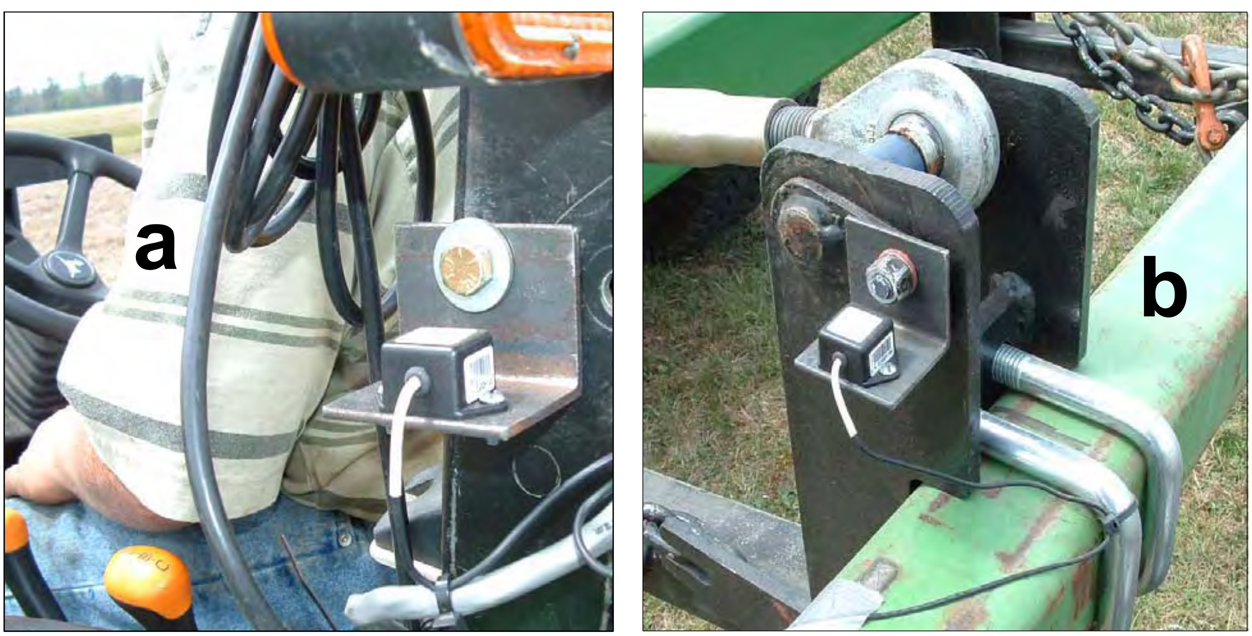

Figure 2. Placement of one-dimensional (z-axis) accelerometer from Crossbow Technology: (a) tractor's frame, and (b) roller's frame.

RESULTS AND DISCUSSION

2004 Growing Season

a. Roller type and speed

In 2004, the average height of rye was 1.7 m with an average dry mass of 625g m^{-2} unit area. One week after rolling, no differences in termination rate were found between the two rollers at speeds of 3.2 and 6.4 km h^{-1} (Table 1). Two weeks after rolling, higher rye mortality was found for both rollers at 6.4 km h^{-1} and for the straight bar roller at 3.2 km h^{-1}. However, lower rye mortality was recorded for the smooth roller/crimper at 3.2 km h^{-1}. Three weeks after rolling, higher kill rate for rye was recorded for straight bar roller at both speeds in comparison with the smooth roller/crimper (Table 1). Despite these differences, both rollers effectively terminated the cover crop (> 94%) without the need for chemical application. Studies conducted by Ashford and Reeves (2003) showed similar termination rates after three weeks.

When comparing results for both rollers in the second experiment, in contrast to the first experiment the smooth roller/crimper produced lower rye mortality than the straight bar roller. This difference might be explained by incomplete contact of the oscillating bar with the ground. This insufficient contact was caused by depressions created by tractor tires in the soft soil, which reduced contact of crimping bar against the rolled cover crop. Higher termination rates produced by straight bar roller were most likely due to the higher pressure from crimping bars which resulted in deeper bar penetrations into the rye, thus nearly eliminating empty pockets between tire depressions and crimping surfaces of crimping bars.

b. Vibrations

The 4.1-m wide roller had a mass of 1,400 kg. Vibration levels produced by the two rollers, measured on roller's frame, were not different at the same operating speed (Fig. 3a). At 3.2 km h^{-1}, the straight bar roller generated 6.47 m sec^{-2} whereas the smooth roller / crimper generated

Table 1. Speed effects on rye mortality (%) for three-sections roller type and different weeks after rolling/crimping.

Time after rolling	Roller type and speed (treatment)					
	Straight bar roller (3.2 km h^{-1})	Smooth roller/crimper (3.2 km h^{-1})	Straight bar roller (6.4 km h^{-1})	Smooth roller/crimper (6.4 km h^{-1})	Straight bar roller + glyphosate	LSD (0.1)
week 1	25.0b*	23.8b	26.3b	23.8b	95.0a	7.1
week 2	32.5b	26.3c	32.5b	30.0bc	97.8a	3.8
week 3	96.0b	94.5c	96.5b	94.0c	100.0a	1.4

* Values of the means within rows with the same letters are not significantly different at the 10% level.

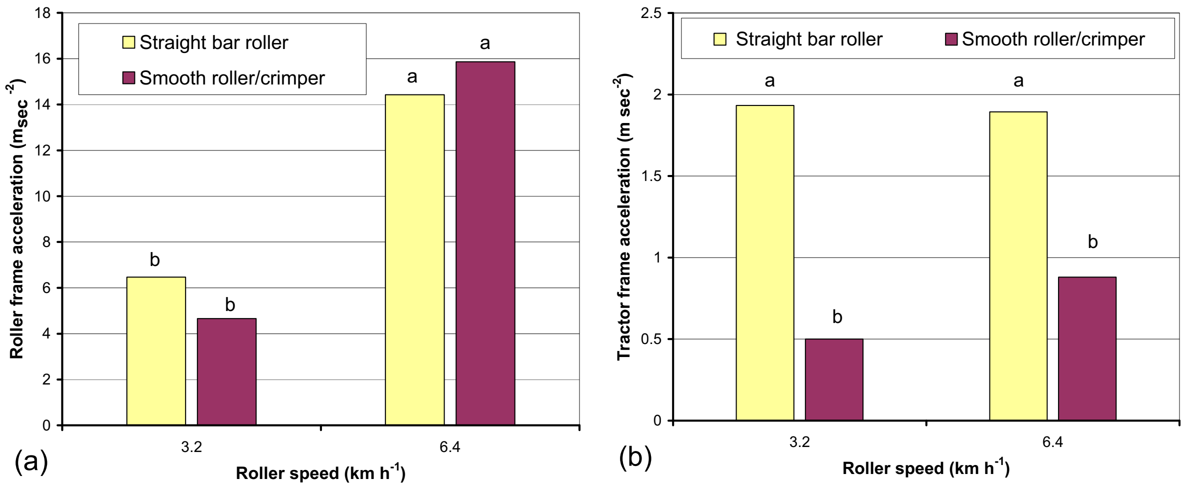

Figure 3. (a) Vibration levels measured on roller's frame. Means with the same letters are not significantly different at the 10% level. (LSD= 3.21 m sec^{-2}); (b) Vibration levels measured on tractor's frame. Means with the same letters are not significantly different at the 10% level (LSD=0.6 m sec^{-2}).

4.66 m sec^{-2}. With increased operating speed of 6.4 km h^{-1}, vibration levels increased for both rollers: 14.4 m sec^{-2} for the straight bar roller and for smooth roller/crimper to 15.86 m sec^{-2} (Fig. 3a). The smooth roller/crimper transferred lower vibration levels to tractor's frame at both speeds in comparison with straight bar roller (Fig. 3b). It appears that the roller with crimping bar transferred most of its energy to the cover crop, thus minimizing vibration transferred to the tractor. Vibration levels at both operating speeds were not different for each roller type. However, there were differences between roller types at both speeds (Fig. 3b). Vibration levels generated by the two rollers on tractor frame were above ISO (1997) and Australian limits (Mabbott et al., 2001). However, the smooth roller/crimper generated lower vibration levels: 0.5 m sec^{-2} and 0.88 m sec^{-2} at 3.2 and 6.4 km h^{-1}, respectively, that are below the "very uncomfortable limit" as determined by ISO (1997). On the other hand, straight bar roller generated vibration levels of 1.93 m sec^{-2} and 1.89 m sec^{-2} at 3.2 and 6.4 km h^{-1}, respectively, that was within "very uncomfortable limit" and could cause a discomfort to the operator.

c. Cotton yield

Cotton yield was collected in November 2004. The highest cotton yield of 2257 kg ha^{-1} resulted from using the smooth roller/crimper at 6.4 km h^{-1} and was higher than the same roller at 3.2 km h^{-1}. However, no differences in cotton yield were found between straight bar roller at both speeds, smooth roller/crimper at 6.4 km h^{-1} and straight bar roller with glyphosate. The lowest cotton yield was recorded with smooth roller/crimper at 3.2 km h^{-1} operating speed. Generally, cotton yield data indicate that two roller types did not influence cotton yield (Fig. 5). Typically, cotton yields are higher than reported in this study for the area in which the study was conducted. In fall 2004, Hurricane Ivan caused damage resulting in a decreased cotton yield.

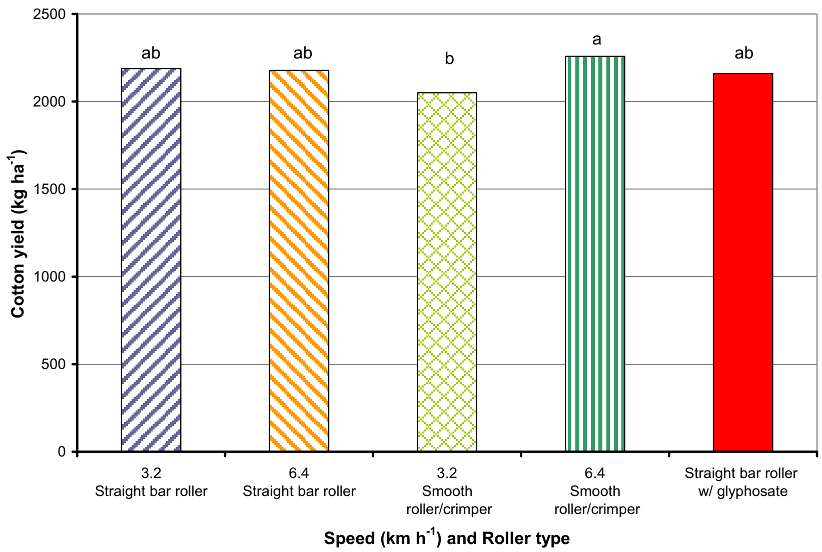

Figure 4. Operating speed and roller type effect on seed cotton yield. Means with the same letters are not significantly different at the 10% level (LSD=171 kg ha^{-1}).

2005 Season

a. Roller type and speed

Spring 2005 was cool and wet compared to 2004. Because of the weather, the growth of rye was inhibited, thus rolling treatments were applied late (beginning of May) compared to 2004. The average height and the dry biomass for rye were 1.2 m and 510 g m^{-2}, respectively. No differences in rye mortality were found between tested roller types after each evaluation. After the first week, rye mortality was higher (from 77% to 80%) than reported for 2004 and was most likely related both to roller crimping action and natural senescence. A difference in rye termination rates was found with straight bar roller + glyphosate in comparison with the roller type alone for each week after rolling (Table 2). Despite this difference, all rollers effectively terminated the cover crop (97%) after three weeks without the need for chemical application. An increase in operating speed did not affect termination rate for all roller types, except after the first week from rolling. At 6.4 km h^{-1}, the highest termination rates were found for straight bar roller (82%). No significant differences were found between straight bar roller and the smooth roller/crimper with the modified cam mechanism. The lowest rye termination rate (77%) was found with the original cam smooth roller/crimper (Table 2). When comparing results for both rollers in the second experiment, in contrast to the first experiment, smooth roller/crimper produced lower rye mortality than the straight bar roller.

b. Vibrations

Vibration levels produced by the rollers both at roller and tractor frame were comparable with levels generated in 2004 test. At a speed of 3.2 km h^{-1}, straight bar roller generated the highest vibration levels on roller's frame (6.3 m sec^{-2}) in comparison with the original and modified smooth roller/crimper. With increasing operating speed to 6.4 km h^{-1} vibration increased for three roller types. At a speed of 6.4 km h^{-1}, higher vibration was found with straight bar roller (11.6 m sec^{-2}); however there were no differences between the three rollers (Fig. 5a).

Table 2. Speed effects on rye mortality (%) for three-sections roller type and different weeks after rolling/crimping.* Values of the means within rows having with the same letters are not significantly different at the 10% level.

Time after rolling	Roller type and speed (treatment)								
	(3.2 km h^{-1})				(6.4 km h^{-1})				
	Straight bar roller	Original smooth roller/ crimper	Modified smooth roller/ crimper	LSD (0.1)	Straight bar roller	Original smooth roller/ crimper	Modified smooth roller/ crimper	Straight bar roller + Glyphosate	LSD (0.1)
week 1	78b	80b	77b	4.39	82ab	77c	78bc	85a	3.74
week 2	90b	90b	90b	0	90b	90b	90b	100a	0
week 3	97b	97b	97b	0	97b	97b	97b	100a	0

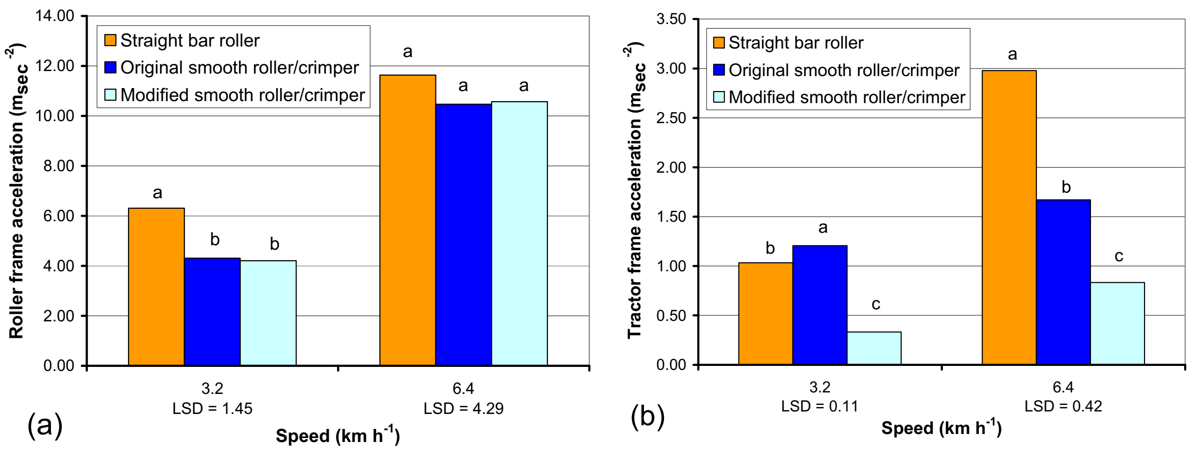

Figure 5. (a) Vibration levels measured on roller's frame. Means with the same letters are not significantly different at the 10% level. (LSD= 3.21 m sec^{-2}); (b) Vibration levels measured on tractor's frame. Means with the same letters are not significantly different at the 10% level (LSD=0.6 m sec^{-2}).

The smooth roller/crimper transferred significantly lower vibration levels to tractor's frame at both speeds in comparison with long straight bars roller (Fig. 5b). With increased operating speed, vibrations measured on the tractor's frame also increased. There were significant differences in tractor frame vibrations between three roller types at both speeds. At lower speed, significantly higher vibration was generated by the original smooth roller/crimper (1.3 m sec^{-2}); the modified smooth roller/crimper generated the lowest vibration (0.35 m sec^{-2}). At higher speed, the highest tractor frame vibration levels were found with the straight bar roller (3.0 m sec^{-2}) that were above "extremely uncomfortable limit (ISO, 1997). The lowest tractor frame vibration levels were generated by the modified smooth roller/crimper (0.8 m sec^{-2}) and were half the vibrations generated by the original smooth roller/crimper (1.7 m sec^{-2}), and one third the vibration of the straight bar roller. Both smooth rollers/crimpers generated vibration levels that were below the "very uncomfortable limit" as determined by ISO, (1997).

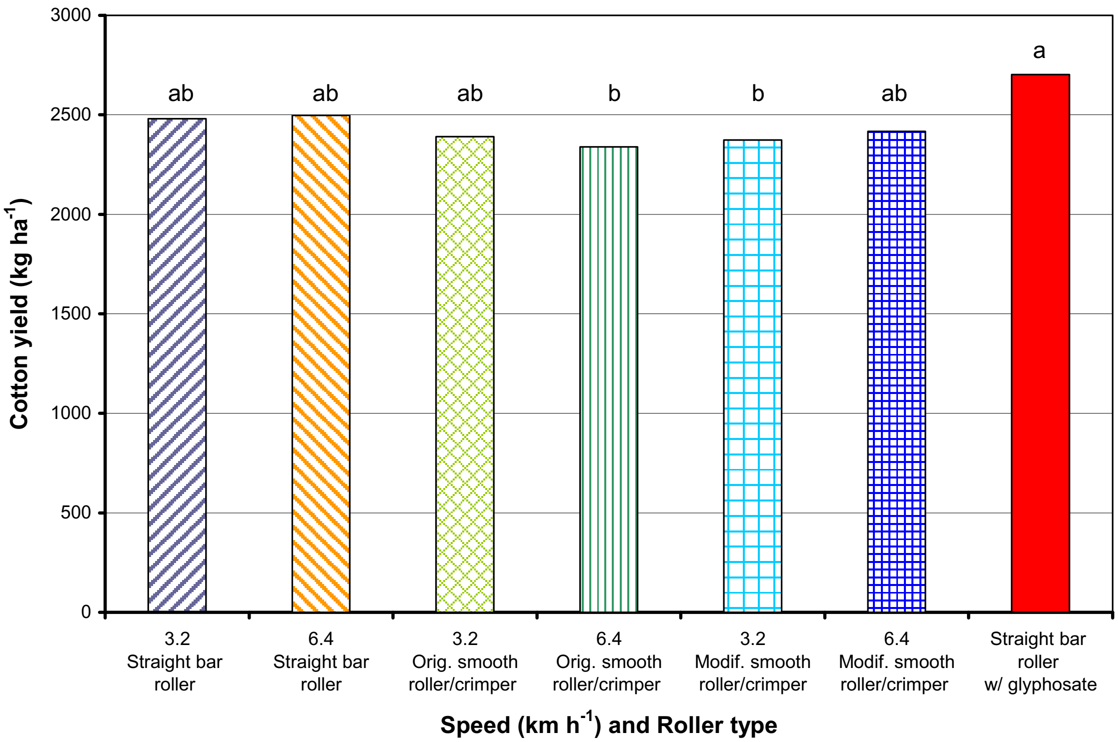

Figure 6. Operating speed and roller type effect on cotton yield. Means with the same letters are not significantly different at the 10% level (LSD=316.8 kg ha^{-1}).

c. Cotton yield

Cotton yield was collected in October 2005. Higher cotton yield (2717 kg/ha) was recorded with straight bar roller and glyphosate treatment (Fig. 6). No differences were found between straight bar roller at both speeds, straight bar roller and glyphosate, smooth roller/ crimper with original cam at 3.2 km h^{-1} and smooth roller/crimper with the modified cam at 6.4 km h^{-1}. Lower cotton yield was found with smooth roller/crimper with the original cam at 6.4 km h^{-1} and the smooth roller/crimper with modified cam at 3.2 km h^{-1}. Higher cotton yield that was found with straight bar roller and glyphosate application might be associated with a increased soil moisture conditions. Average volumetric soil moisture content collected after rolling for 3 weeks was above 14% which was 2% greater for straight bar roller + glyphosate in comparison with other roller types and speeds treatments.

CONCLUSIONS

1. In 2004 experiment, both triple-section roller types effectively terminated cover crop (> 94%) three weeks after rolling, without the need of herbicide. Similarly, in 2005 experiment, after three weeks all three rollers effectively terminated cover crop (97%).
2. In 2004, increase in operating speed had no effect on termination rates. In 2005, an increase in operating speed did not affect termination rate for both roller types, except after the first week from rolling.
3. In 2004 and 2005 experiments, increased operating speed significantly increased vibration levels which were measured on the roller's frame for all roller types. However, in 2004, no

differences in vibration levels on roller's frame observed between the two rollers within the same operating speed. The smooth roller/crimper transferred lower vibration levels to the tractor's frame than straight bar roller, and these levels are below "very uncomfortable limit" as determined by ISO (1997). In 2005, differences in vibration levels at tractor frame were reported for the three rollers at both speeds. The lowest vibrations at tractor frame were generated by modified smooth roller/crimper that were below ISO limits and were 2 times lower than vibrations generated by the original smooth roller/crimper.

4. In 2004, higher cotton yield was observed for the smooth roller/crimper at 6.4 km h^{-1}. No differences in cotton yield were observed between roller types, speeds and chemical treatment (glyphosate) except a lower cotton yield recorded for the smooth roller/crimper at speed of 3.2 km h^{-1}. Cotton yield in 2004 was decreased by hurricane and these results might not be representative for normal weather conditions. In 2005, higher cotton yield was reported for straight bar roller + glyphosate application in comparison with the original smooth roller/crimper at 3.2 km h^{-1} and the modified smooth roller/crimper at 6.4 km h^{-1}. Increase in roller operating speed did not affect cotton yield.

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TILLERING IN DRYLAND GRAIN SORGHUM CLUMPS AS INFLUENCED BY LIGHT, PLANTING DENSITY AND GEOMETRY

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ABSTRACT

Tillering is an important morphological component of grain sorghum (*Sorghum bicolor* L. Moench) development because it affects light capture, water use, grain yield, plant competition and other physical and biological processes. Our objective was to determine light and temperature differences associated with different tillering patterns when grain sorghum plants grown in clumps were compared with uniformly spaced plants. Four planting geometries and four plant densities were tested in two separate experiments at Bushland, TX in 2005. In experiment one, four plants seeded (adjacent to each other, 2.5 cm apart from each other in a square pattern, and 10 cm apart from each other in a square pattern) were compared to uniformly spaced plants (25 cm apart) in rows. In experiment two, four plant densities (clumps spaced 75 cm apart in 75 cm rows with one, two, four, and six plants per clump) were studied. Red/far-red (R:FR) light ratio, temperature, tiller number, crop phenology, and leaf number were measured in both experiments. Results of both experiments, showed no treatment effects on plant temperature, due to an absence of water stress associated with good soil moisture conditions after the five-leaf stage. Number of tillers plant^{-1} and R:FR ratio increased with increasing distance between plants in clumps. Additionally, the number of tillers plant^{-1} and R:FR ratio decreased with increasing plant density. Planting dryland grain sorghum in clumps of four plants with plants 2.5 cm or less apart from each other reduced tillering, apparently due to lower R:FR ratio sensed by the phytochrome system.

INTRODUCTION

Dryland cropping systems of the Texas High Plains are characterized by limited precipitation and high evaporative demand (Stewart and Burnett, 1987) due to high radiation, wind speed, vapor pressure deficit, and temperature. Grain sorghum, with special characteristics to adapt and grow under dryland conditions, is a major crop in the Texas High Plains. Grain sorghum yield in dryland cropping systems of the High Plains is largely dependent on availability of stored soil water at the time of planting (Unger and Baumhardt, 1990), planting date (Stewart and Steiner, 1990), planting density (Stewart and Steiner, 1990), planting geometry and effective utilization of solar radiation (Steiner, 1986). Sorghum often has adequate water from precipitation and stored soil moisture early in the season, and produces one to several tillers leading to high amounts of aboveground biomass and leaf area. However, severe stress conditions are common during later growth stages of the crop and result in failure for many tillers to produce heads, or result in small heads with small kernels. Agronomic studies conducted during 2002 to 2004 at Bushland, TX and during 2004 at Tribune, KS revealed that planting grain sorghum in clumps produced fewer tillers and increased yields when compared to uniformly spaced plants under water stress conditions (Bandaru, 2005). However, the optimal spacing and geometry needed to grow grain sorghum plants clumps in order to decrease tillers was unclear. Also, the mechanisms that led to a decrease in the number of tillers formed when grain sorghum was grown in clumps were not well-understood. Jones (1985) reported that reduced plant competition for light, nutrients and water favors tiller production, whereas low temperature and short day lengths result in fewer tillers in grain sorghum. Jackson and Thomas (1997) found that phytochrome *A* (long day plants) and Phytochrome *C* (short day plants) are responsible for daylight sensitivity. Gautier et al. (1999) showed that red/far-red (R:FR) light ratio regulates tillering in perennial grasses and a reduction in R:FR ratio decreases tillering. Monaco and Briske (2000) showed that in a perennial grass species a low R:FR ratio is involved in shade avoidance response that in some part of the growth cycle result in increased plant height.

The hypothesis of this study was that plants grown in clumps would increase plant height and decrease number of tillers due to a low R:FR ratio of incident light sensed by the phytochrome system. The specific objectives were to evaluate 1) how close together plants need to be in clumps to reduce tillering, 2) the number of plants needed in a clump to reduce tillering, and 3) light and temperature differences associated with tillering patterns of sorghum grown in clumps compared with uniformly spaced plants.

MATERIALS AND METHODS

Two experiments were conducted at the Texas Agricultural Experiment Station, Bushland, TX ($35^o11^{'}$N, $102^o5^{'}$W) during 2005. A randomized split-plot design was used in both experiments with three replications. Two hybrids ─ Pioneer 8699 and NC+ 5C35 were tested as the main plot treatments in both experiments. Four planting geometries and four plant densities were tested as the subplot treatments in two experiments. The data were analyzed using SAS (Statistical Analysis System) software (SAS, 1998) using General Linear Model procedure (PROC GLM).

Experiment I

Equal plant populations of 5.3 plants m^{-2} were maintained in 75-cm rows. All four planting geometries had four plants for every meter of rows. The four planting geometries were 1) adjacent clump with four plants seeded close to each other (AC); 2) loose clump with four plants seeded 2.5 cm apart from each other in a square (LC); 3) wide clump with four plants seeded 10 cm apart from each other in a square (WC); and 4) four individual plants seeded as uniformly spaced plants 25 cm apart in 75-cm rows (USP). The rows ran east to west and plots were 6 m long and 3 m wide. Planting occurred on July 13, 2005 using a mechanical hand planter for the AC and USP treatments. The LC and WC treatment were planted manually using a pattern cut out of cloth with holes to dibble the seeds by hand. Two seeds more than the desired number of plants were dropped 5 cm deep in to the soil and emerged plants were later thinned to establish equal plant populations. The germination was not uniform due to poor soil moisture conditions at the time of seeding.

Experiment II

Four planting densities in clump planting geometry were tested as subplot treatments. One plant, two plants, four plants, and six plants were established close to each other in clumps 75 cm apart from each other in 75-cm rows. Therefore, for every 0.56 m^2 there were one, two, four or six plants (1.8 plants m^{-2}, 3.6 plants m^{-2}, 7.1 plants m^{-2}, and 10.7 plants m^{-2}). Rows ran east to west and plots were 3 m long and 2.25 m wide to accommodate 12 clumps in each plot.

Measurements taken

Similar measurements were taken in both the experiments on the same dates. Specific plants were randomly identified in all plots to assess growth and development. Plant growth stages ranging from emergence to physiological maturity were identified and numbered from 0 to 9 (Vanderlip, 1993). Up to growth point differentiation, phenology was measured on the basis of leaf number. Later, flag leaf emergence, booting, half bloom and full bloom were recorded as measures of phenology. A tiller was counted after visibly emerged from the leaf sheath. Visibility of leaf collar was used to count the leaf number until emergence of flag leaf. Later, only physiologically active leaves were counted. Plant height was measured from the base of the plant (at the soil surface) to tip of the tallest leaf. Light reflectance was measured 28 days after planting (DAP) using a hyperspectral radiometer. The sensor was focused on the base of the plants to measure the amount of reflected light. Later in the growing season (37 DAP), incident light was measured with a Skye 660/730 nm sensor. The wavelengths of red and far-red light were measured in micromole m^{-2} sec^{-1} $microamp^{-1}$ ($\mu mol\ m^{-2}\ s^{-1}\ \mu A^{-1}$) (Skye Instruments, 2005). The red and far-red light measurements were used to calculate the red to far-red (R:FR) ratio. Two sensors were used to measure light at each plant. One sensor was placed vertically close to the plant stem in the shaded region, and the other sensor was held in the open sun near the plant base. The distance of the sensor placed in the sunlight was varied from 2.5 cm to 15 cm to avoid shade from leaves and neighboring plants. Measurements were taken in the open sunlight by moving the sensor away from the plant up to 30 cm and consistent readings were recorded. Stem temperatures were measured with an infrared thermometer aimed at the base of the stalk and leaf temperatures at the canopy level. Light and temperature measurements were taken from 08:00 h to 18:00 h on 37 and 59 days after planting. Grain yields were not obtained because of damage caused by birds.

RESULTS AND DISCUSSION

The growing conditions early in the season were unfavorable due to delay and uneven distribution of precipitation. Although 280 mm of precipitation was received in 2005 prior to planting the grain sorghum, distribution was poor and planting had to be delayed until 13 July because of inappropriate soil moisture in the topsoil. However, abundant supply of stored water deeper in the soil profile coupled with about 100 mm of evenly distributed precipitation after emergence resulted in favorable growing conditions and there was no visible water stress during the growing season.

Experiment I

At 12 DAP the plants in clumps were further developed than the plants in rows (Fig. 1). Growth stages measurements (1.0 – three leaf stage; 1.5 – four leaf stage; 2.0 – five leaf stage; 4.0 – flag leaf stage; 5.0 – booting stage; 5.5 – heading stage; 6.0 – half-bloom stage) for plants in the AC (1.5), LC (1.5), and WC (1.4) treatments indicated that they were very close to, or at, the four-leaf stage. In contrast, plants in the uniformly spaced rows were at 1.27 (in between three and four-leaf stage) growth stage. However, hybrids were not significantly ($P>F=0.05$) different at 12 DAP, but at 51 and 59 DAP the hybrids were significantly different. At 51 DAP

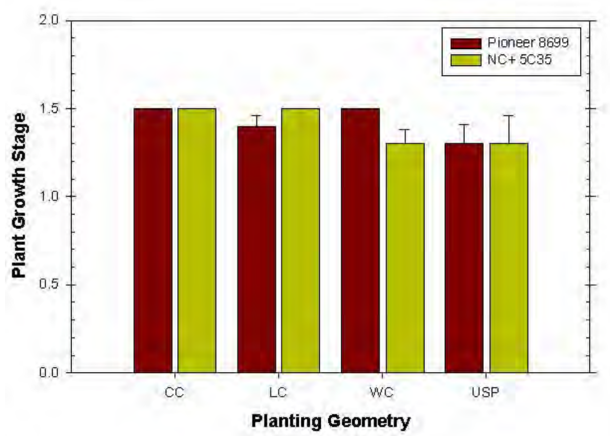

Fig. 1. Plant growth stage (0.5–two leaf stage, 1.0–three leaf stage, 1.5–four leaf stage) by planting geometry and hybrid (12 DAP). Lines on the bars represent standard error.

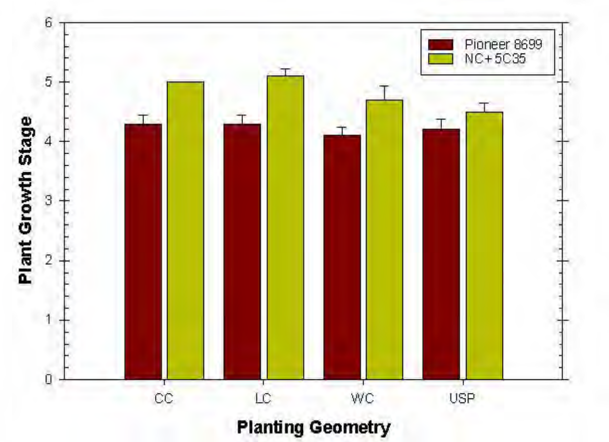

Fig. 2. Plant growth stage (4–flag leaf stage, 5–Booting stage, 5.5–heading stage) by planting geometry and hybrid (51 DAP). Lines on the bars represent standard error.

(Fig. 2) NC+ 5C35 (4.8 - near booting stage) was further developed than Pioneer 8699 (4.2 - at flag leaf stage). Also, plants in LC were further developed (4.7) than those in WC (4.4). At 59 DAP, NC+ 5C35 plants were near the full bloom stage (6.3) but Pioneer 8699 plants (5.7) had not reached the half-bloom stage. At 20 and 28 DAP, there was a trend for AC and LC treatments to have fewer tillers than the WC and USP treatments, but the differences were not statistically significant (*P*>0.05). However, at 51 DAP (Fig. 3), plants close to each other in clumps (AC and LC treatments) had significantly fewer tillers than those in the USP treatment. Plants close to each other (AC and LC) had about one tiller each. In contrast, plants that were 25 cm apart in rows (USP) had 2 tillers plant^{-1} .

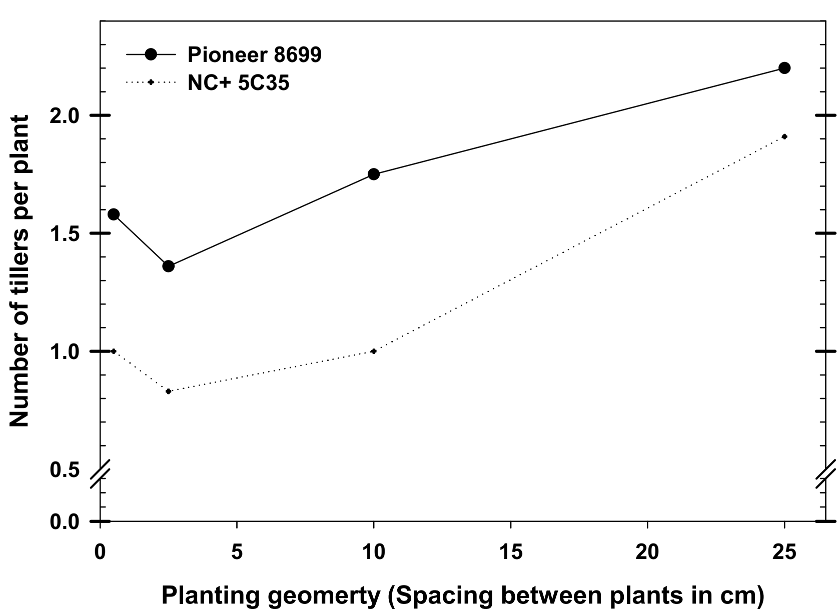

Fig. 3. Tiller number by planting geometry and hybrid (51 DAP).

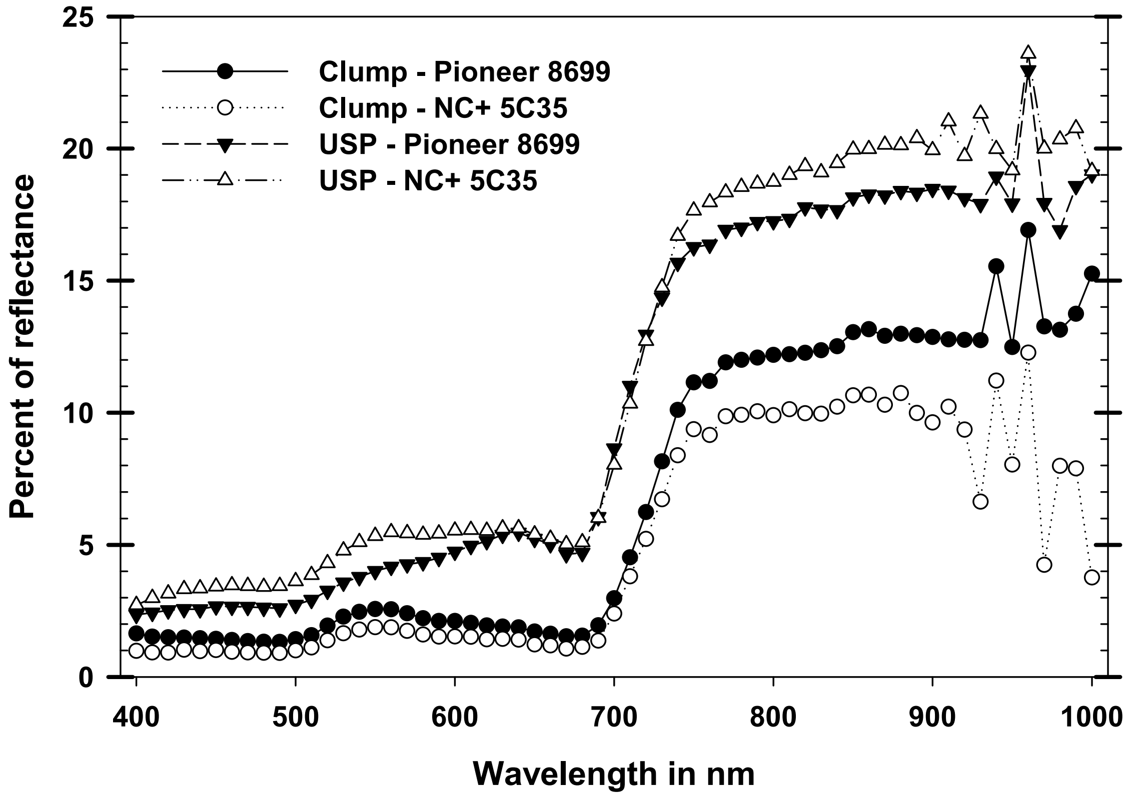

Fig. 4. Light reflected (14 DAP) by clump and USP geometries for two hybrids.

At 71 DAP the tiller numbers were similar to those at 51 DAP and Pioneer 8699 plants had an average of 1.7 tillers plant^{-1} (average of all treatments) compared to an average of 1.2 for NC+ 5C35 plants. Reflected light measured by a hyperspectral radiometer for plants in AC and USP treatments for two hybrids are presented in Fig. 4. The plants in USP rows reflected higher amount of light when compared to USP. The R:FR ratio for the plants in USP treatment was higher than the plants in AC treatment.

For most of the day, the R:FR ratio of incident light at 37 DAP on the sunlit side of the plants averaged 0.99 compared to 0.31 for the shaded side. These values are similar to those reported by Deregibus et al. (1985) for measurements above and below the canopy of forage grass. At 13:00 h 37 DAP the R:FR ratio on the shaded side for the plants in the LC treatment was 0.19 compared to 0.22 for plants in the AC treatment (Fig. 5). In contrast, a higher R:FR ratio of 0.26 was measured for plants in the WC and USP treatments. The amount of light (R:FR) received was not significantly different (P>F=0.05) among hybrids.

The R:FR ratio decreased as the plants grew in closer proximity to one another because of mutual shading. The amount of incident light reaching the site of tiller formation (base of the plants) was lower and resulted in production of fewer tillers. These findings agree with those of Deregibus et al. (1985).

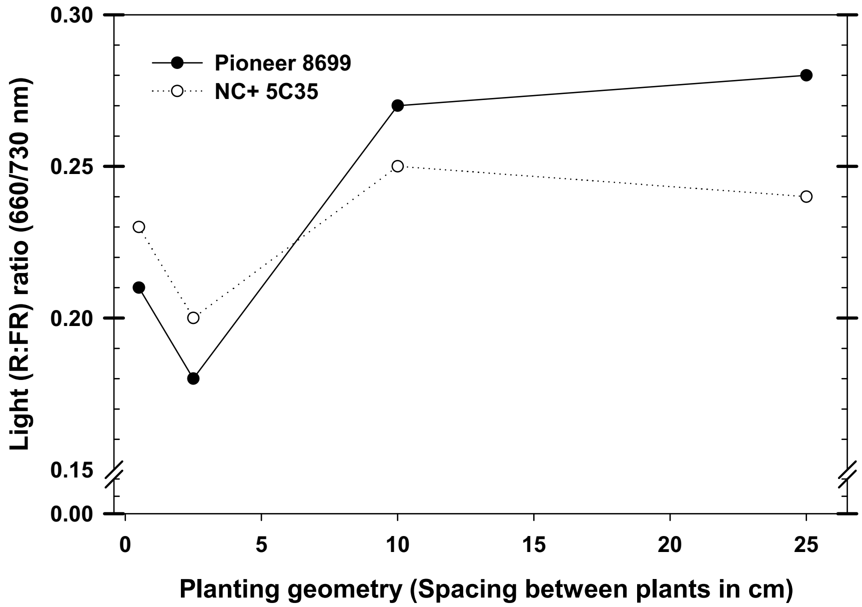

Fig. 5. Light (R:FR) ratio by planting geometry and hybrid (37 DAP).

There was no treatment effect on plant temperature (data not shown). This was apparently due to the absence of water stress because of near adequate soil moisture conditions throughout the cropping season. The number of leaves plant^{-1} and plant heights were similar for all treatments.

Experiment II

The time periods for reaching various plant growth stages were affected by the four different plant densities used in the study. There were differences between the hybrids with NC+ 5C35 at more advanced stages of developing than Pioneer 8699 at 51 and 59 DAP. At 59 DAP, Pioneer 8699 was between heading and half-bloom (5.7) whereas NC+ 5C35 was between half-bloom and full-bloom stage (6.2). Leaf counts of physiologically active leaves revealed interesting details with differences between hybrids and plant densities in the study. At 20 DAP, the main stalks in single plants had more leaves per plant (6.7) than clumps with two plants (5.9 leaves) or six (5.7 leaves) plants. The trend was similar at 59 and 72 DAP with Pioneer 8699 plants having more leaves than NC+ 5C35 plants. Craufurd et al. (1993) reported that leaf appearance reduced under water stress conditions and as the stress was severe, the leaf appearance was completely ceased. At 72 DAP (Fig. 6), single plants (9.2) and clumps with two plants (8.8) had more leaves plant^{-1} than clumps with four plants (7.9) and six plants (7.8). With increase in plant density there was a decrease in plant available water. It was also observed that plants in clumps with four or six plants matured faster than those with two plants or single plants. Plant heights measured at 51 DAP were not statistically different (P>F=0.05) for various densities.

Tiller numbers decreased with increases in planting density, as summarized in Table 1 for four planting densities, two hybrids and four different dates after planting. At 20 DAP, clumps withtwo plants and single plants had 1 and 2 tillers plant^{-1} respectively. In contrast, clumps with four plants averaged 0.6 tillers plant^{-1} and clumps with six plants averaged only 0.3 tillers plant^{-1}. This trend was consistent at 28 DAP, 51 DAP and 72 DAP indicating that with the increase in

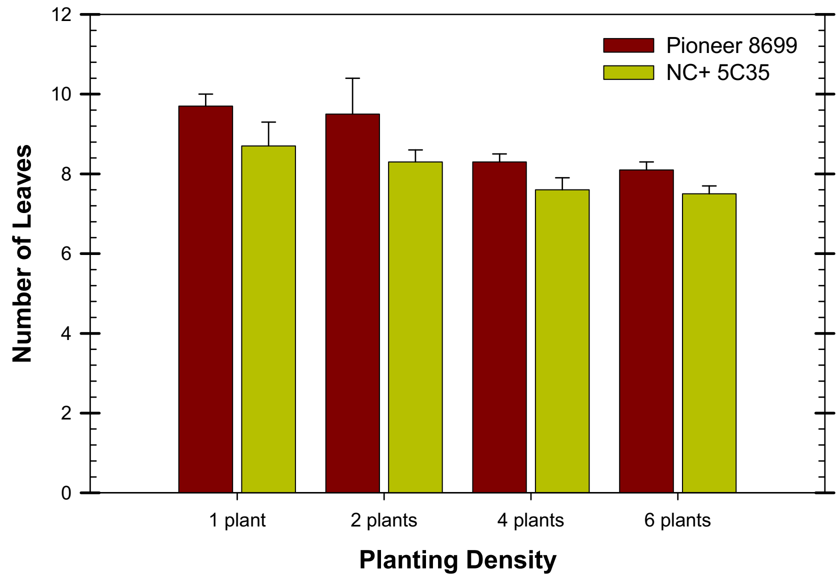

Fig. 6. Leaf number by plant density and hybrid (72 DAP).

Table 1. Number of tillers (mean values) as influenced by planting density and variety

Hybrid→	Number of tillers plant^{-1} for Pioneer 8699				Number of tillers plant^{-1} for NC+ 5C35			
Treatment	20 DAP	28 DAP	51 DAP	72 DAP	20 DAP	28 DAP	51 DAP	72 DAP
1 Plant by itself	2.3 c	2.7 c	2.7 c	3.0 c	2.0 c	2.3 c	4.0 c	6.0 c
2 plants in clump	1.3 b	1.5 b	1.5 b	1.5 b	1.2 b	1.5 b	1.7 b	2.3 b
4 plants in clump	0.6 a	1.0 a	0.9 a	0.9 a	0.6 a	0.7 a	0.6 a	0.6 a
6 plants in clump	0.3 a	0.7 a	0.6 a	0.6 a	0.3 a	0.4 a	0.3 a	0.5 a

Means followed by same letter are not significantly (*P*>F=0.05) different using LSD.
DAP – Days after planting.

plant density the tiller number plant^{-1} decreased. These results are similar to those by Casal et al. (1986) who found that the number of tillers per plants in grasses decreased with increase in plant density.

The incident light ratio (R:FR) decreased consistently with increased number of plants in clumps. The light ratios measured in the shade of the plant base at 13:00 h on 37 DAP are presented in Fig. 7. At 37 DAP the R:FR ratio at the base of a single plant was 0.33 and was significantly (*P*>F=0.05) higher than the ratio at the base of clumps with four plants (0.20) and six plants (0.20). Additionally, clumps with two plants sensed light with a higher R:FR ratio (0.28) than clumps with four and six plants (0.20). The results for R:FR ratios at 59 DAP were consistent with those at 37 DAP indicating that R:FR ratio decreases with increases in plant density.

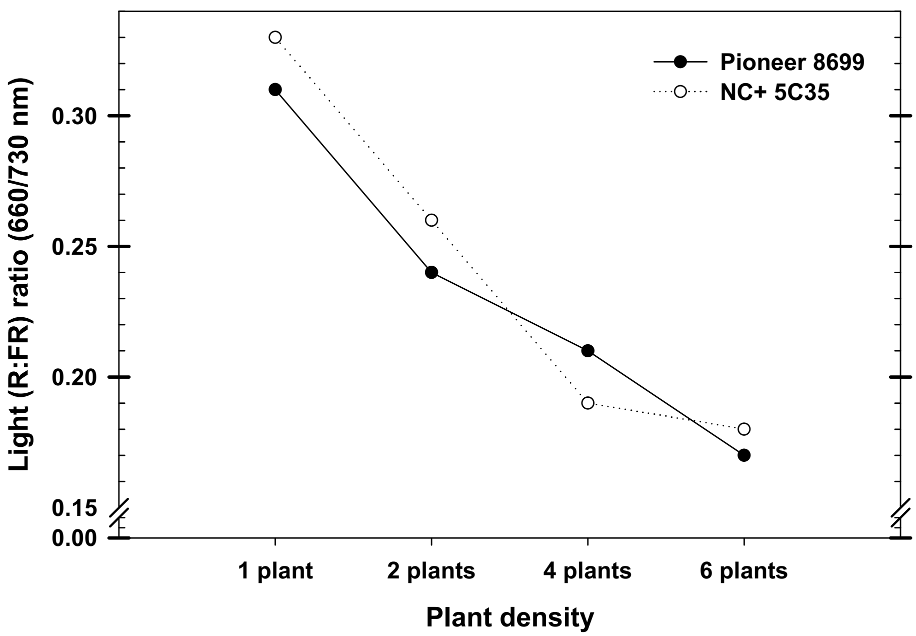

Fig. 7. Light (R:FR) ratio by planting geometry and hybrid (37 DAP).

Conclusions

Our results provide additional evidence and a clear understanding about the effect that planting dryland grain sorghum in clumps has on decreasing the number of tillers produced. Under our dryland conditions tillers are more often than not "excessive baggage" that results in much of the stored soil water being depleted during vegetative growth stages leading to severe water stress during the reproductive and grain filling stages. When grain sorghum was planted in clumps of four plants close to each other (2.5 cm or less apart), mutual shading resulted in lower R:FR ratios at the base of the plants and in fewer tillers plant^{-1}. The R:FR ratio and number of tillers plant^{-1} decreased with increased plant density and decreased spacing between the plants in the clumps. Apart from reducing tiller number, plants in clumps were observed to develop faster and had a change in architecture. Clumped plants adapted to environmental conditions by altering the number of leaves, and leaves tended to grow upward in contrast to outward for uniformly spaced plants. Additional study is needed to why these changes occurred and what physiological processes governed them.

Acknowledgments

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CONTRIBUTIONS OF TILLAGE, RYE COVER CROP AND HERBICIDE PROGRAMS TO WEED CONTROL IN GLYPHOSATE-TOLERANT COTTON

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ABSTRACT

The effects of a rye (*Secale cereale* L.) cover crop, tillage, and glyphosate, applied alone or in combination with preemergence herbicides, were investigated on weed populations in glyphosate-tolerant cotton. The rye cover crop and tillage reduced the populations and occurrence of winter annual weeds with the exception of horseweed (*Conyza canadensis*) and cutleaf evening primrose (*Oenothera laciniata*). Weed control provided by the rye cover crop was sufficient to eliminate the use of preemergence herbicides. Glyphosate treatments reduced weed populations to near zero between applications. However, in the time from the last glyphosate application to cotton defoliation, weeds, especially browntop millet (*Brachiaria ramose* (L.) Stapf), re-grew beneath the cotton canopy and became the most prevalent weed. Browntop millet populations were highest in treatments having the rye cover crop. This added weed pressure could allow more competitive weeds to become established and also complicate mechanical harvest and effect the lint color grade and trash content.

INTRODUCTION

Cotton production practices in the Mississippi Delta usually include fall tillage either as shallow tillage to re-establish beds and irrigation furrows, or deep tillage followed by bedding to reduce soil compaction and restore beds. These operations bury cotton residues and can cause considerable soil erosion. Addition of a winter cover crop to cotton production systems may improve soil stabilization as well as contribute to improved weed control and soil properties. Winter cover crops are known to reduce populations of many winter annual weeds, and some summer annual weeds (Peachy et al. 1999). Although termination of most cover crops is required, reducing the number of species may result in a more uniform burndown, and reduce the amount of preemergence treatment required at planting. However, little is known about whether a cover crop can alter weed distributions or cause species shifts during subsequent crop development. Before the addition of a cover crop into a production system may be accepted or adopted, it is important to understand the contributions that each component makes to the entire weed control system. The objective of this study is to determine seasonal and long term changes in weed populations with respect to tillage, herbicides applications and a rye (*Secale cereale* L.) cover crop.

MATERIALS AND METHODS

Research was conducted at the USDA-ARS Southern Weed Science Research Farm, Stoneville, MS on a Dundee silt loam (fine-silty, mixed thermic Aeric Ochraqualf) soil with pH 6.7 and 1% organic matter. Field preparation consisted of fall disking and bedding. One month prior to planting, the experimental area was treated with glyphosate at 1 lb/A to kill existing vegetation and the rye cover crop, which was approximately one ft high. Experimental plots were eight rows spaced 40 inches apart and 96 ft long. A randomized complete block design with a split plot treatment arrangement and four replications was utilized. Main plots consisted of tillage and cover crop, and subplots were the herbicide programs. Conservation tillage consisted of a single-pass with a shallow furrow-opening sweep in the fall. Herbicide programs were: 1-PRE: metolachlor (1 lb/A), fluometuron (1.1 lb/A), glyphosate (1 lb/A), followed by glyphosate (1 lb/A) POST at 1-leaf and 4-leaf cotton; 2-No PRE: glyphosate (1 lb/A) at planting followed by glyphosate (1 lb/A) POST at 1-leaf and 4-leaf cotton. Herbicide treatments were applied with a tractor-mounted sprayer with TeeJet 8004 standard flat spray tips delivering 20 gal/A water at 30 psi..

Glyphosate-resistant cotton cultivar 'DP 436RR' was planted on May 1, 2004; and May 2, 2005 at 50,000 seeds/A using a John Deere7300 planter in 40-inch rows. Crops were furrow irrigated as needed. Cotton plant height was kept below 40 inches by applying mepiquat chloride (*N,N*-dimethylpiperidinium chloride) POST at first matchhead square stage followed by a second application 2 wk later. Harvest preparation consisted of defoliation by tribufos (*S,S,S*-tributyl phosphorotrithioate) at 1.4 lb/A, and boll opening by ethephon [(2-chloroethyl) phosphonic acid] at 1 lb/A.

Weed (shoot) dry weight was determined in three randomly selected quadrats of 11.2 ft^2 within each plot. Weed counts and species diversity were determined after preplant burndown and after defoliation. Cotton was mechanically harvested from the center two rows.

The data were subjected to an analysis of variance using Proc Mixed to determine significance of main effects and any interactions among main effects (SAS 2002). Treatments were separated at the 5% level of significance using an LSD test.

RESULTS AND DISCUSSION

Seed cotton yields were highest with no tillage and a rye cover crop in 2004 (Table 1). However, in 2005, the opposite result of greater seed cotton yields with tillage and no rye cover crop were found (Table 1). The reasons for the different responses are not clear. Inclusion of a preemergence herbicide program had no effect on seed cotton yield or weed biomass at harvest in either year. Browntop millet biomass at harvest was greater in no tillage in 2005. A similar trend was observed in 2004 although results were not significant in that year.

The percentage of the ground covered by browntop millet was greater with no tillage or a rye cover crop (Table 2). These data are consistent with the biomass data presented in Table 1. Tillage without a rye cover had the lowest percentage of weed cover and addition of a rye cover crop resulted in increased weed cover at harvest (Table 2). No tillage had high weed cover regardless of the presence a cover crop. Browntop millet was the most prevalent weed at canopy closure, and after defoliation, was almost entirely responsible for the ground cover. The presence of weeds at harvest may reduce harvest efficiency and quality in cotton. Browntop millet presents added concerns because its leaves and stalks are difficult to separate from cotton during the ginning process. In this study, weed control with glyphosate applications was sufficient to maintain weed control until layby; the weed biomass at harvest represents the population that was re-established when glyphosate treatments ceased at layby. Reddy et al. (2003) found that a rye cover crop without additional herbicide treatments reduced browntop millet biomass by 14 % at 7 weeks after planting. The low suppression of browntop millet by rye indicates that alternative control methods need to included if browntop millet populations are present.

Glyphosate resistant horseweed and cutleaf evening primrose, also a more difficult weed to control with glyphosate, survived the pre- and postemergence herbicide treatments in 2004 and 2005, although data on their populations were not determined. In 2006, these weeds were noticeably abundant and their populations were determined (Table 3). Glyphosate-tolerant horseweed was more abundant in no till plots at P= 0.08. These results demonstrate that, like herbicides, cover crops and tillage treatments may cause weed shifts.

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Table 1. Effects of tillage and rye cover crop on cotton yield and the brown top millet biomass present at harvest.

		Seed Cotton (lbs /A)		Browntop millet Biomass (g / 11.2 ft^2)	
		Year			
Tillage	Rye Cover	2004	2005	2004	2005
Till	Yes	2305	2454	5.9	70.9
Till	No	2128	2692	9.5	26.1
Notill	Yes	2564	2325	30.7	160.7
Notill	No	2393	2516	87.7	123.5
	$lsd_{(.05)}$	197	149	103.0	60.0

Table 2. Effect of tillage and rye cover crop on the percentage of ground covered by browntop millet at harvest in 2005.

Tillage	Rye	Browntop Millet (% coverage)
Till	Yes	52
Till	No	12
Notill	Yes	87
Notill	No	92
	$lsd_{(.05)}$	19

Table 3. Effects of tillage and rye cover on horseweed and cutleaf evening primrose densities in 2006.

		Number per plot	
Tillage	Rye Cover	Horseweed	Cutleaf Evening Primrose
Till	Yes	2.2	5.6
Till	No	0	7.9
Notill	Yes	7.8	4.2
Notill	No	17.3	13.5
	$lsd_{(0.05)}$	18.9	44.9

NITROGEN RELEASE FROM PEANUT RESIDUE

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ABSTRACT

Residue management is an important aspect of crop production systems. Availability of plant residue nitrogen (N) to succeeding crops is dependent on N mineralization rates and therefore on rates of N release during decomposition. Much of the information available on N release rates from peanut residue is based on controlled-environment studies. The objective of this study was to assess N release rates in the field from the residues of three peanut varieties (NC-V 11, GA-02C and ANorden) at two depths (surface and 4 in deep) and two locations (Upper Coastal Plain Experiment Station in Edgecombe County, North Carolina and Wiregrass Experiment Station in Henry County, Alabama), representing the northern and southern limits of commercial peanut production in the US. Litterbags containing the equivalent of 2.0 tons ac^{-1} were placed in a completely randomized design, blocked by location, with four replications and retrieved periodically up to 335 days after application. Results show a statistical difference for depth by time (within location) interactions and fit single or double exponential decay models. Buried residues mineralized N at higher rates than surface residues in North Carolina during the initial 49 days of decomposition. The Virginia type cultivar NC-V 11 released N at higher rates than the two runner types tested in North Carolina. After the initial rapid phase of decomposition, there was no difference in rates of N release at either experiment station. No treatment differences were found at the Wiregrass Experiment Station. The data suggest that N is released quickly after peanut harvest if residue is left in the field.

COVER CROP RESIDUE EFFECTS ON EARLY-SEASON WEED ESTABLISHMENT IN A CONSERVATION-TILLAGE CORN-COTTON ROTATION

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ABSTRACT

Use of winter cover crops is an integral component of conservation systems in corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.). A field experiment was initiated in 2004 to evaluate weed suppression provided by winter cover crops in a conservation-tillage corn and cotton rotation. Rotation for winter cover crops included clover (*Trifolium incarnatum* L.) preceding corn and rye (*Secale cereale* L.) preceding cotton. The covers were planted at five different planting dates based on thirty year average first frost. Termination dates in the spring were 4, 3, 2 and 1 week prior to cash crop planting, based on thirty year average historical soil temperature. It was observed even a week's delay in winter cover crop planting can severely impact the biomass production and thus have a negative bearing on the cover crop benefits. More than ten times difference in cover biomass produced by clover was observed when the covers were planted on the earliest and terminated on last date compared to late planting and early termination. Rye produced almost eight times more biomass in the same comparison. Correspondingly, weed biomass was 556 kg/ha in the treatment with least rye biomass, eight times higher compared to the treatment with greatest rye biomass. Though the difference was only 34 kg/ha in case of clover, it is important to mention that weed populations observed in clover were less than in rye.

INTRODUCTION

Conservation tillage systems are increasingly becoming an integral part of sustainable agriculture. They are primarily used to address concerns about declining water and air quality, soil erosion and soil productivity. An important component of conservation tillage systems in the Southeast is the use of winter cover crops. Cover crop residue provides soil cover, which is critical in reducing erosion, improving infiltration, soil moisture retention and nutrient enhancement (Blevins et al. 1971; Kaspar et al. 2001; Reeves 1997). An important advantage of using cover crops is their ability to suppress weeds through physical as well as chemical allelopathic effects (Nagabhushana et al. 2001; Putnam et al. 1983). Previous research has shown that weed control using cover crops with conservation tillage systems is comparable to chemical control in certain situations (Teasdale and Mohler 1992; Johnson et. al. 1993).

Approximately 90% of the U.S. cotton grown in 2001 received herbicides (Anonymous 2002). Cotton is the main cash row crop for many growers in the Southeast. Practical alternatives to the intensive use of herbicides for controlling weeds in cotton production offer economical as well as environmental benefits. Cereal rye and soft red winter wheat (*Triticum aestivum* L.) are the two most common winter cover crops recommended for corn and cotton production in the southeastern U.S. with the addition of vetch and annual clover for corn (Mask et al. 1994; McCarty et al. 2003; Monks and Patterson 1996). Crop rotation is also an important component of cotton production in the Southeast as continuous cotton production causes many problems, including increased soil borne pathogen populations and an increase in hard to control weeds due to the lack of herbicide chemistry rotation. Rotations with corn are typical, due to lower production costs, ease of production, and because corn is a non-host to many cotton pathogens.

Historically, cover crop planting and termination has occurred at the discretion of growers' schedules and weather conditions. Previous research has shown that a winter cover's planting date and termination date influences both quality and quantity of residue production, and subsequent weed suppression. Therefore, a field study was conducted to determine optimum dates for planting and terminating a winter cover crop to maximize biomass production and early season weed suppression.

MATERIALS AND METHODS

Field experiments were established in 2003 at the Alabama Agricultural Experiment Station's E.V. Smith and Tennessee Valley Research and Extension Centers. In 2004, a similar experiment was also established at the University of Florida's West Florida Education and Research Center. The experimental design was a randomized complete block with three replicates having a split block restriction on randomization. Each plot had four rows of corn or cotton and both phases of the rotation were present each year.

The experiment involved two cover crops, rye preceding cotton and clover preceding corn rotated annually at each site. We examined five different planting dates and four different termination dates. Horizontal strips consisted of five cover planting dates and vertical strips consisted of four cover termination dates. Both covers were established with a no-till drill at 2 and 4 week prior to, 2 and 4 week after, and on the historical average first frost. The rye seeding rate was 100 kg/ha, and 56 kg of nitrogen (N) as ammonium nitrate was applied to rye in fall after establishment. The clover seeding rate was 28 kg/ha.

In the spring, covers were terminated at 4, 3, 2, and 1 week prior to cash crop planting. Clover was terminated using glyphosate (1.12 kg ae/ha) plus 2,4-D amine (0.20 kg ai/ha) at a rate of 140 L/ha. Rye was terminated using glyphosate at 1.12 kg ae/ha and flattened prior to planting with a mechanical roller-crimper to form a dense residue mat on the soil surface. Cover biomass from each plot was measured immediately before termination. The above-ground portion of rye and clover was clipped from one randomly-selected 0.25-m^2 section in each plot, dried and weighed.

The cotton varieties DP 444 BG/RR, ST 5242 BR and DP 555 BRR were planted at E.V. Smith, Tennessee Valley and West Florida, respectively. The corn variety Dekalb 69-72RR was planted at all the locations. Cash crops were planted with a four-row planter equipped with row cleaners and double-disk openers. Since both the E.V. Smith and West Florida sites had a well-developed hardpan, the experimental areas were in-row subsoiled prior to planting with a narrow-shanked parabolic subsoiler, equipped with pneumatic tires to close the subsoil channel. Weed biomass was determined in two 0.25-m^2 sections as described above when cotton reached the 4-leaf and corn reached 8-leaf growth stages. At this stage glyphosate was applied at 1.12 kg ae/ha. Plots were then kept weed-free until harvest utilizing Alabama Cooperative Extension System recommended herbicide applications. Though evaluations also included soil coverage by cover, cash crop stand establishment and height, and cash crop yield, in this paper we are only reporting the weed suppression provided by the two covers. Data were analyzed by analysis of variance using mixed model methodology as implemented in SAS Proc Mixed.

RESULTS AND DISCUSSION

The significance of treatments and treatment combinations can be found in Table 1. Since there was no environment (location and year)*planting date*termination date interaction the data was averaged over locations for studying the effect of planting dates and termination dates on cover and weed biomass (Table 2). As expected, the highest cover crop biomass in both the cases was produced by an earlier planting and later termination date combination.

In rye, the highest biomass of 6745 kg/ha (Table 2) was produced when rye was planted four weeks prior to average first frost and terminated two weeks prior to cotton planting. This was almost eight times more than the least biomass of 795 kg/ha produced for the treatment in which the rye was planted four weeks after average first frost and terminated four weeks before cotton planting. In clover, the highest biomass of 2637 kg/ha (Table 3) was produced when covers were planted two weeks before the average first frost and terminated four weeks prior to corn planting. The least biomass produced was 182 kg/ha by the treatment combination of last planting date and third termination date.

With an increase in the cover biomass the weed biomass decreased in most instances. In cotton, weed biomass (591 kg/ha) was almost ten times higher when the cover biomass was lowest compared to when cover biomass was highest. In corn (Table 3), the weed biomass was not as predictable as in cotton, but it showed a similar trend (i.e. the higher the amount of cover biomass, the lesser the amount of weeds.) The lowest weed biomass observed was 36 kg/ha corresponding to clover biomass of 2453 kg/ha and the highest was 158 kg/ha corresponding to clover biomass of 373 kg/ha. This is probably due to the fact that high cover biomass provides more soil coverage which can negatively impact the weed seed germination and alter other physical conditions required for weed emergence and establishment. Our observations of decrease in weed biomass by corresponding increase in cover crop biomass agree with other research reportings (Teasdale et al. 1991).

When the planting date and termination date effects were studied separately (Tables 4-7) for each environment, general observation showed an earlier planting date always produced more biomass and correspondingly less weed biomass. Similarly, weed biomass decreased with later termination of the cover at all the locations. It was, however, observed that clover provided more effective weed control though it produced less biomass compared to rye irrespective of the year and location.

CONCLUSIONS

In general, cover crop biomass increased with earlier planting and later termination, and weed biomass decreased with increasing biomass. Observations indicate that high cover biomass should decrease early season weed interference and allow flexibility of postemergence application timing.

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Table 1. Significance (p-values) of environment (Env), planting dates (PD) and termination dates (KD) on various parameters for corn and cotton.

		Cover		Weeds		Stand		Yield	
Effect	df	Corn	Cotton	Corn	Cotton	Corn	Cotton	Corn	Cotton
Env	4	<0.001	<0.001	<0.001	0.003	0.098	<0.001	<0.001	<0.001
PD	4	<0.001	<0.001	> 0.15	<0.001	<0.001	<0.001	> 015	0.011
KD	3	0.015	<0.001	0.094	<0.001	> 0.15	> 0.15	<0.001	0.010
Env*PD	16	<0.001	<0.001	0.088	<0.001	0.133	<0.001	0.007	0.137
Env*KD	12	> 0.15	<0.001	> 0.15	<0.001	0.006	0.127	> 0.15	> 0.15
PD*KD	12	> 0.15	0.003	> 0.15	> 0.15	> 0.15	> 0.15	> 0.15	> 0.15
Env*PD*KD	48	> 0.15	> 0.15	> 0.15	> 0.15	> 0.15	> 0.15	> 0.15	> 0.15

Table 2. Effect of planting dates (PD) and termination dates (KD) on rye and weed biomass (kg/ha) in cotton (SE_{Rye}= 335, SE_{Weeds}= 69).

	PD1		PD2		PD3		PD4		PD5	
	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS
KD1	4043	371	3237	367	2465	553	1516	519	795	556
KD2	5737	149	5045	193	3782	336	2205	303	1190	591
KD3	6745	78	6433	162	4266	257	2403	221	1290	366
KD4	6229	57	6094	67	4655	190	3165	191	2002	293

Table 3. Effect of planting dates (PD) and termination dates (KD) on clover and weed biomass (kg/ha) in corn (SE_{Clover}= 294, SE_{Weeds}= 24).

	PD1		PD2		PD3		PD4		PD5	
	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS
KD1	2364	65	1514	101	518	105	378	84	373	158
KD2	2412	37	2099	91	711	143	205	133	230	98
KD3	2329	40	2018	56	1124	124	473	82	182	93
KD4	2453	36	2637	59	898	95	823	134	522	132

Table 4. Effect of planting dates (PD) on rye and weed biomass (kg/ha) in individual environment in cotton (SE_{Rye}= 454, SE_{Weeds}= 88).

	EVS 2004		EVS2005		TVS2004		TVS2005		JAY2005	
	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS
PD1	5566	316	5331	289	8878	31	5062	133	3605	48
PD2	5053	318	4893	381	7852	54	5232	182	2982	50
PD3	4344	470	2610	440	6584	406	2863	275	2559	80
PD4	2779	474	518	467	4500	250	2129	298	1687	53
PD5	1276	970	213	378	2649	345	913	479	1545	87

Table 5. Effect of planting dates (PD) on clover and weed biomass (kg/ha) in individual environment in corn (SE_{Clover}= 311, SE_{Weeds}= 32).

	EVS 2004		EVS2005		TVS2004		TVS2005		JAY2005	
	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS
PD1	1808	26	4750	62	2861	81	1928	27	601	26
PD2	2135	28	3827	120	1446	109	2462	54	468	72
PD3	1223	83	1061	136	604	155	945	167	230	42
PD4	1321	75	359	90	304	153	263	171	103	53
PD5	914	109	414	115	93	187	121	135	90	55

Table 6. Effect of termination dates (KD) on clover and weed biomass (kg/ha) in individual environment in corn (SE_{Clover}= 271, SE_{Weeds}= 30).

	EVS 2004		EVS2005		TVS2004		TVS2005		JAY2005	
	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS	CLOVER	WEEDS
KD1	1054	72	2162	142	653	131	977	89	300	77
KD2	1691	68	1813	77	832	142	1119	161	201	54
KD3	1315	76	2005	116	1125	143	1464	38	217	23
KD4	1860	40	2348	83	1637	132	1015	157	474	45

Table 7. Effect of termination dates (KD) on rye and weed biomass (kg/ha) in individual environment cotton (SE_{Rye}= 424, SE_{Weeds}= 81).

	EVS 2004		EVS2005		TVS2004		TVS2005		JAY2005	
	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS	RYE	WEEDS
KD1	1837	1061	2282	603	4394	265	1734	345	1809	91
KD2	4659	532	2794	430	5460	165	2693	397	2352	48
KD3	4731	341	3089	389	6421	153	3767	150	3128	51
KD4	3987	104	2686	141	8095	287	4765	201	2613	64

*SE = Standard Error

COTTON (*GOSSYPIUM HIRSUTUM*) CROP WATER NEEDS UNDER CONVENTIONAL AND CONSERVATION PRODUCTION SYSTEMS

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ABSTRACT

Conservation tillage systems have not been widely adopted in the Mississippi Delta, even though evidence has shown the economic advantages. Questions remain as to how to best manage cover crops on the deep alluvial soils of the region, and the irrigation needs of crops under conservation systems. In this study, we are examining changes in soil organic matter in two soils types common to the region during the transition from conventional tillage to conservation systems. We are also determining crop and soil moisture levels for the soil types under different tillage regimes, with an end to developing appropriate irrigation scheduling guidelines for cotton (*Gossypium hirsutum*, sps. L.) production. The two soil types examined in the study are Sharkey clay; and a Dundee loam, which ranges in the field from sandy to silty clay. Treatments are conventional: with and without fall subsoiling at 45 cm depth, no cover crop; and conservation: with and without fall subsoiling, winter wheat or gin trash cover. Measurements include soil surface organic matter, soil moisture at 15 cm increments down to 91 cm, and soil temperature. Plant growth is followed throughout the season, and final yield and fiber quality determined at harvest.

COVER CROP EXTRACT EFFECTS ON RADISH RADICLE ELONGATION

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ABSTRACT

Conservation systems using cover crops offer many benefits, including enhanced weed suppression. Researchers have shown that some cover crops leach allelopathic chemicals that contribute to weed growth inhibition. Twelve cover crops were evaluated for allelopathic potential in two experiments using an extract-agar technique. Five weeks after planting, plants were clipped at the soil surface and cut into 15 mm pieces, which were soaked in distilled water for 24 h. After 24 h, filtered extracts, along with a distilled water control, were mixed with autoclaved agar and poured into petri dishes. After solidification, five pre-germinated radish seeds with radicals less than 2 mm in length were placed on each petri dish. Radish radicle lengths at 48 h were recorded. Significant differences were found among cover crops in both experiments. All cover crop extracts inhibited radicle elongation significantly more than distilled water, supporting previous research which noted allelopathic effects in cover crops.

INTRODUCTION

Conservation systems using cover crops offer many benefits, including enhanced weed suppression. High biomass cover crops can physically suppress early-season weeds. In addition, field researchers have shown that some cover crops possess allelopathic chemicals that can inhibit weeds; however, conclusive allelopathic research is difficult to obtain due to the inability to distinguish allelopathic effects from other cover crop effects (Sustainable Agriculture Network, 1998). Extract-agar bioassays have been developed to separate allelopathic potential of crop residues from plant competition effects (Pederson, 1986; Ben-Hammouda et al., 1995). Allelopathic bioassays often use standard indicator species, such as radish, for preliminary allelopathic testing (Wu et al., 2001). This study assessed the effects of cover crop extracts on radish radicle elongation.

MATERIALS AND METHODS

Twelve cover crops were evaluated for allelopathic potential in two experiments. For experiment 1, cover crops included black oat (*Avena strigosa* Schreb.) cv. SoilSaver, crimson clover (*Trifolium incarnatum* L.) cv. AU Robin, white lupin (*Lupinus albus* L.) cvs. AU Homer and AU Alpha, rye (*Secale cereale* L.) cv. Elbon, wheat (*Triticum aestivum* L.) cv. Vigoro Grazer, and triticale (*X Triticosecale* Wittmack) cv. Trical 2700. For experiment 2, cover crops included winter forage rape (*Brassica napus* L. var. *napus*) cv. Licapo, sunn hemp (*Crotalaria juncea* L.), Austrian winter field pea (*Pisum sativum* spp. *arvense* (L.) Poir), black medic (*Medicago lupulina*), hairy vetch (*Vicia villosa* Roth), black oat cv. SoilSaver, and crimson clover cv. AU Robin.

A modified procedure of Pederson (1986) was followed for both experiments. Cover crops were planted in the greenhouse. Each cover was replicated eight times. At 5 weeks after planting, plants were clipped at soil level and cut into 15 mm pieces, which were soaked for 24 h at a ratio of 10 g (fresh weight) to 50 ml distilled water. A control, 50 ml of distilled water only, was added to each rep. After 24 h, samples were filtered through coffee filters. Granulated agar (12 g L^{-1}) was autoclaved, cooled to 50°C and mixed with 20 ml of filtrate in a 1:1 ratio. The solutions were poured into petri dishes and allowed to solidify.

Radish seeds were surface sterilized and pre-germinated on moistened paper towels. Five seeds with radicles less than 2 mm in length were placed onto each solidified plate. Plates were kept in the dark at room temperature for 48 h. Radicle length was measured for each seed. The five lengths from each plate were averaged for a plate value. Plate values were compared using SAS analysis of variance (ANOVA). Mean separations for cover crop were made using Fisher's LSD ($p \leq 0.05$).

RESULTS AND DISCUSSION

For both experiments, radish radicle elongation was significantly higher in plates containing distilled water than those plates containing any cover crop extract (Tables 1 & 2), supporting previous research which noted allelopathic effects in cover crops.

Significant differences in allelopathic potential among cover crops were noted in both experiments. The extent of these differences and relative ranking of each cover crop differed among runs, implying that allelopathy potential in cover crops can vary based on external factors not addressed in this experiment. However, some cover crop differences were consistent throughout all three runs. In experiment 1, radicle elongation was significantly higher in lupin (AU Homer) and triticale extracts than for black oat extracts. In experiment 2, hairy vetch and black medic extracts inhibited radicle elongation more than forage rape or crimson clover extracts. Additionally, elongation was higher for forage rape extract than for sunn hemp extract in all three runs.

Table 1. Experiment one radish radicle length means 48 h after placement on plates containing agar-extract solution.

Species	Radish radicle length		
	Run 1	Run 2	Run 3
	---------------------------- mm	----------------------------	
Distilled water	39.5a†	42.0a	28.3a
Lupin (AU Homer)	20.3b	21.7bc	17.5b
Triticale	12.9c	24.1b	17.7b
Crimson clover	12.7c	24.5b	16.8bc
Rye	11.7cd	16.1de	16.4bc
Wheat	9.1d	14.3de	17.7b
Lupin (AU Alpha)	9.0d	18.5cd	12.7d
Black oat	8.6d	12.4e	14.5cd
LSD 0.05	3.4	5.2	2.8

† Radicle length means within the same column followed by the same letter are not significantly different at the 0.05 level according to Fisher's LSD.

Table 2. Experiment two radish radicle length means 48 h after placement on plates containing agar-extract solution.

	Radish radicle length		
Species	Run 1	Run 2	Run 3
	---------- mm ----------		
Distilled water	45.6a†	34.0a	39.7a
Forage rape	29.6b	20.3bc	27.2b
Crimson clover	21.8c	23.1b	15.3d
Winter pea	18.0cd	15.4cd	21.6c
Black oat	14.7de	24.9b	14.1de
Sunn hemp	16.6de	15.1de	16.6d
Hairy vetch	12.2e	13.7de	10.1e
Black medic	15.4de	10.2e	10.3e
LSD 0.05	5.1	5.1	4.7

† Radicle length means within the same column followed by the same letter are not significantly different at the 0.05 level according to Fisher's LSD.

In experiment 1, radish radicle length from the two lupin cultivar extracts differed significantly in two out of three runs. Therefore, allelopathic potential may also vary among cultivars of the same species.

Conclusions

All cover crop extracts inhibited radicle elongation more than distilled water, showing that the cover crops evaluated in this experiment exhibited allelopathy. Cover crops differed significantly in their allelopathic potential. Allelopathic potential may also vary between cultivars within a cover crop species. Therefore, to maximize allelopathic effects, both cover crop species and cultivar must be considered.

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ANALYSIS OF THE TEXAS HIGH PLAINS EVAPOTRANSPIRATION NETWORK DATA TO DETERMINE THE OPTIMUM PLANTING DATE FOR DRYLAND GRAIN SORGHUM

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ABSTRACT

Grain sorghum (*Sorghum bicolor* L. Moench) is a leading cereal in semi-arid regions. Lack of water constrains dryland production in the Texas High Plains. One of the important features in increasing its water use efficiency is seeding at an appropriate time to minimize water stress. The objective is to analyze data from the Texas High Plains Evapotranspiration Network (TXHPET) to determine the best time for seeding dryland grain sorghum. Daily data, namely growing degree days (GDD), precipitation, potential evapotranspiration (PET) and precipitation availability index (PAI) for short season grain sorghum seeded at four planting dates (1 May, 15 May, 1 June, and 15 June), were analyzed for 15 locations. Only 82 days were required at Chillicothe and Munday for sorghum to reach the black layer stage in contrast to 122 days at Dalhart for June 15 planting date. An important finding was that the amount of growing season precipitation was nearly the same regardless of the planting date, but the amount prior to seeding increased considerably as planting date was delayed. Since some of the precipitation that occurs before planting is stored in the soil profile and can be used during the growing season, delayed planting will likely result in more total water being available to the crop during the growing season and should result in higher grain yields. Therefore, it appears on average that planting sorghum in June will result in more total water being available to the crop than planting in May, but variation among years is high.

INTRODUCTION

Sorghum is a leading cereal in arid and semi-arid agriculture, ranking fifth in importance among the world's grain crops (Doggett 1988). It is one of the oldest known crops and its origin can be traced to Africa and India. It is an important food crop in regions where heat, drought and poor soils make other crop production systems unsuccessful, particularly in Africa and Asia. It has been commercially introduced in the United States (US) in the 1800's (Bennett et al., 1990) and is the third most important cereal crop in US after corn and wheat. Sorghum grain and silage are important sources of livestock feed in dryland areas with lowest potential for agricultural production in the US. Texas, Kansas and Nebraska are the leading dryland grain sorghum producers in the Great Plains region.

The climate in the Texas panhandle is characterized by limited annual rainfall of irregular seasonal distribution with a great loss of water due to runoff during torrential showers and a very high rate of evaporation. Most of the precipitation is received during April-September inclusive and is very irregular in its distribution. The monthly averages do not represent normalcy. However, in reality, a heavy torrential shower is followed by a severe drought. Evaporation of moisture from the soil and crops is very high reaching a maximum during periods of drought and high winds. Sorghum can be planted at any time during May-June. The early growth stages

Table 1. Years of available PET and yield data for various locations across the Texas panhandle.

Station	Years of PET data	Years of yield data
Perryton	1997-2005	1972-2004
Dalhart	1995-2005	1972-2004
Etter	1995-2005	1972, 73, 75-2004
Morse	1992-2005	1972-2004
White Deer	1995-2005	1972-2004
Bushland	1992-2005	1972-2000
Wellington	1996-2005	1972-2003
Dimmitt	1995-2005	1972-2004
Farwell	1997-2005	1972-2004
Earth	1996-2005	1972-2004
Halfway	1997-2005	1972-2004
Chillicothe	1999-2005	1972-85, 87, 91-2000
Lubbock	1997-2005	1972-80, 82-2004
Munday	2000-2005	1972-2000
Lamesa	1997-2005	1972-80, 82-2003

utilize most of the available soil moisture and also the growing season rainfall. This makes the later growth stages, particularly the anthesis and grain formation susceptible to water stress. Owing to its importance as a feed crop in the Texas High Plains, there is a need to plant the grain sorghum at an appropriate time where there will be minimal stress on the plant, especially during its critical stages of growth. The objective is to analyze the data from the TXHPET to determine the best time for seeding dryland grain sorghum in the Texas High Plains.

The number of days required to reach a particular growth stage are related to the air temperature and genetic background of the crop. A possible approach to predict the growth stage of a crop is to calculate the cumulative number of GDD. It is an index used to express crop maturity and it is computed by subtracting a base temperature of 50°F from the average of the maximum and minimum temperatures for the day. Minimum temperatures less than 50°F are set to 50°F and maximum temperatures greater than 100°F are set to 100. The black layer growth stage is assumed to be physiological maturity. The different growth stages identified for this study are 3-leaf, flag leaf, and flowering and black layer stages and the cumulative GDD required to reach each growth stage are 500, 1287, 1848, and 2673 respectively (Gerik et al., 2003).

Materials and Methods

The study area includes 15 automated weather stations comprised in the Texas High Plains ET Network (North Plains and South Plains Networks). The stations extend throughout the Texas panhandle and include Perryton, Dalhart, Etter, Morse, White Deer, Bushland, Wellington, Dimmitt, Farwell, Earth, Halfway, Chillicothe, Lubbock, Munday, and Lamesa. The length of record varies with the locations and range from 14 years at Bushland and Morse to 6 years at Munday (Table 1). The stations were mapped on part of a Texas map using a geographical information system (Figure 1). Average annual precipitation ranged from a low of 16.2 in at Farwell to a high of 26.3 in at Munday. Elevation ranged from 1476 ft above sea level at Munday

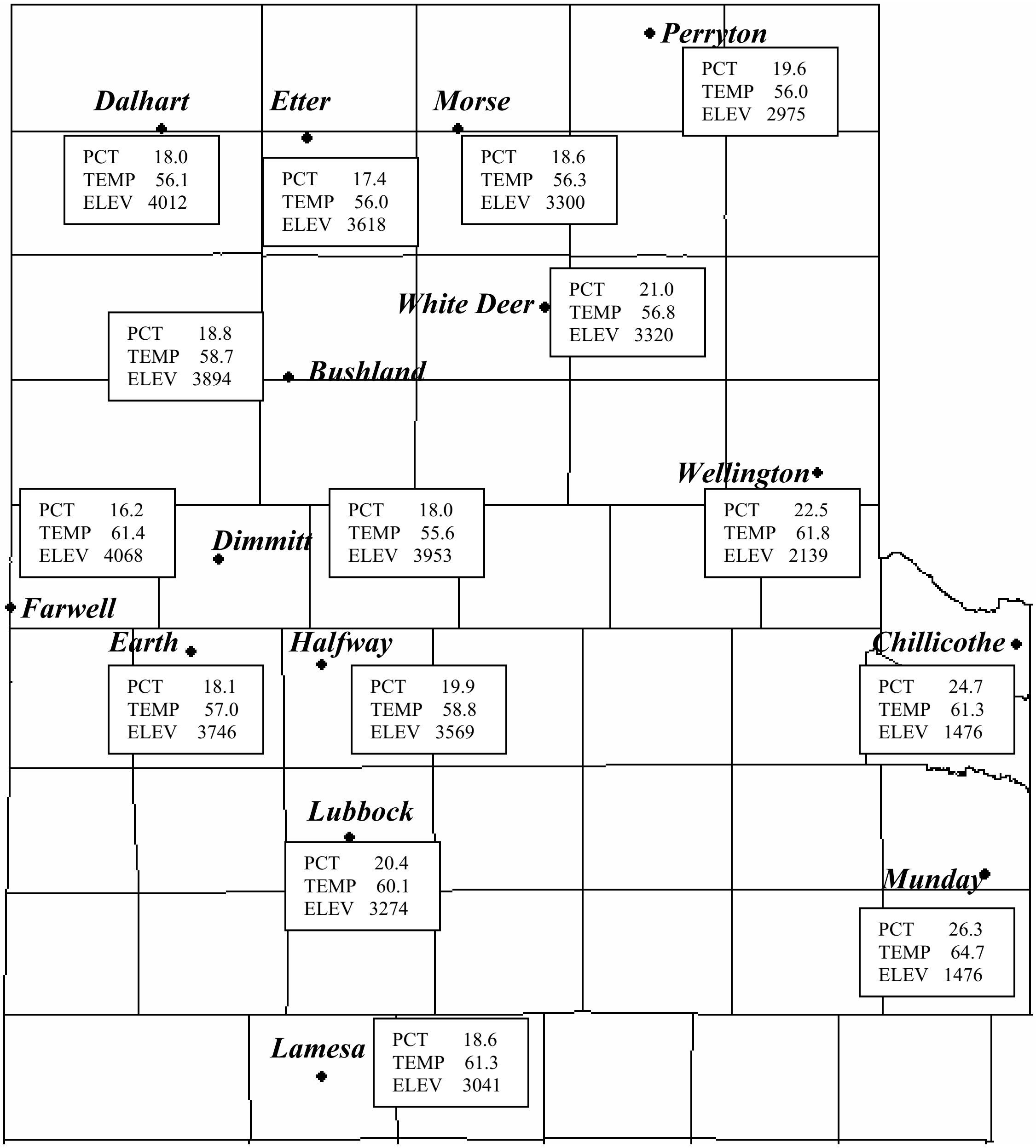

Figure 1. Texas Panhandle map showing various locations from the TXHPET, their 30-year average annual precipitation (in), average annual temperature (^{0}F), and elevation (ft).

and Chillicothe to 4068 ft at Farwell, and average annual temperature ranged from 55.6 °F at Dimmitt to 64.7 °F at Munday (Figure 1).

Daily data for short season dryland grain sorghum were collected from the TXHPET Network (TXHPET, 2005) for all the available years through 2005 for the four planting dates of 1 May, 15 May, 1 June, and 15 June. Number of years of available data varied from a maximum of 14 at Morse and Bushland to only 6 for Munday. The number of days from seeding to four different growth stages was calculated for each location. Also, the amount of precipitation occurring between 1 Jan. and the planting date, and the amounts of growing season precipitation that occurred during each of the four growth stages, as well as the total growing season precipitation, were summed for each location. Lastly, the precipitation availability index (PAI) was calculated for each period and season and shows the portion of the PET that was met by the growing season precipitation. Dryland grain sorghum also uses some of the precipitation that was stored in the soil profile at the time of seeding but the TXHPET Network does not provide any information about stored soil water. However, Jones and Johnson (1996) showed for a 9-yr study at Bushland that an average of 3.5 inches of water was used by dryland grain sorghum during the growing season. The PET is the amount of water required to fully meet the water demands of the growing crop and depends on the temperature, radiation, relative humidity, and wind conditions. The daily PET value can be measured by using a crop lysimeter, or calculated based on measurements of the climatic factors listed (FAO, 1999). The PET values for dryland grain sorghum will typically range from about 0.1 in per day or less at the 3-leaf stage to more than 0.35 in per day during flowering, and values greater than 0.5 in per day can occur on hot, dry, and windy days.

The average long-term grain sorghum yields (1972 to 2004 for most locations, Table 1) were calculated from yearly data obtained from the United States Department of Agriculture National Agricultural Statistical Service (USDA NASS, 2005). The calculated values represent the county average of all dryland grain sorghum acres harvested in the county where a TXHPET climatic site was located. The average ratio of acres harvested to acres planted for each county was also calculated. The 30-yr average monthly precipitation and annual precipitation amounts, and the average monthly temperature and annual temperature values, for each location was obtained from Intellicast (2005). Since the average precipitation and temperature records for Etter and Halfway were not available, the data of the nearest locations, Cactus and Plainview were respectively considered.

RESULTS AND DISCUSSION

The number of days required for grain sorghum to reach the black layer stage (physiological maturity) ranged from 82 to 122 d depending on date of planting and location (Figure 2). The 122 d requirement was for Dalhart and the same number of days was required for the earliest planting date, 1 May, and the latest planting date, 15 June. The shortest time of 82 d was for Chillicothe and Munday for the 15 June planting date. The elevation at Dalhart is much higher and the mean annual temperature considerably cooler than present at Chillicothe and Munday (Figure 1). The PET values, however, were higher at Dalhart than any other location in the network indicating Dalhart has the highest need for water to fully meet the water needs of grain sorghum for the entire growing season. This is because of the longer length of growing season required to accumulate enough growing degree days to mature the crop. Although the average amount of water required per day was less at Dalhart, the many more days that the crop required resulted in a higher total water use. In general, all of the southern locations had lower seasonal PET amounts than the northern locations. There was also a general trend at all locations for the seasonal PET amounts to decrease with the later planting dates. Again, this can mostly be explained by the later planting dates requiring fewer growing days. As the date of planting becomes later, the daily temperatures become higher, particularly during the early growth stages, and fewer days are required. However, the 15 June planting date required slightly more growing days than the 1 June planting date at nearly every location. Somewhat surprising, the PAI values were essentially equal for all locations regardless of the planting date. The northern locations had PAI values of about 0.35 indicating that precipitation during the growing season contributed only 35% as much water as would have been required to fully meet the needs of the crop. The PAI values were only about 0.25 for the southern locations but were generally 0.40 or higher for the eastern locations where the precipitation amounts and relative humidity values are generally higher.

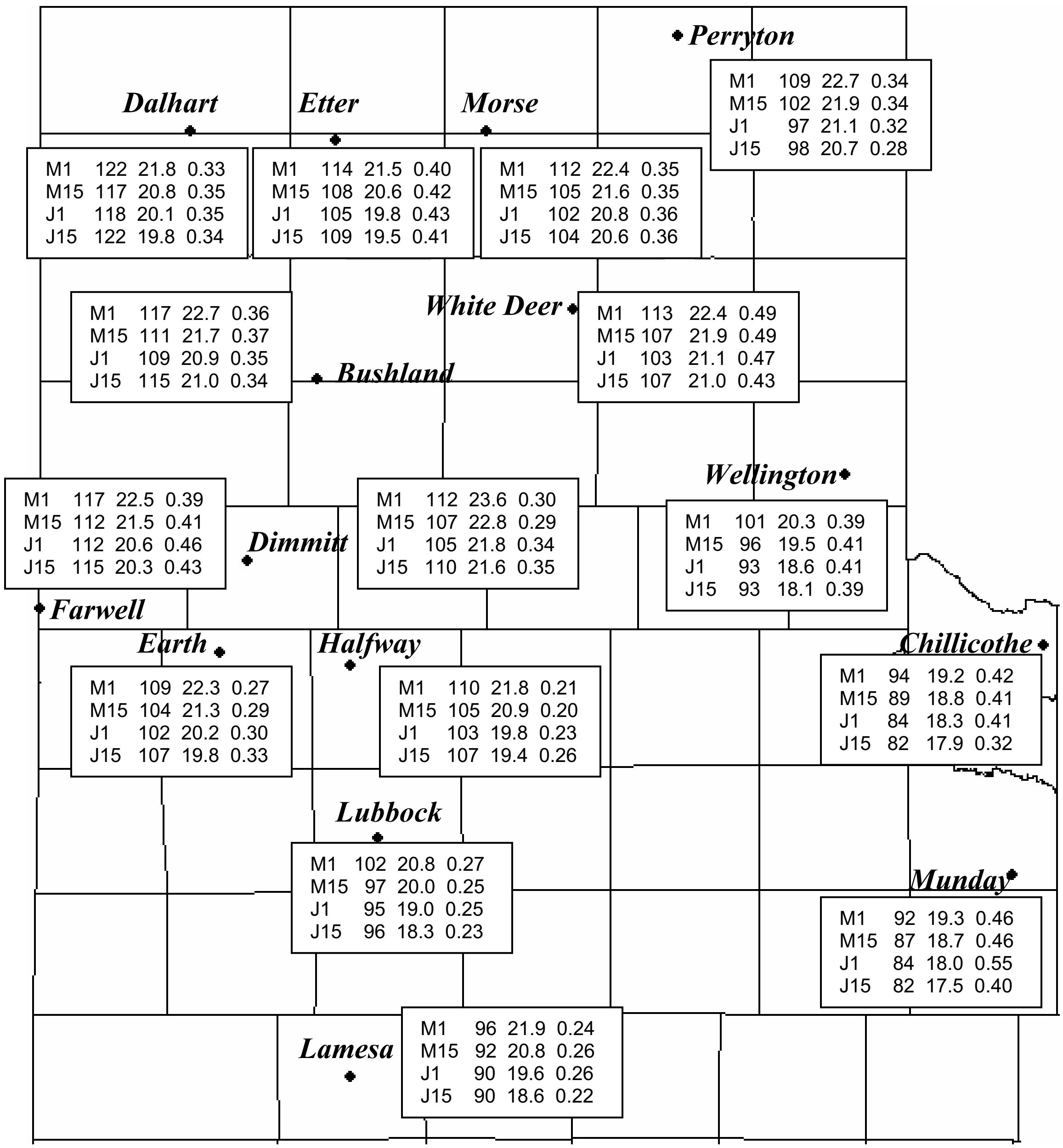

Figure 2. Texas panhandle map showing various locations from the TXHPET and the days taken to reach black layer, seasonal PET and PAI for years of available data for four planting dates (1 May, 15 May, 1 June, 15 June).

Dryland grain sorghum depends entirely on growing season precipitation and stored soil water that is present in the soil profile at the time of planting. Figure 3 shows the average amounts of precipitation that occurred between the time of planting and the black layer stage for each of the locations. The number of years that was averaged for different locations varied because the PET network began in 1990 with only Bushland and Morse. Table 1 shows the years that the PET network has obtained data for the various locations. It is important to note that the amount of growing season precipitation was largely independent of date of planting at essentially

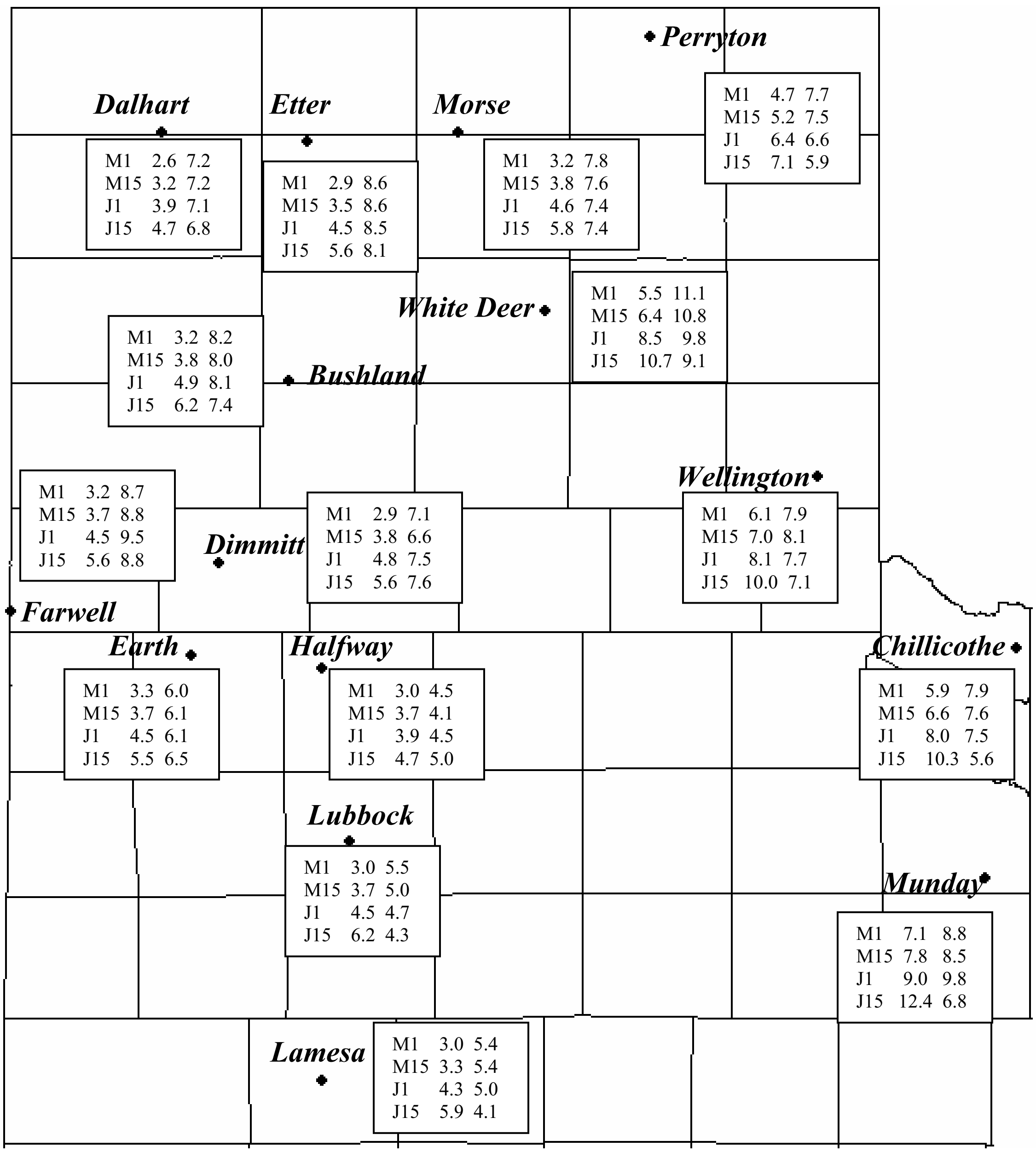

Figure 3. Texas panhandle map showing various locations from the TXHPET, their pre-plant and growing season precipitations (in) for four planting dates (1 May, 15 May, 1 June, 15 June) for years of available data.

all of the locations. The amounts of precipitation between 1 Jan. and the different dates of planting are also shown in Figure 3. As would certainly be expected, the amount of precipitation that occurred prior to planting increased as date of planting was delayed. The increased amounts between 1 May and 15 June ranged from about 2 inches at Dalhart to about 5 at Munday. It is well known and understood that some of the precipitation that occurs prior to planting a summer crop is stored in the soil profile and can be extracted by plants during the growing season. Dryland grain sorghum can extract soil water from a soil profile to a depth of four or more ft, and

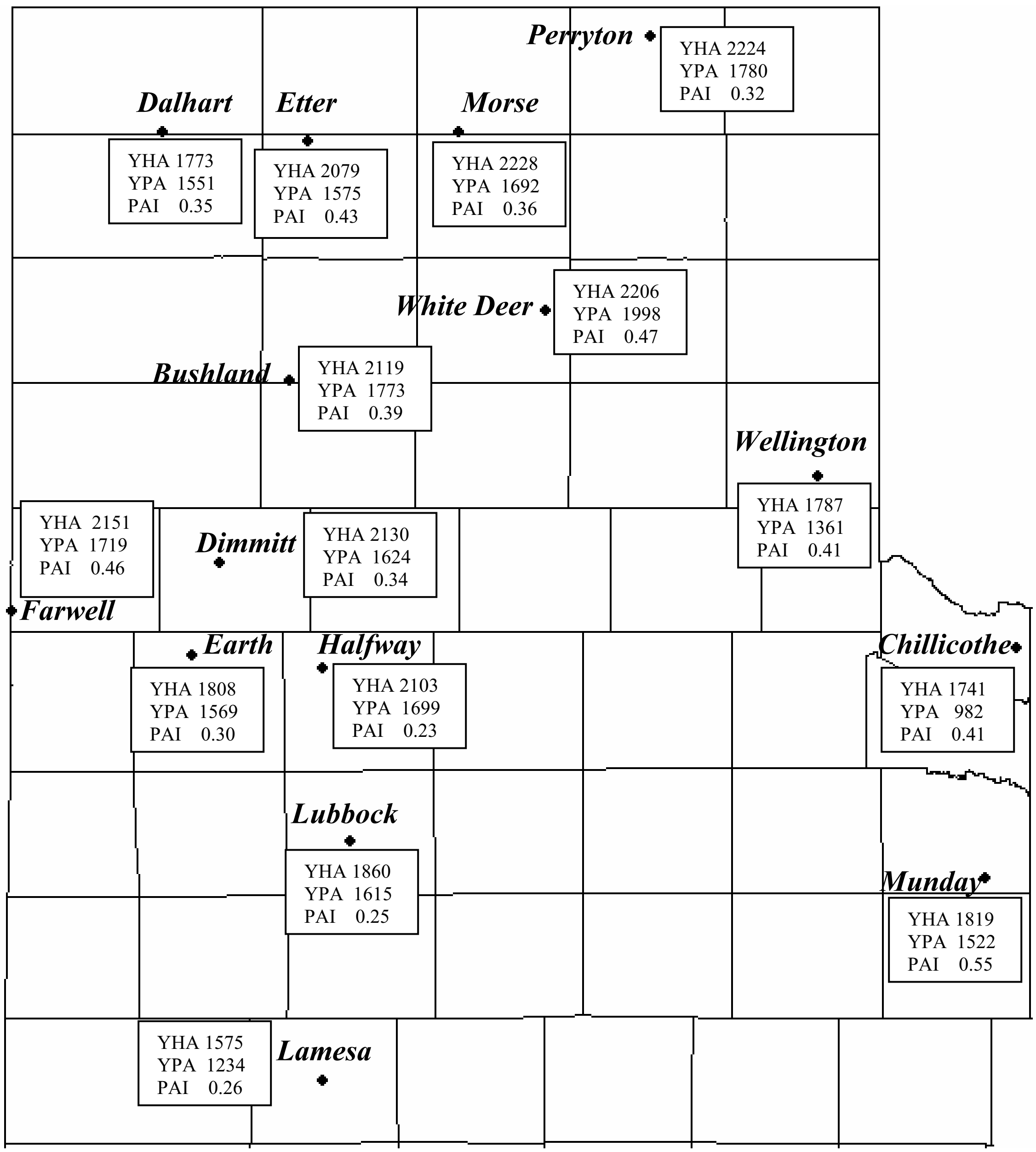

Figure 4. Average YHA and YPA for the county in which a PET Network site is located and PAI.

Jones and Johnson (1996) have shown that dryland grain sorghum at Bushland utilized an average of 3.5 inches of stored soil water during a 9-yr study. Even if only 20% of the precipitation that occurs prior to planting is stored in the soil for use by the grain sorghum crop, it could be important because small increases in stored soil water can result in significant increases in grain yield. Stewart and Steiner (1990) summarized several dryland grain sorghum studies and concluded that grain yields were increased 350 pounds for every inch of additional water use. Therefore, the information presented in Figure 3 indicates that more total plant available water will be available to a grain sorghum crop by delaying planting to 1 June or 15 June because there should be more stored soil water and growing season precipitation should be similar when compared to planting in May.

Grain sorghum is a major dryland crop in the Texas High Plains because it is one of the few crops that can be grown under severe drought conditions that occur almost every year. The long-term grain yields are shown in Figure 4 for the counties in which each of the network sites are located. Both the yield per harvested acre and yield per planted acre are shown. The yields were obtained from the USDA NASS (2005) and are the average for 1972 to 2004 for most locations, but for fewer years for some locations as shown in Table 1. On average, about 20% of the acres planted to grain sorghum are never harvested, so the yield per planted acre is considerably lower than the yield of harvested acre. For any location, the yield per planted acre can be divided by the yield per harvested acre to determine the proportion of planted acres that were actually harvested. For example, an average of 87% of the acres planted in the county where Dalhart is located was harvested compared to 78% for the county in which Lamesa is located. Average grain sorghum yields decrease from north to south, and the PAI values that represent only the years that the TXHPET network has been collecting data also decrease from north to south. Somewhat surprising is that the PAI values for the eastern counties where Wellington, Chillicothe, and Munday are located are also considerably higher than most of the other locations but the average yields are not higher. These locations are considerably lower in elevation and have higher mean annual temperatures than the other locations. The growing season temperatures are also higher as shown in Figure 2. The higher temperatures, particularly the higher night time temperatures, may have a negative effect on yields. As discussed earlier with Figure 2, the number of days required to grow grain sorghum at these locations is several days less than for the High Plains locations where the elevation is much higher (Figure 1).

The TXHPET network is used primarily for irrigation scheduling. The model assumes that the stage of growth changes with the same number of GDD regardless of the planting date. However Ottoman et al. (1997) showed that the number of GDD required for grain sorghum production was somewhat dependant on the planting date.

CONCLUSIONS

The amount of precipitation during the growing season was nearly the same regardless of the planting date, but the amount of precipitation prior to seeding increased considerably as planting date was delayed. Since some of the precipitation that occurs before planting is stored in the soil profile and can be used during the growing season, a later planting date will likely result in more total water being available to the crop during the growing season and should result in higher grain yields. Therefore, it appears on average that planting dryland grain sorghum in June will result in more total water being available to the crop than planting in May, but variation of precipitation among the years is high.

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TILLAGE EFFECTS ON N MINERALIZATION AND LOSSES OF WINTER APPLIED MANURE

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ABSTRACT

A better understanding is needed of how conservation practices affect the concentration of soil N resulting from winter application of manure. This study was conducted to evaluate the effects of manure applications on the mineralization and concentration of N during the winter. The experiment was established in fields that were previously under conventional and conservation tillage with and without manure application. Dairy composted manure was applied annually in the fall prior to planting of a winter cover crop. The quantification of N released from composted manure and the amount of N uptake by plant tissues of the cover crop during winter months was determined. The concentration of N was higher in the conventional tillage plots at the beginning of the study and quickly diminished throughout the growing season. The conservation tillage plots with manure retained the most N compared to the other treatments. This treatment also had the highest plant biomass compared to the other treatments, indicating much more was retained in the plant tissues. These results show use conservation tillage in conjunction with cover crops when applying manure in winter months could potentially minimize the amount of N lost.

INTRODUCTION

Winter application of manure has been a common practice for many years; however, recent environmental concerns have led many researchers to question this practice. There has even been action taken to address the potential environmental affects of manure nutrient loss from agricultural lands. The Alabama Natural Resource Conservation Service (NRCS) has adopted new nutrient management standards (NRCS Code 590), which effectively ban the application of animal manures in North Alabama during winter months (Torbert et al. 2005). Hence, increasing pressure on farmers to provide sufficient storage for manure generated during winter months. Therefore, research is needed to better evaluate alternative management strategies.

Research has been reported regarding effects that winter manure application has on nutrient loss due to surface runoff, thereby affecting water quality (Young and Holt, 1977; Converse et al., 1976; Witzel et al., 1969; Hensler et al., 1970). Others have reported that NO_3-N leaching from manure is increased compared with fertilizer N applied at equivalent N rates (Roth and Fox, 1990; Jemison and Fox, 1994). This increase was attributed to late fall or early spring N mineralization producing soil inorganic N during periods when there is no plant N uptake (Stoddard et al., 2005). Conservation tillage practices such as no-tillage, which enhances water infiltration, could potentially create situations where NO_3-N leaching is likely (Stoddard et al., 2005). Earlier studies have shown both higher and lower concentrations of NO_3-N in leachate under no-tillage as compared to conventional tillage systems (McMahon and Thomas, 1976;

Tyler and Thomas, 1977; Angle et al., 1993). However, most of these studies have been carried out in the Midwestern and Northeastern Regions of the U. S. and were conducted without the use of winter cover crops. Therefore, there is a need to evaluate the effects of nutrient loss from manure application during winter months in the Southeast in order to better understand how conservation tillage practices combined with winter cover crops affects N loss.

MATERIALS AND METHODS

This study is a component of a larger farm system experiment (Terra et al., 2006), which was established on a site that had a long-term history of row cropping; mostly cotton (*Gossypium hirsutum* L.), under conventional tillage (moldboard or chisel plowing) for 30 years prior to the establishment of plots in 2001. Soils at this site are mostly fine and fine-loamy, siliceous, subactive, thermic Typic, Oxyaquic and Aquic Paleudults.

The study was a 2 x 2 factorial design with two soil management systems with and without annual application of composted dairy manure evaluated in a corn (*Zea Mays L.*)-cotton rotation. The four treatments consisted of: (1) conventional tillage system (CT); (2) conventional tillage system with manure (CTM); (3) conservation tillage system (NT); and (4) a conservation tillage with manure (NTM). The conventional tillage consisted of fall (chisel plowing/disking) and spring (cultivation and in-row sub-soiling) tillage operations; conventional tillage systems did not include winter cover crops. Winter weeds in the CT and CTM were not controlled. Conservation tillage systems consisted of no-tillage with non-inversion sub-soiling and a winter cover crop of black oats (*Avena strigosa* L.) and rye (*Secale cereale* L.) before cotton and winter cover crops crimson clover (*Trifolium incarnatum* L.) and white lupin (*Lupinus albus* L.) before corn.

Soil samples were taken prior to fall manure application. Six soil cores (1 inch dia., 8 inches deep) per plot were collected and composited. Samples were air-dried, ground and passed through a .08 inch (2 mm) sieve. Total C and N were determined by the DUMAS dry combustion method using a LECO CN 2000 analyzer (LECO Corp, St. Joseph, MI). Soil pH (1:1 soil/water) and CEC was determined by the Auburn Soil Testing Laboratory, and results are presented in Table 1.

Composted dairy manure was surfaced applied to the field at a rate of ~ 4 tons/A dry matter in the NTM and CTM plots prior to planting winter cover crops. The winter N mineralization study was initiated on October 22, 2004 (the day of manure application) and continued until the killing of the cover crop (March 12, 2005) prior to planting the summer crop. Soil samples were collected from the corn and cotton plots throughout the winter months (0, 3, 7, 14, 21, 28, 49, 70, 91,112, 133, 140 days after manure application), extracted using 2M KCl as described by Keeney and Nelson (1982), and measured for concentrations of NH_4 and NO_2 + NO_3 colorimetrically using the Bran-Luebbe automated laboratory equipment (Bran-Luebbe, Norderstedt, Germany). Soil water and moisture content was measured using a HOBO weather station (Onset Computer Corporation, Bourne, MA). Local weather data (rainfall and air temperature) were provided by a station located approximately 0.5 miles from the study site.

The study was a randomized complete block design (RCB) with three replications. Statistical analyses of data were performed using the mixed procedure of Statistical Analysis System (Littell et al., 1996). A significance level of $P<0.10$ was established *a priori*.

RESULTS AND DISCUSSION

At the beginning of the study, the concentration of inorganic N was higher for CT compared to that of NT (Figure 1). The higher values in the CT were not surprising since the conventional plots were subjected to tillage after harvest thereby pulverizing the soil and mixing the crop residue into the soil resulting in microbial breakdown of the residue. In conservation tillage, the crop residues are recycled back to the soil in a more stable form (slower decomposition rate) than those under conventional tillage. Plots receiving manure were higher in inorganic N although not significantly. On the day of manure application (day 0), the amount of inorganic N was higher in the CTM followed by the NTM due to the addition of manure N (Figure 2). However, it is important to note that although the CTM exhibited the highest inorganic N at the initiation of the experiment, the concentration rapidly diminished during the course of the winter season. This was likely due to leaching of inorganic N in the form of NO_3 and cover crop N uptake. Denitrification losses were probably not a significant contributor to N losses, since the sandy texture of the soil allowed most of the water to filter through instead of becoming saturated.

In general, the amount of inorganic N lost from all treatments followed changes in soil water content and temperature over time. Temperature seemed to have affected the concentration of N observed in this study. As temperature decreased, the concentration of N did not increase; this is probably because the temperature had dropped below the optimum for mineralization to occur (Figure 3). Also, at the beginning of the study, the concentration of N in the soil decreased after each rainfall event most likely due to leaching (Figure 4).

At the end of the study, the NTM contained significantly higher inorganic N compared to the other treatments (Figures 2 & 5). The amount of plant biomass collected from the NTM plots was significantly higher compared to the other treatments showing that the NTM treatment played an integral role by retaining N (Figure 6). Nitrogen uptake, although not significant probably due to the high variability of the data, was higher in the plant tissues under the NTM treatment (Figure 7) compared to the other treatments. This indicated that the utilization of a cover crop benefits the conservation tillage system by retaining more plant nutrients than the conventional tillage. These result are similar to Nyakatawa et al. (2002) who reported cover crop use during winter months can be used to scavenge residual N that would otherwise be lost to leaching, thereby alleviating groundwater pollution.

This study shows that agronomic practices that provide continuous plant cover should be utilized during winter months to minimize leaching of N associated with fallow soils under conventional tillage. Inorganic N (nitrate) tends to accumulate in fallow soil without plant cover or residue during winter months, thereby providing NO_3 that is susceptible to leaching (Mosier et al., 2002). Use of winter cover crops winter in conjunction with conservation tillage practices that maintain residue on the surface can play a major role in minimizing N loss due to leaching.

CONCLUSIONS

This study demonstrates that conservation practices can influence the loss of inorganic N from soil. Results suggest that winter manure application used in conjunction with conservation tillage practices that maintain surface residue and minimize soil disturbance could help reduce inorganic N losses compared to practices that leave the soil fallow. Also, some of the manure N that is retained can help increase the growth of cover crops in conservation tillage systems. This cover crop can be retained on the soil surface for the next growing season as residue and benefits the following crop. These finding show that there is a need for more research on the dynamics of

N leaching under different conservation tillage practices in conjunction with various cover crops in order to develop a N leaching Index of N loss when applying manure during winter months.

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Table 1. Selected soil properties.

Treatment	pH	CEC	Total C	Total N	C:N ratio
		cmol/kg	'--------- %	----------	
NTM	6.2	7.01	0.85	0.08	11.21
NT	5.5	6.02	0.54	0.56	9.72
CT	5.8	5.72	0.54	0.56	9.51
CTM	6.2	7.61	0.76	0.67	11.37

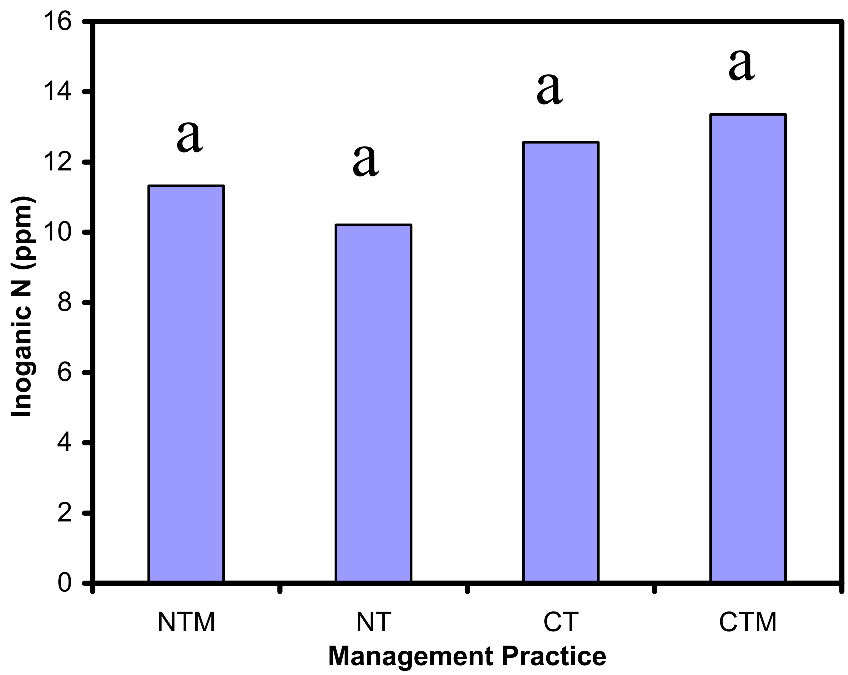

Figure 1. Amount of inorganic N at the initiation of the experiment for the No-tillage with manure (NTM), No-tillage (NT), Conventional Tillage (CT), and Conventional Tillage with manure (CTM) treatments. Values followed by the same letter are not significantly different ($p<0.10$).

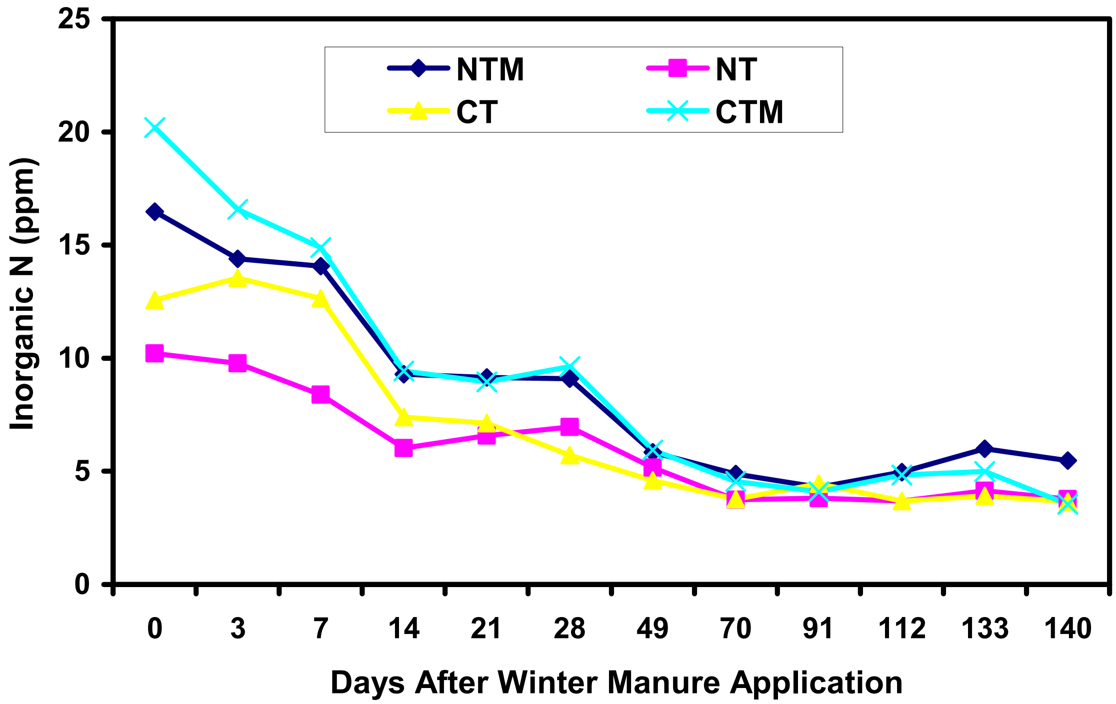

Figure 2. Winter mineralization of N for the No-tillage with manure (NTM), No-tillage (NT), Conventional Tillage (CT), and Conventional Tillage with manure (CTM) treatments.

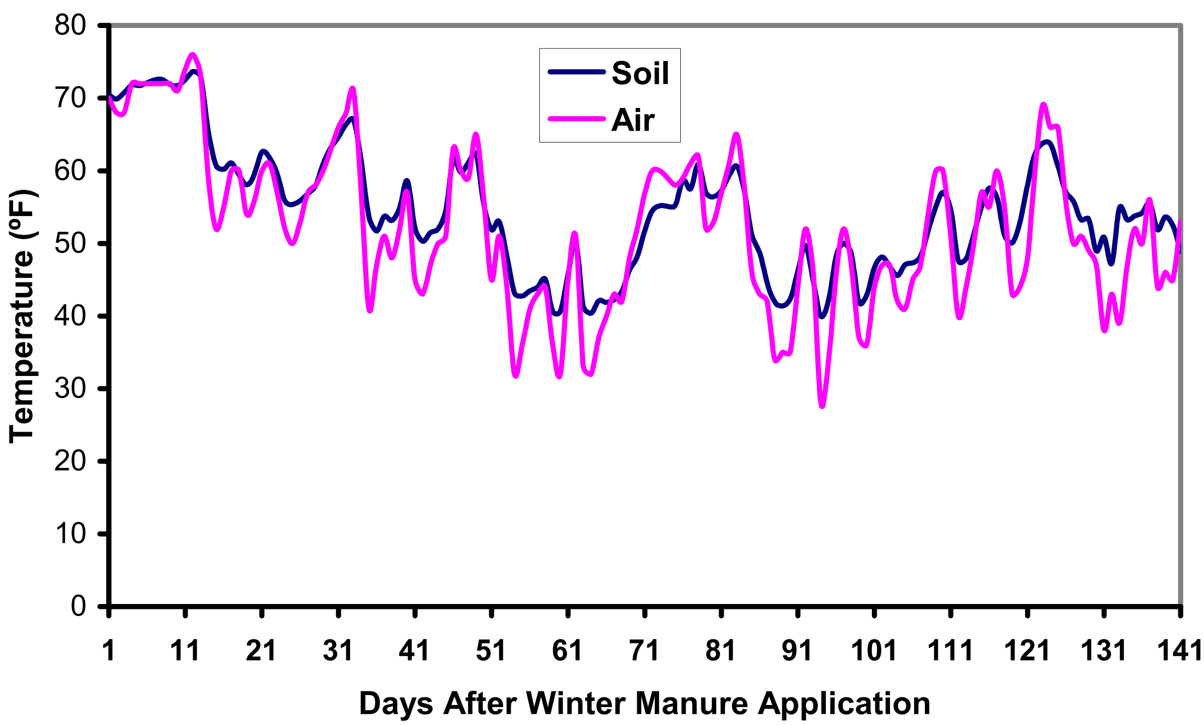

Figure 3. Soil and air temperature of the winter N mineralization study.

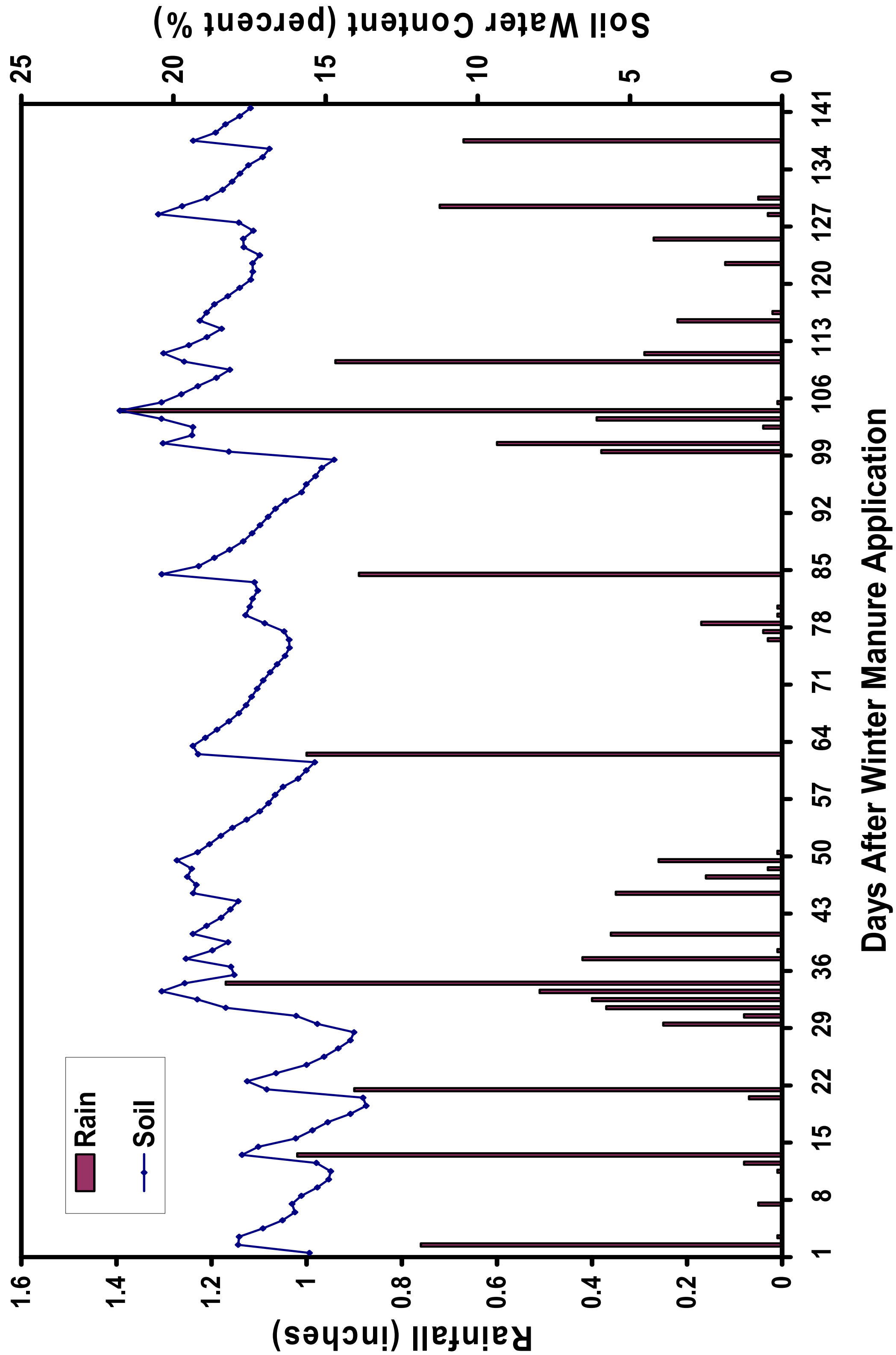

Figure 4. Soil water content and rainfall of the winter N mineralization study.

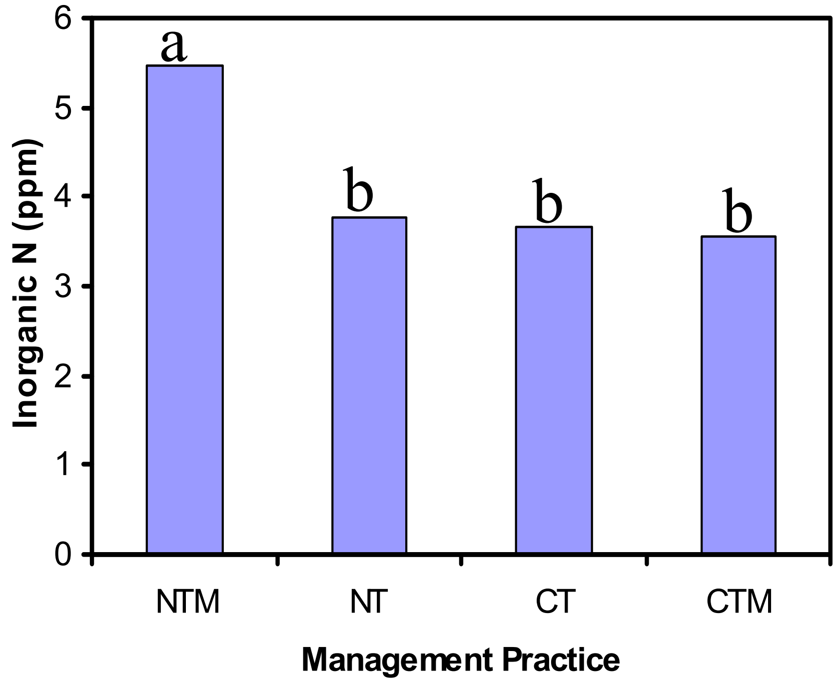

Figure 5. Final inorganic N mineralized for the No-tillage with Manure (NTM), No-tillage (NT), Conventional Tillage (CT), and Conventional Tillage with manure (CTM) treatments. Values followed by the same letter are not significantly different ($p<0.10$).

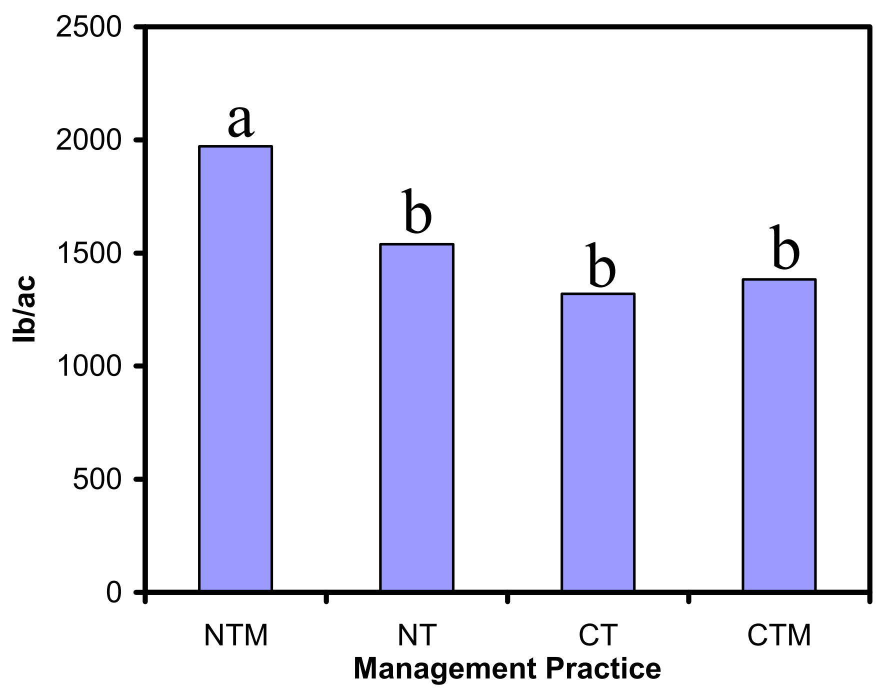

Figure 6. The amount of plant biomass collected for the No-tillage with Manure (NTM), No-tillage (NT), Conventional Tillage (CT), and Conventional Tillage with manure CTM) treatments. Values followed by the same letter are not significantly different ($p<0.10$).

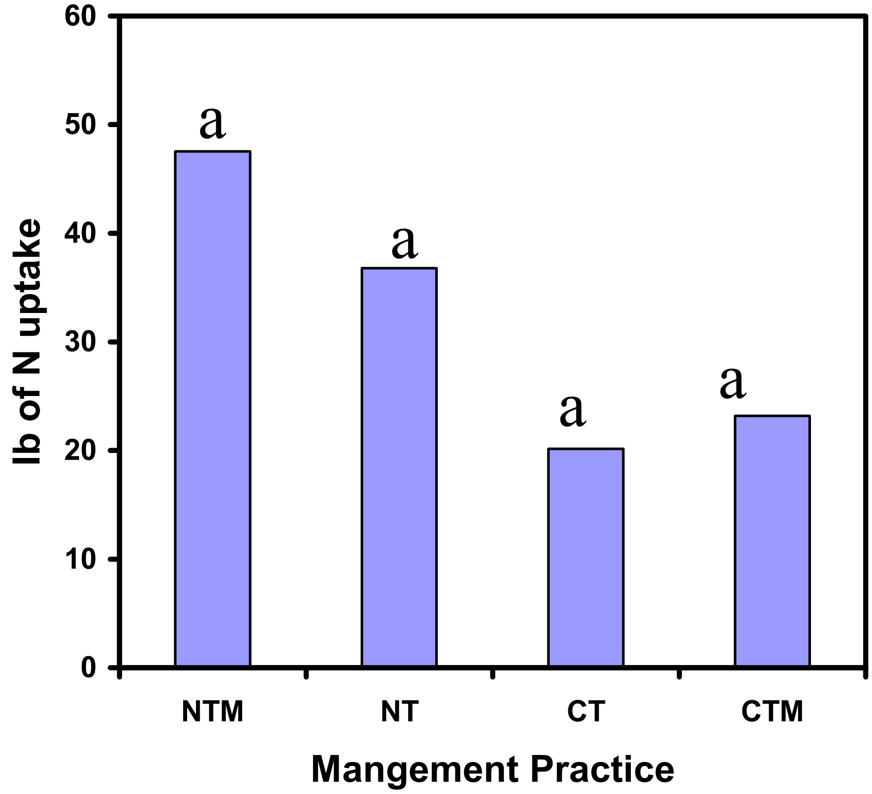

Figure 7. The amount of N taken up in the plant tissue for the No-tillage with Manure (NTM), No-tillage (NT), Conventional Tillage (CT), and Conventional Tillage with manure (CTM) treatments. Values followed by the same letter are not significantly different ($p<0.10$).

IMPACT OF CROP ROTATIONS AND TILLAGE FREQUENCIES AT VARYING NITROGEN FERTILITY ON CORN YIELDS

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ABSTRACT

Crop rotation and alternative tillage systems tend to maximize surface crop residue and can have a long range impact on soil particle losses due to wind and water. Their impact on plant nutrient availability through changes in soil microbial activity and mineralization of soil organic matter needs further investigation. Objectives of this study included the effects of crop rotation and tillage intensity on production of corn at varying levels of N with the inclusion of soybean in the rotation. The multi-year study was conducted on Victoria clay under rainfed conditions. Cotton and soybean were rotated with corn and compared to continuous corn under conventional tillage (CT) and minimum till (MT) systems. Results of the studies showed the rotation benefit from cotton or soybean on corn yields fluctuated with season and precipitation. Under ideal soil moisture and without N fertilization corn yields increased 74% when corn followed cotton compared to monoculture corn. Under the same conditions, the contribution from soybean increased corn yields 47%. However, in the fourth year, the soybean rotation effect was substantially greater than the effect from cotton. The influence of rotation was minimal in the two droughty years. Nitrogen fertilization appeared to decrease benefits from crop rotation. In general, tillage intensity did not have a major influence on corn yields, but the soybean rotation effect was usually most pronounced with the MT system.

INTRODUCTION

Tillage and crop rotations can influence the physical and biological environments of soils (Barber and Matocha. 1994; Matocha, et al. 2002; Wright, et al. 2005) can be influenced by tillage and crop rotations. The degree of change in these environments may be associated with the quantity and distribution of organic matter, an important constituent of soils (Matocha, et al. 1998). Response to N fertilization and plant productivity can be a function of some of these biotic and abiotic changes. The purpose of this study is to determine the influence of crop rotation and tillage intensity on grain productivity from corn at varying levels of N fertilization.

MATERIALS AND METHODS

A Victoria clay (montmorillonitic Udic Pellusterts), a vertisol with at least 30 inches of dark gray surface soil, was the experimental site. Predominate clay in this soil is a swelling and shrinking montmorillonite. The site was located at the TAMU Research Center at Corpus Christi, and had been cropped to grain sorghum and cotton on alternate two-year cycles and low N rates for the previous three years. Initially, the soil tested low to medium in available N and P and high in available K. Four crop rotation schemes using the two basic row crops (corn and cotton) grown in the region and soybean as the main blocks while two tillage systems (minimum, MT, and conventional tillage, CT) were compared in split-plot within each main block. Minimum tillage involved four tillage operations with less than 3-inch plow depth while CT had eight operations with plow depth at 6-inches. Each tillage treatment within each cropping system was split into three sub-plots which received 0, 30, and 60 lb N/ac. Nitrogen rates for the soybean crop were 0, 15, and 30 lb/ac. Phosphorus was blanketed to all plots at 20 lb P_2O_5/ac. All 24 treatments were compared in four replications. A medium maturity corn hybrid and an early maturing GP 3174 + cotton cultivar were used in the study. Soybean variety RA 452 (Group IV) was seeded in alternate years to complete the rotation scheme.

RESULTS

Extreme drought in Year 1 produced negligible grain yields, therefore yields are not reported. Results for the second year when normal rainfall was received are presented in Figures 1 and 2. The rotation effects from cotton or soybean on grain yields were considerably greater than in Year 1. Without N fertilization, corn yields under MT increased approximately 1430 lb/ac (74%) when corn followed cotton as compared to monoculture corn which produced a total yield of only 1913 lb/ac. With CT, the rotation increased yields approximately 982 lb/ac or 35% compared to continuous corn. As N rate was increased to 60 lb/ac, the net contribution from the rotation decreased to 37 and 20%, respectively, for MT and CT systems. The rotation effect from soybean under both tillage systems was generally less than with cotton. Without N fertilization, the soybean contribution ranged from 47% to 38% for the MT and CT systems, respectively. With N fertilization, the rotation effect decreased to 13 and 0% for MT and CT, respectively. The lesser contribution from soybean than cotton to the rotation effect in Year 2 may be partly attributed to the drought stressed soybean crop having restricted N fixation capabilities in the Year 1 season. The effect from crop rotation was generally accentuated when corn was grown with MT compared to CT.

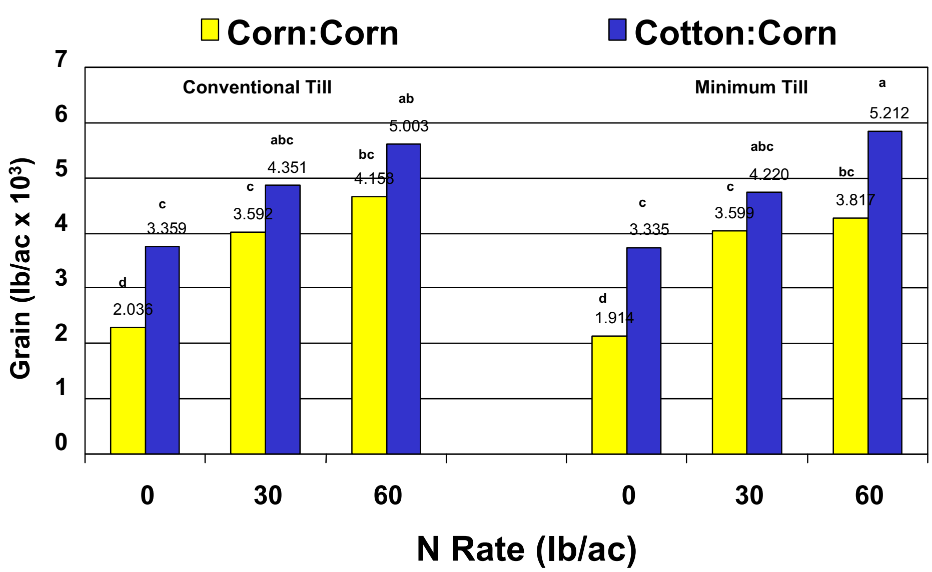

Fig. 1 Corn grain yields as influenced by cotton rotation, N rate and tillage in Year 2. Bars highlighted with the same letter are not significantly different across tillage systems, Fischer's LSD $_{0.05}$.

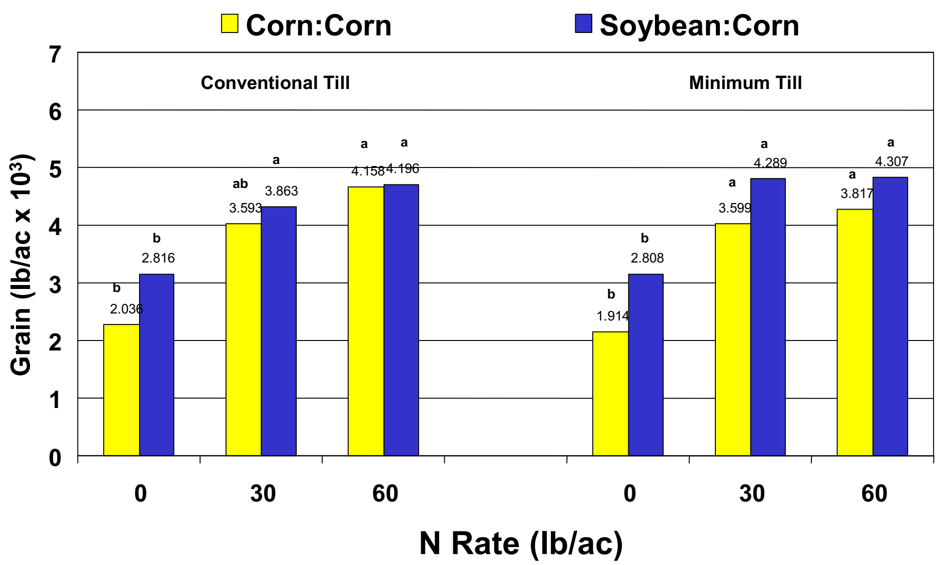

Fig. 2 Corn grain yields as influenced by soybean rotation, N rate and tillage in Year 2. Bars highlighted with the same letter are not significantly different across tillage systems, Fischer's LSD $_{0.05}$.

Soil moisture was above average starting the growing season in Year 3 but negligible rainfall throughout the growing season caused severe plant stress for moisture and final grain yields were approximately 30-40% of Year 2 yields. In Year 3, corn was grown under 12 separate treatments, six of which were in a monoculture of continuous corn cropping system and six in a cotton-corn rotation. The rotation scheme for Year 3 did not include soybean.

In the third season, very small differences in treatment response were measured due to drought related abnormally low yields. In general, corn grain yields ranged from a high 2391 to a low 1351 lb/ac (Fig. 3). Averages over fertilizer treatments within cropping systems show little or no yield difference due to tillage. However, response to N fertilizer was slightly higher for continuous corn compared to the cotton-corn system under MT, while response to N was better for the cotton-corn system under the CT system. The slight decrease in yields from the cotton-corn rotation compared to continuous corn was possibly due to lower soil moisture in the soil profile to start the season when cotton preceded corn. These data show that under identical fertilization regimes, corn following cotton in the droughty season produced only a slight increase in grain compared to continuous corn when grown under CT. This rotation benefit was not evident under MT.

Grain yields during the fourth year of the study increased substantially over those for Year 3 and were about 80% of those yields for Year 2 (Fig. 4). The rotation benefit from cotton was considerably below that measured in Year 2 and ranged from 5% for MT without N fertilization to 11% for the CT system. Unlike the findings during Year 2, the rotation effect in Year 4 appeared to increase with N fertilization in both tillage systems. Highest yields were measured when corn was grown with the MT system at the high N rate.

Substituting soybean for cotton in the Year 4 rotation improved corn grain yields considerably over continuous corn when N fertilization was withheld (Fig. 5). The approximate 1072 lb/ac increase (38%) in grain due to soybean for the MT system decreased to 742 lb/ac (28% increase) for corn grown with CT, but still equaled or exceeded the soybean benefit measured earlier in the Year 2 season.

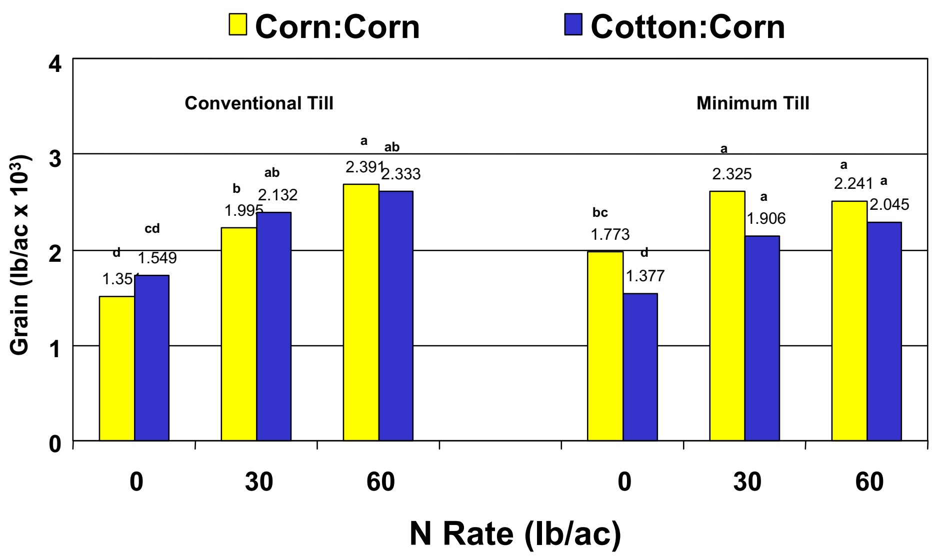

Fig. 3 Corn grain yields as influenced by cotton rotation, N rate and tillage in Year 3. Bars highlighted with the same letter are not significantly different across tillage systems, Fischer's LSD $_{0.05}$.

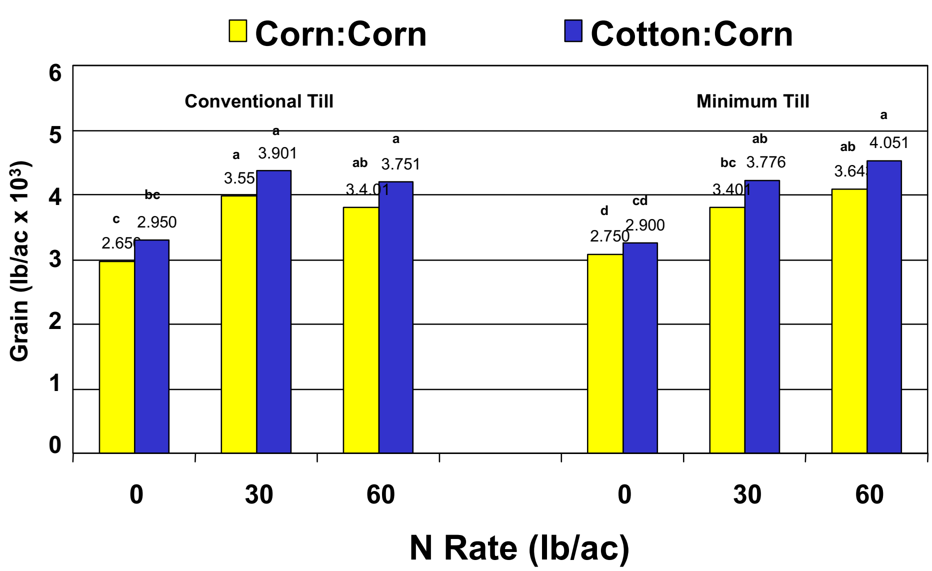

Fig. 4 Corn grain yields as influenced by cotton rotation, N rate and tillage in Year 4. Bars highlighted with the same letter are not significantly different across tillage systems, Fischer's LSD $_{0.05}$.

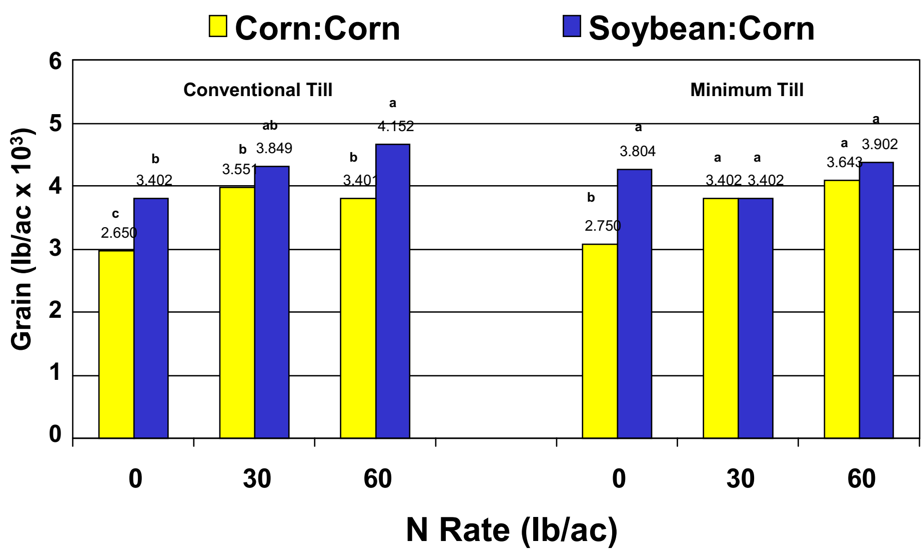

Fig. 5 Corn grain yields as influenced by soybean rotation, N rate and tillage in Year 4. Bars highlighted with the same letter are not significantly different across tillage systems, Fischer's LSD $_{0.05}$.

Using soybean in the rotation rather than cotton produced significantly higher corn yields as compared to the cotton rotation only when N fertilizer was excluded (Figs. 4-5). The benefits of the soybean rotation were greatest in the MT system.

SUMMARY

This study showed that precipitation and available soil moisture will greatly influence response of corn to crop rotation and tillage treatments. With adequate precipitation in the second study year corn following cotton produced higher yields than when following soybeans both with and without N fertilization. However, in the fourth year of the study, the contribution from soybean rotation was considerably greater than from the cotton rotation, especially at 0 N rates. These data suggest the beneficial effects from a soybean rotation with corn on soil quality and yields may have greater temporal dependency than the cotton rotation. Although tillage intensity effect appeared smaller than the rotation effect on corn yields, the positive effects from both cotton and soybean rotations were usually best expressed in the MT system.

ACKNOWLEDGMENTS

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WINTER COVER BIOMASSS PRODUCTION AND SOIL PENETRABILITY

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ABSTRACT

Winter cover crops can benefit production systems in the southeastern US. Winter cover crops, such as rye (*Secale cereale*) can reduce weed pressure, increase water infiltration, and improve soil quality over a long period of time. Although several studies have focused on the effects of having a winter cover present, none have focused on studying the effect of different biomass amounts. The objective of this study was to determine the effect of rye biomass amounts on soil penetrability. Using different rye planting dates and termination times, several levels of biomass were obtained. Soil penetrability, as measured with a penetrometer, was improved with increasing biomass amount. Low rye biomass amounts did not result in decreased cone index values. Winter cover crops can effectively be used to improve soil conditions for crop production in combination with other conservation agriculture practices, such as non-inversion tillage.

INTRODUCTION

Winter cover crops are widely accepted in the southeastern US as part of conservation agriculture systems. Benefits from winter cover crops include weed suppression, increased infiltration, reduced erosion, and others (Endale et al., 2002; Baldwin et al., 1985; NeSmith et al, 1985). Rye is commonly used as a winter cover because seed is readily available, can produce large amounts of biomass, and it is somewhat easy to establish. Benefits can include crop yield increases, decreased weed pressure, and runoff reductions under conservation tillage, therefore reducing non-point source pollution

Work conducted by Raper et al. (2000a) has shown that rye is as effective as non-inversion tillage in reducing the effects of consolidated soil on cotton yields for Piedmont soils. They showed that the use of a cover crop almost eliminated excessive soil strength and increased cotton yields when compared to strict no-till. The use of a subsoiler did not increase crop yields significantly compared to the cover crop.

In other work conducted by Raper et al. (2000b) it was reported that spring non-inversion tillage was more effective than fall tillage in reducing soil strength. They also reported that a combination of shallow (~7 in) non-inversion tillage with rye as a winter cover crop was more effective in increasing yields when compared to no-till and deep tillage.

Although the effect of winter cover biomass on soil properties, including soil penetrability, has been studied, no work to date has addressed the impact of different amounts of cover biomass. Thus, the objective of this study was to determine the effect of different rye biomass amounts on soil penetrability.

MATERIALS AND METHODS

The study was conducted at the Row Crops Unit of the E.V. Smith Research and Extension Center near Shorter, AL in a Compass loamy sand (Coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults) in 2005. Different amounts of rye biomass were obtained by planting and terminating the cover crop at different times during the fall and spring, respectively. These included five different planting times and four termination dates arranged in a strip plot design with three replications. The planting dates were established to be four and two weeks prior to the week when the first average frost typically occurs, the week of the first average frost, and two and four weeks after first average frost. Termination dates included four and two weeks prior to the average planting date for that region, the week of the average planting date, and one week after the average planting date.

Rye was planted in plots 13.3 ft wide by 25 ft long in the fall with a no-till drill at a 40 lb ac^{-1} seeding rate. Sixty lb ac^{-1} of ammonium nitrate were applied in the fall after cover crop establishment. The rye cover was terminated with glyphosate and flattened with a roller equipped with flat bars. Two 2.7 ft^2 areas were harvested from each plot at termination time to determine rye biomass production. Rye biomass was placed in a bag and dried in an oven at 131° F for 48 hours.

Four rows of cotton (Gossypium hirsutum L.) were planted in each plot with a 40 in spacing. The two middle rows of each plot were harvested with a cotton picker to determine yields.

A penetrometer system equipped with five rods was used to determine soil penetrability (Raper, 1999). The middle rod of the penetrometer was centered over the planting row, with two other rods on each side. Distance between rods was 10 inches. The penetrometer system was mounted to a small tractor. Penetration force and depth were recorded with a portable computer. Because of time and labor constrains, seven plant and termination dates were chosen for penetration resistant measurement. This gave a good range of rye biomass production to evaluate penetration resistance. Penetrometer readings were taken one day after a significant rainfall event (>0.50 in) shortly after planting.

RESULTS AND DISCUSSION

Biomass production between the planting and termination dates varied greatly, providing a good range of available biomass for evaluating the effect of winter cover biomass on soil penetrability (Fig. 1). Generally, early planting dates produced greater rye biomass with termination date having less of an effect. Average dry biomass production for the first planting date was 4,744 lb ac^{-1}, followed by the third planting date (2,322 lb ac^{-1}) and the last planting date (189 lb ac^{-1}).

Soil penetrability, as measured by cone index (CI), was affected by rye biomass (Fig. 2). Decreasing CI values were observed with increasing biomass to approximately 12 in of depth. Lower CI values were observed for the first planting date down to 20 in of depth.

Rye biomass production affected soil penetrability for most of the soil profile (Figs. 3, 4 and 5). Less dense soil conditions, as measured by the penetrometer, were present in the row and between row locations with greater rye biomass production (Fig. 3). Cone index values were low in the row for all biomass levels. These lower CI levels were probably caused by the non-inversion tillage practice (i.e. strip-till) conducted a few weeks before cotton planting, which is a common practice in this region. The value of strip-tilling these soils is evident in the CI data presented here, where lower CI values are associated with the location tillage was conducted (Fig. 4 and 5). Nevertheless, even after non-inversion tillage, relatively large CI values were observed between rows in areas with low rye biomass (Fig. 5). Although strip-tilling created an adequate environment for root growth in the row, cotton roots could have been restricted to grow laterally in areas with low rye biomass production. Therefore, to fully take advantage of rye as winter cover crop it must be managed for maximum biomass production.

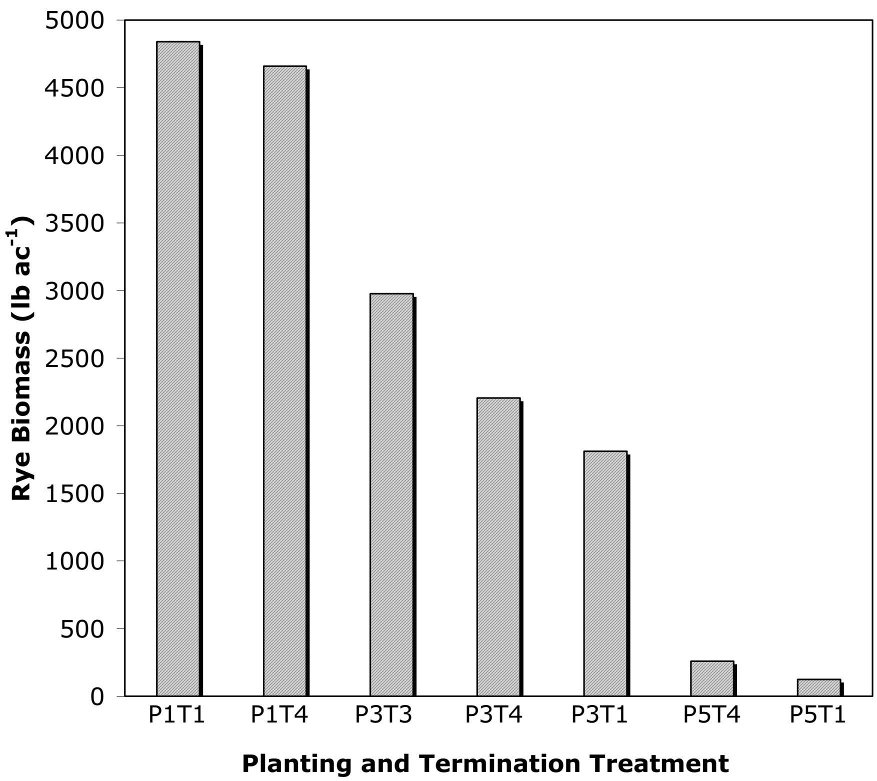

Figure 1. Rye biomass as a function of planting and termination date. The 1st planting date is listed as P1, 3rd as P3, and last plant date as P5; T1 is 1st termination, T3 the 3rd, and T4 the last.

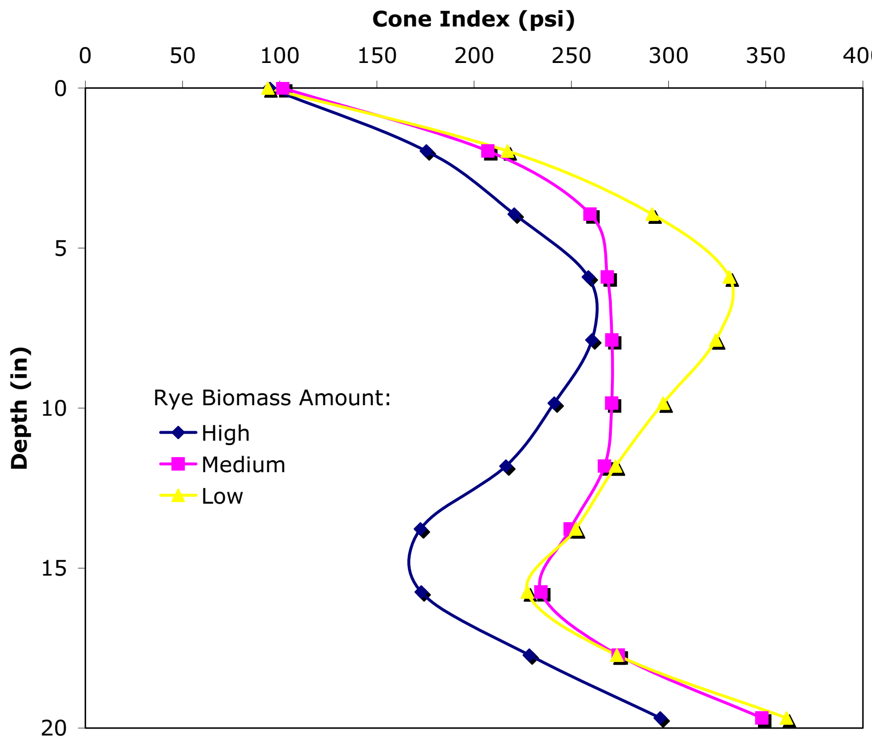

Figure 2. Cone index values averaged over high, medium, and low rye biomass amounts (4,744; 2,322; and 189 lb ac^{-1}, respectively).

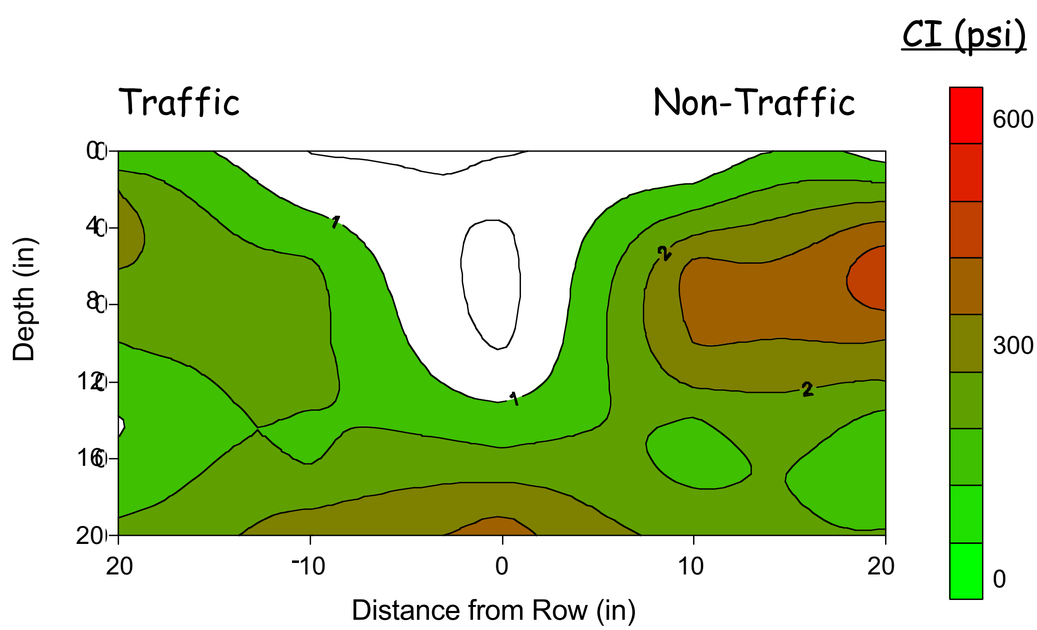

Figure 3. Average soil penetrability for the soil profile under the high (4,744 lb ac^{-1}) rye biomass production treatment.

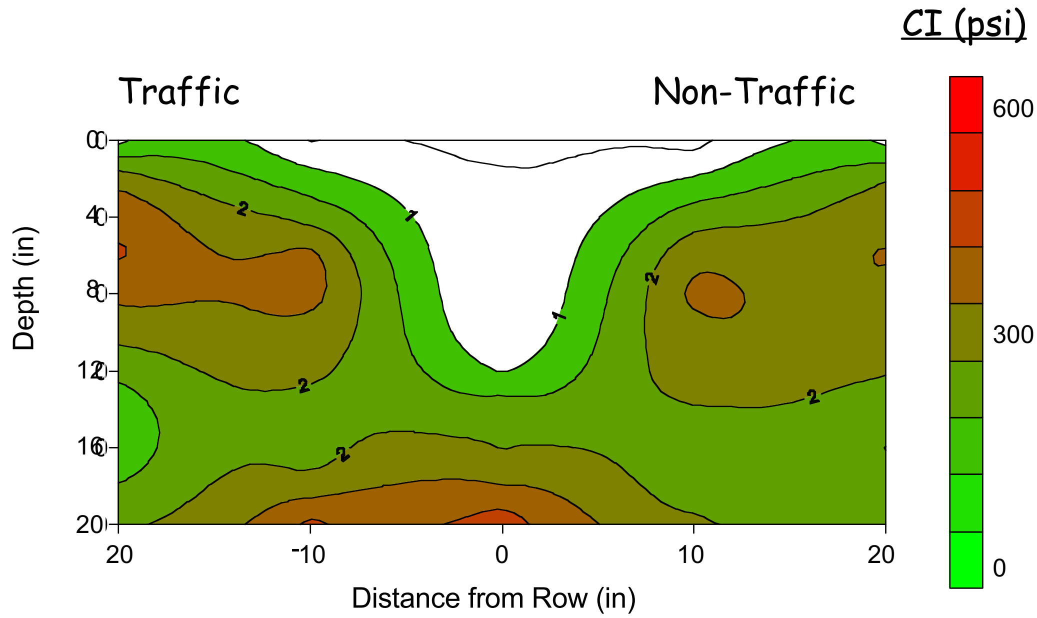

Figure 4. Average soil penetrability for the soil profile under the medium (2,322 lb ac^{-1}) rye biomass production treatment.

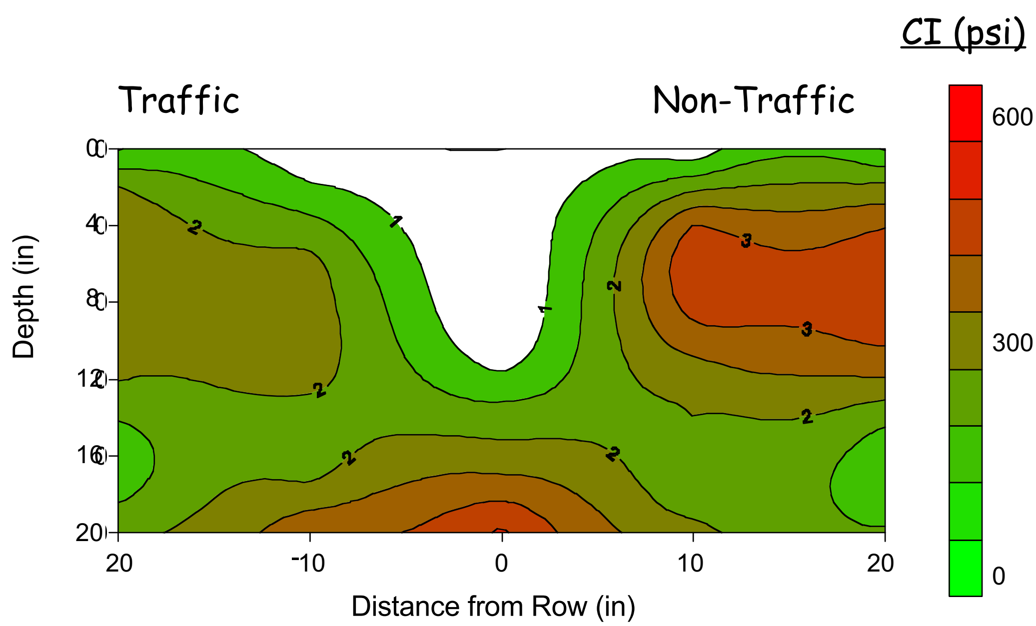

Figure 5. Average soil penetrability for the soil under the low (189 lb ac^{-1}) rye biomass production treatment.

CONCLUSIONS

The use of different winter cover planting and termination dates had a significant impact on rye biomass production. Early planting times resulted in greater rye biomass production when compared to latter planting dates. Termination dates had a less pronounced effect.

Rye biomass production had a significant impact on soil penetrability. Greater rye biomass amounts resulted in reduced CI values. Strip-tilling created adequate conditions for root growth in the row, but high residue from the winter cover resulted in improved overall soil conditions for root development. The root action of the winter cover helped loosen the soil most of the profile, where non-inversion tillage only targets the row. Thus, winter cover crops should be managed to maximize biomass production to fully benefit from their use. Further research in this area should include below ground biomass production, other cover crop species, and soil conditions.

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SOIL ORGANIC CARBON SEQUESTRATION SIMULATED BY EPIC IN COTTON ROTATIONS FROM THREE MAJOR LAND RESOURCE AREAS IN THE SOUTHEASTERN USA

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SUMMARY

Carbon sequestration in soil has emerged as a technology with significant potential for stabilizing atmospheric concentrations of greenhouse gases at non-threatening levels (Izaurralde et al., 2001). Estimates of long-term soil organic carbon (SOC) storage in agricultural cropping systems are needed to evaluate the effectiveness of different management systems across a wide range of soils, crop, and climate conditions (Causarano, et al., 2005). However, the amount of SOC sequestered in a field or region is costly to measure and monitor. In addition, protocols are still being developed, making it difficult to base policies directly on environmental performance (Feng et al., 2004). There are relatively few long-term studies addressing SOC sequestration, and therefore, simulation modeling should be considered to estimate the effects of management on various soil properties under a wide range of conditions (Williams, et al., 1984).

The USDA–Natural Resource Conservation Service (NRCS) uses the Soil Conditioning Index (SCI) to predict changes in SOC with different agricultural management practices. The SCI is used to calculate payments to landowners enrolled in the USDA-NRCS Conservation Security Program (CSP) (Causarano, et al., 2005). The Erosion Productivity Impact Calculator model (EPIC) (Williams et al., 1984) was recently updated to include a new C and N transformation submodel, based on concepts and some equations from the CENTURY model (Izaurralde et al., 2006).

The objectives of our study were to (1) simulate the long-term effects of different agricultural management practices on SOC, crop yield, and water-use efficiency in three Major Land Resource Areas (MLRA) in the southeastern USA using the revised EPIC model (v. 3060) and (2) compare predictions of SOC change using EPIC and SCI. The treatments represented a hierarchy of management practices that were expected to increase biomass input to the soil and minimize soil disturbance.

Significant changes in SOC during 50-year simulations for the Texas Blackland Prairies region occurred, in which SOC declined by 6 Mg ha^{-1} under monoculture cotton with conventional tillage and increased by 30 Mg ha^{-1} under cotton/winter cover crop with no tillage. As more residues were added to the soil using a corn–cotton rotation with cover crops under no tillage, simulated SOC increased. The SCI for each of the three MLRAs and four management systems

produced similar results; the SCI suggested that SOC would increase at a greater magnitude under no tillage compared with conventional tillage at all locations. Contrasting with the SCI, EPIC simulations did not suggest a difference in SOC between conventional and no tillage in the Coastal Plain and Southern Piedmont regions.

The revised EPIC model may need to be calibrated with field data from southeastern USA soil and climate regimes and further tested before reliable estimates of SOC can be made. Several field studies in the southeastern USA have shown the benefits of reduced tillage and crop rotations on sequestering SOC. Calibration of the revised EPIC model under different boundary conditions for soils and climates other than those previously tested will help determine and verify whether the model can satisfactorily simulate SOC sequestration throughout the southeastern USA. Efforts are currently underway to test the EPIC-CENTURY model as a decision-making tool for C management from remotely-sensed images of residue management and tillage practices from the midwestern USA (NASA, 2005). A similar effort would be useful to verify that the revised EPIC model can accurately simulate long-term changes in SOC throughout the southeastern USA.

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REMEDIATION OF SALT AFFECTED SOILS WITH GYPSUM IN THE SOUTHERN HIGH PLAINS

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ABSTRACT

The purpose of this project is to reduce the exchangeable sodium (Na) within the soil by the addition of gypsum. Even though the addition of gypsum is the standard reclamation technique used on sodic soils, the effectiveness has not been shown in cotton production in the Southern High Plains. Exchangeable sodium disperses the soil, which increases the potential for wind erosion. The addition of gypsum to sodic soils will improve the aggregation of the soil particles. The Ca^{+2} improves particle to particle association, which provides better water infiltration and percolation. The accepted rate to reduce the sodium adsorption ratio (SAR) and soil electrical conductivity (EC) is approximately 2 tons per acre. Rates half and twice the needed rate were applied in a split plot design. The application of gypsum to the soil was broadcast and "in bed". Plant emergence at 14 days after planting and yield will be used to measure the effectiveness of gypsum application. Standard wind erosion measurement techniques are being used to measure gypsum's effects on reducing wind erosion. The use of gypsum is being compared to control (no conservation treatment), cover crop and the addition of gypsum.

USE OF GEOGRAPHICAL INFORMATION SYSTEMS TO INFLUENCE SELECTION OF SAMPLING SITE LOCATIONS FOR THE EVALUATION OF MICROBIAL DIVERSITY

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ABSTRACT

Microbial soil population densities can easily reach one billion cells per gram of soil; and microbial soil diversity has been estimated to reach ten thousand individual species per gram of soil. Soil type and underlying soil structure are considered primary determinants of microbial community structure in soils. Disturbance of soil due to agricultural practices (tillage) has been shown to reduce or alter microbial diversity while long term agricultural production also can influence microbial diversity. The objective of this study was to evaluate the effects of crop type and residue on soil microbial populations. We used denaturing gradient gel electrophoresis-polymerase chain reaction (DGGE-PCR) assay employing universal PCR primers that target prokaryotic and eukaryotic ribosomal genes and other primer sets to evaluate microbial diversity. Field survey and soil samples were obtained from 41 field sites in Ochiltree County (silty clay Sherm soil) on the same day as a Landsat 5 satellite passed overhead during the 2005 planting season. Tillage information (crop coverage) was used to classify sorghum and wheat into high and low crop residue categories. Three high and low crop residues were selected for each crop type. Community DNA samples were prepared and subjected to various community analysis using DGGE-PCR and other PCR based assays. An interaction between crop type, crop residue coverage and geographical distance was observed. Crop type affected microbial community composition approximately 60 % of the time. This suggests that additional long term agricultural production information is required to successfully predict microbial community composition.

SOIL QUALITY IN A COTTON FIELD IN SOUTHERN NEW MEXICO

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ABSTRACT

The goal of sustainable agriculture is to maintain a non-negative and preferably an increasing trend in per capita productivity while maintaining the soil quality. The objective of this research was to understand interactions among key soil physical and chemical properties for long-term sustainability of the existing cropping system. We collected core and bulk soil samples in a continuous cotton farm at 0-10, 10-20 and 20-30 cm depths. The soil was classified as Glendale (fine-silty, mixed, calcareous, thermic typic Torrifluvents)-Harkey (coarse-silty, mixed, calcareous, thermic typic Torrifluvents). Experimental field was minimum tilled in 2004 and conventional tilled in 2003 and 2005. Soil properties measured were bulk density (BD), drainable porosity (θ_a), effective porosity (θ_e), available water capacity (AWC), volume of transport pores (VTP), volume of storage pores (VSP), saturated hydraulic conductivity (K_s); organic carbon (SOC), nitrate-N, ammonium-N concentration; pH, electrical conductivity; and texture. We found a negative relationship among BD and K_s (R = -0.88), VTP (-0.81), nitrate-N content (r= -0.73), and θ_e (r = -0.61), respectively. A positive relationship was obtained among K_s and θ_e (r = 0.80) and VTP (r = 0.79), respectively. In general, soil properties did not vary with depth, except for AWC and VSP, which were lowest at the 10-20 cm depth. Using critical levels and relative weighting factors (RWF) for soil physical and chemical properties available in literature, ten measured soil properties were assigned a rating factor f and were added to provide a cumulative rating (CR) for each depth, separately. The CR for the farm ranged from 25 to 27 for various depths indicating that the existing cropping system is sustainable with high input. Use of cover crops, crop rotations, and less intense tillage may likely improve soil structural properties and sustainability of the cropping system.

INTRODUCTION

It is a common knowledge that productive soil is an important resource for agricultural sustainability. Over the last several decades, the major focus of research was centered on the twin objectives of increasing productivity and protecting the environment quality under different farming systems. Such efforts have shown that conventional farming systems and management practices involving use of fertilizers and pesticides increase crop yields enhance food security and sustain agriculture production system around the globe. More recently, in spite of the high yields associated with the conventional farming, the sustainable soil fertility and environmental quality associated with conventional system has become questionable. Conventional farming systems are reported to be associated with problems such as decline in soil structure, increase in soil bulk density, decline in soil aggregation, increase in soil salinity, decrease in water infiltration and increase in nitrogen leaching and ground water contamination. The answers to problems associated with conventional cropping practices can be found in alternate cropping systems, such as conservation or minimum tillage, that use best management practices and can improve soil structure, increase water storage and transmission, enhance soil C and N concentration in soil profile (Gantzer and Blake, 1978; Jordahl and Karlen, 1993; Shukla et al. 2003).

To determine sustainability of a cropping system, criteria based upon the critical limits of key soil properties in relation to threshold values beyond which productivity decline is severe or impact on the environment is very drastic can be used (Lal, 1994; Shukla et al. 2004). Several minimum data sets have been proposed to quantitatively assess sustainability of a soil management practice (Doran and Parkin, 1994; Larson and Pierce, 1994). It is important to establish critical levels of SQIs, assign a weighting factor, and relate them to productivity. The area under conservation tillage system is consistently increasing in the USA and around the globe. According to Baker and Rouppet (1996), New Mexico farmers have also practiced conservation tillage system for many years. The "swampbuster" and "sodbuster" portions of 1985 Food Security act required growers to initiate an approved conservation plan by 1990 on highly erodible cropland. However, the potential of conservation tillage in the arid- New Mexico is not fully utilized (Baker and Rouppet, 1996). This study was undertaken on a farm, which is currently on the first year of minimum and conventional tillage rotation. The objectives of this study were to: (1) examine soil physical and chemical properties, (2) understand interactions among soil physical and chemical properties, and (3) assess sustainability of the land use and management system based on critical levels.

METHODS AND MATERIALS

We selected a field that was minimum tilled in year 2004 and conventional tilled in years 2003 and 2005 (Fig. 1). Experimental field is located about 3780 ft above sea level at N32° 03'13'', W106° 38'29'' in Anthony, Dona Ana County, New Mexico. Soils of the area are classified as Glendale (fine-silty, mixed, calcareous, thermic typic Torrifluvents)-Harkey (coarse-silty, mixed, calcareous, thermic typic Torrifluvents). These soils are deep, nearly level, well drained, and formed in alluvium on flood plains and stream terraces along the Rio Grande Valley. The alluvium is modified by wind and Aeolian material. The typical surface layer for a Glendale soil is clay and the layers below are clay loam and very fine sandy loam. The upper surface for a Harkey is loam and layers below are very fine sandy loam and silt loam. The climate of the experimental area was classified as arid with mean annual temperature range from 18 to 20^{o}C and mean annual precipitation from 180 to 230 mm mostly between May and August (Bulloch and Neher, 1980). The experimental farm was under continuous cotton (Pima DP340) and Urea Ammonium Nitrate (URAN) liquid fertilizer was applied at the rate of 100 gallons per acre.

Core and bulk soil samples were collected in triplicate for 0-10, 10-20, and 20-30 cm depths from the experimental farm during September 2005. Core samples were obtained using 7 cm diameter and 7 cm long stainless steel cylinders and soil bulk density (BD) calculated on oven dry basis (Blake and Hartge, 1986) and saturated hydraulic conductivity (K_s) by the constant head method (Klute and Dirksen, 1986). Soil moisture characteristics [h(θ)] were determined on the same cores for 3 kpa and 6 kpa using the tension table (Leamer and Shaw, 1941) and for 30 kpa, 300 kpa, and 1500 kpa suctions using the pressure plate apparatus (Klute, 1986). The soil moisture content at 1500 kpa was determined on the ground soil sample <2-mm size. The difference between volumetric moisture content at saturation and 30 kPa was computed to assess effective porosity (θ_e) and between θ at 30 kpa and 1500 kpa to assess plant available water capacity (AWC).

Pore size distribution was obtained from the SWC curves and was divided into three classes on the basis of their equivalent cylindrical diameter (e.c.d): (i) transmission pore (VTP) (>50 µm), (ii) storage pores (VSP) (0.2 and 50 µm), and residual pores (<0.2-µm) (Greenland, 1977).

Bulk soil samples were air-dried and passed through a 2 mm sieve. About 50 g of the sieved soil was used for particle size analysis by the hydrometer method (Gee and Bauder, 1986). The pH and electrical conductivity (EC) were measured on 1:1 soil: water paste by a portable handheld pH and EC meter (OAKTON Instruments, Vernon Hills, IL), respectively. Nitrate and nitrite N were determined in 2.0 M KCl extracts on a Technicon Autoanalyzer II (Technicon, Tarrytown, NY) using Cadmium Reduction Method (Maynard and Kalra, 1993). Ammonium N was also determined in 2.0 M KCl extracts by the Technicon Autoanalyzer II using Indophenol Blue Method (Maynard and Kalra, 1993). Soil organic C was measured by dry combustion methods (Elementar, GmbH, Hanau, Germany).

The analysis of means was carried out for depth x sample interaction using the proc mean option of SAS Institute (1989). The least significant differences were calculated for alpha = 10%. The correlation analysis was carried out using the data analysis tool pack of Microsoft Excel.

Fig. 1. The experimental site

RESULTS AND DISCUSSION

Soil texture for all three depths was silt loam according to the USDA classification and showed low variability (CV<0.16). Coarse fractions were always < 3% at all depths. Sand content was higher at the 10-20 cm depth than at other depths, however, standard deviations for sand content were also larger at this depth. Therefore, analysis of means for depth x sample interactions also showed no significant differences among sand, silt or clay contents (Table 1). These results were expected as soil texture is strongly related to the pedogenetic than a management processes.

Soil bulk density did not change with depth, a direct consequence of deep conventional tillage up to 10 to 14 inch depth (Table 2). Although, soil moisture content decreased with depth at the time of core sampling, saturated hydraulic conductivity did not follow the same trend. Saturated hydraulic conductivity was greatest at the 0-10 cm and lowest at 10-20 cm depth. Such a variation in hydraulic conductivity cannot be explained by the small variations in sand, silt or clay contents.

The available water content did not vary with depth but volume of transport pores and effective porosity did (Table 3). Volume of transport pores and effective porosity values were highest at the 0-10 cm depth. The higher saturated hydraulic conductivity values for 0-10 cm depth were likely due to the higher volume of transport pores and effective porosities.

Table 1. Mean ± Standard deviations of sand, silt and clay content

Depth (cm)	Sand (%)	Silt (%)	Clay (%)
0-10	13.6 ± 3.2	63.1 ± 1.9	23.2 ± 1.4
10-20	16.0 ± 6.4	59.2 ± 4.9	24.8 ± 1.6
20-30	11.7 ± 3.1	64.1 ± 1.2	24.2 ± 2.7

Table 2. Mean ± Standard deviations of bulk density (BD), volumetric moisture content (θ) and saturated hydraulic conductivity (K_s) of soil

Depth (cm)	BD (g cm^{-3})	θ (cm^3 cm^{-3})	K_s (cm h^{-1})
0-10	1.51 ± 0.01	0.38 ± 0.07	1.90 ± 2.42
10-20	1.50 ± 0.05	0.37 ± 0.05	0.73 ± 0.60
20-30	1.48 ± 0.01	0.32 ± 0.01	1.20 ± 1.10

Table 3. Mean ± Standard deviations of available water content (AWC), volume of transport pores (VTP), volume of storage pores (VSP), and effective porosity (θ_e) of soil

Depth (cm)	AWC (cm)	VTP (cm^3 cm^{-3})	VSP (cm cm^{-3})	θ_e (cm cm^{-3})
0-10	2.5 ± 0.5ab	0.10 ± 0.05	0.26 ± 0.04ab	0.11 ± 0.06
10-20	2.2 ± 0.1b	0.05 ± 0.02	0.22 ± 0.02b	0.06 ± 0.03
20-30	2.7 ± 0.2a	0.06 ± 0.01	0.30 ± 0.03a	0.07 ± 0.01

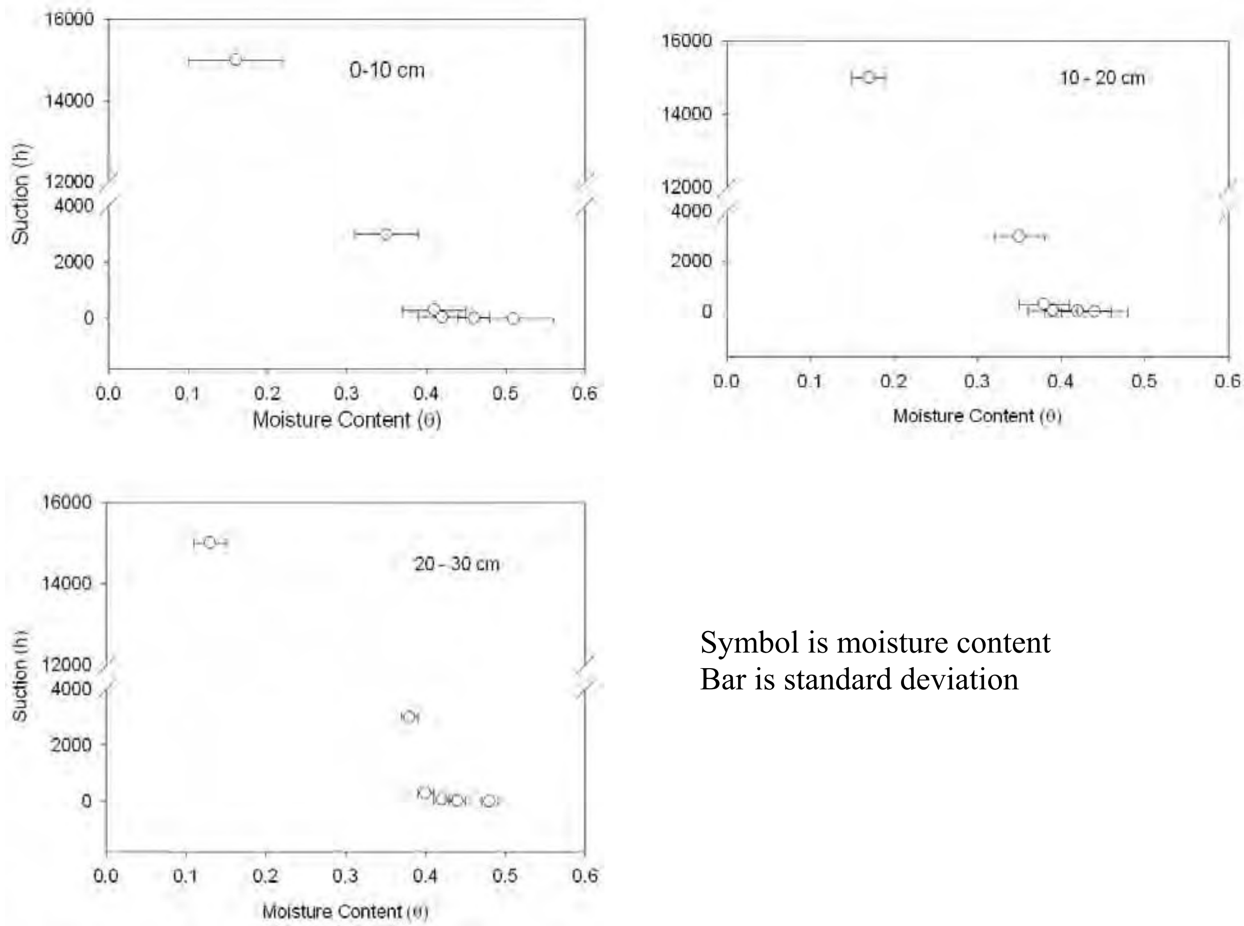

Fig. 2. Soil moisture release curve for the experimental farm

The soil moisture characteristics curves are presented in Fig 2. The standard deviation of soil moisture contents for all five suction heads were smallest at 10-20 cm depth, indicating that with respect to soil moisture release curve the soil at the this depth was relatively homogeneous. Available water content and the volume of storage pores were also higher at 20-30 cm than other two upper layers. On accord with the volume of transport pores and available water content, soil moisture contents were higher at 0-10 cm depth for all suctions than 10-20 cm depths. Water transmission properties were always smallest at 10-20 cm depth.

The soil pH was lower than 8.4 for all depths and showed that inorganic or pedogenic C contents of soil were significant (Table 4). High values of pH were expected because of the high $CaCO_3$ contents in the soil. Soil electric conductivity values were much lower and indicated that no soil salinity problem exists in the study area. Total inorganic N contents were highest at the 0-10 cm depth. The ammonium N contents increased with depth, however, no definite trends were observed for nitrate-N. This may be due to the application of liquid URAN in the field, which likely resulted in the volatilization of ammonium at the soil surface. The other possibilities of increases in ammonium N contents with increasing depth were likely due to the initial leaching of positively charged ammonium followed by the adsorbed on the negatively charged clay.

The interdependence among soil properties was obtained by correlation analysis. We found a strong negative relationship among bulk density and saturated hydraulic conductivity (R= -0.88), volume of transport pores (-0.81), nitrate-N content (r= -0.73) and effective moisture content of soil (r = -0.61), respectively. The effective porosity, saturated water content and volume of transport pores also produced a positive relationship with saturated hydraulic conductivity with r = 0.80, 0.72 and 0.79, respectively. Moderate negative correlation was also obtained among clay content and effective porosity (r = -0.60) and saturated hydraulic conductivity (r = -0.63). A negative relationship between nitrate-N and clay content (r = -0.61) was expected as both are negatively charged, however, we did not see increasing nitrate-N with depth and therefore, no evidence of leaching due to anion exclusion of nitrate-N. A moderate and inverse relationship between EC and clay was rather unexpected because of the adsorption of micronutrients and chemicals on clay particles. This was likely due to the poor aggregation in the soil. A significant inverse relationship between clay content and volume of transport pores (r = -0.53) further indicated poor soil aggregation due to tillage. Sand content showed a positive relationship with volume of transport pores (r = 0.42) and silt content with available water content (r = 0.45) which are in accord with the sizes of these primary particles and their influence on total porosity.

Table 4. Mean ± Standard deviations of pH, electrical conductivity (EC), ammonium-N (NH_4-N), and nitrate-N (NO_3-N) of soil

Depth (cm)	pH	EC (dS m^{-1})	NH_4-N (mg kg^{-1})	NO_3-N (mg kg^{-1})
0-10	8.4 ± 0.1	0.34 ± 0.05	1.97 ± 0.65	6.57 ± 3.71
10-20	8.5 ± 0.1	0.39 ± 0.05	2.20 ± 1.05	1.50 ± 0.72
20-30	8.5 ± 0.1	0.43 ± 0.14	2.87 ± 0.85	4.27 ± 2.87

Table 5. Interdependence of soil physical and chemical properties

Property	**BD**	θ_s	θ_r	**AWC**	**VTP**	**VSP**	θ_{ef}	**K_s**	**Sand**	**Clay**
θ_s	-0.61									
AWC	0.40		-0.76							
VTP	-0.81	0.79								
VSP			-0.78	0.98						
θ_{ef}	-0.78	0.81			0.98					
K_s	-0.88	0.72			0.79		0.80			
Sand					0.42			0.46		
Silt				0.45		0.43			-0.91	
Clay	0.39	-0.56			-0.53		-0.60	-0.63	-0.60	
EC										-0.42
pH		-0.63	-0.52					-0.48		
NO_3-N	-0.73	0.57			0.66		0.68	0.61		-0.64

Table 6. Critical levels and relative weighting factors (RWF) for soil physical and chemical properties

Limitation	RWF	BD Mg m^{-3}	θ_e cm^3cm^{-3}	θ_r cm^3cm^{-3}	AWC cm	K_s cm h^{-1}
None	1	<1.3	>0.20	>0.15	> 30	>2
Slight	2	1.3-1.4	0.18-0.20	0.15-0.18	20-30	0.2-2
Moderate	3	1.4-1.5	0.15-0.18	0.18-0.20	38949	0.02-0.2
Severe	4	1.5-1.6	0.10-0.15	0.20-0.25	38756	0.002-0.02
Extreme	5	>1.6	<0.10	<0.25	< 2	>0.002

Limitation	RWF	SOC Mg ha^{-1}	Texture	CF %	EC ds m^{-1}	pH
None	1	70-130	loam	< 10	< 3	6-7
Slight	2	45-70	SiL, SiCL	10-20	3-5	5.8-6 and 7-7.4
Moderate	3	14-45	CL, SL	20-40	5-7	5.4-5.8 and 7.4-7.8
Severe	4	7.5-14	SiC, LS	40-60	7-10	5.0-5.4 and 7.8-8.2
Extreme	5	<7.5	C, S	>60	>10	<5.0 and >8.2

Each measured soil property was assigned a rating factor using table 6 for each sampling depth. The table 6 shows that the rating and the soil condition are inversely related. The lowest rating of 5 (extreme limitation) was obtained for effective moisture content of soil for 10-20 cm and 20-30 cm depths. Effective soil moisture content for 0-10 cm depth, and pH and bulk density of soil for all three depths showed moderate limitation and received a rating of 3. The available water content, saturated hydraulic conductivity, soil organic C and soil texture received a rating of 2 indicating slight limitation. However, residual moisture content, coarse fraction and electrical conductivity did not show any limitation (rating=1).

The cumulative rating of 25, 27 and 27 were obtained for 0-10, 10-20 and 20-30 cm depths, indicating that the current land use and management system is sustainable with high input (Table 7). Use of cover crops, crop rotation, manures, and less intense tillage can likely improve the soil structural and water transmission and storage properties.

Table 7. Sustainability of a land use in relation to the cumulative rating (CR)

Sustainability	RWF	CR
Highly sustainable	1	<20
Sustainable	2	20-25
Sustainable with high input	3	25-30
Sustainable with another land use	4	30-40
Unsustainable	5	>40

CONCLUSIONS

The correlation analysis of soil physical and chemical properties showed a strong negative relationship ($r > -0.71$) between BD and K_s, BD and VTP, BD and nitrate-N content, and BD and θ_e. A strong positive relationship ($r > 0.7$) was obtained between K_s and θ_e and K_s and VTP. The critical levels were obtained for the key soil properties using the measured data to understand the sustainability of a land use system for the southern New Mexico. This study showed that soil bulk density and macroporosity were limiting factors primarily due to the soil texture and the conventional tillage system practiced in the study area. The water transmission and retention properties were also moderately limiting. The cumulative rating for the land use and management system suggested that the present land use is sustainable with high input.

ACKNOWLEDGMENT

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MANURE APPLICATION IMPACT ON IRRIGATED AND DRYLAND CROPLAND

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ABSTRACT

This study evaluated the impact of manure application on selected soil physical properties and spatial variability in cropland. The study was conducted on Pullman clay loam (fine, mixed, thermic, Torrertic Paleustolls) and Olton clay loam (fine, mixed, thermic, Aridic Paleustolls) soils. Manure was applied to the irrigated wheat-corn silage-wheat rotation (3 crops in 2 years) every other year at 15 t/ac (total 75 t/ac) under the center pivot, and to the dryland wheat in corners every 3 years at 11 t/ac (total 33 t/ac). Triplicate samples were collected at 6 intervals from the pivot edge in both dryland and irrigated cropland. Soil organic carbon (SOC), organic N, P, K, Ca, Mg, and Na were determined, as were soil hydraulic properties and aggregate size distributions. A sigmoidal, 3-parameter Hill equation was used to estimate the impact of P addition rate (t ac^{-1} yr^{-1}) on soil test P. Cattle grazing wheat had the greatest impact on soil physical and hydraulic properties, increasing bulk density, decreasing hydraulic conductivity, and changing the aggregate size distribution (creating more large aggregates, or "clods"). Soil OC was negatively correlated with bulk density, but positively correlated with plant available water, and with aggregates of 0.01 to 0.25 in diameter. These are the aggregates associated with granular structure in soils. No spatial dependence was found for several of the soil management systems with the sampling scale employed.

WATER USE EFFICIENCIES OF GRAIN SORGHUM GROWN IN THREE USA SOUTHERN GREAT PLAINS SOILS

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ABSTRACT

The ratios of economic yield:evapotranspiration (ET), or water use efficiency (WUE), and economic yield:irrigation water application, or irrigation WUE (IWUE), help evaluate the productivity of irrigation in agricultural systems. Water stress at critical growth stages, excessive soil water evaporation, soil water storage, runoff, and drainage are among the many factors which result in declines in either or both of these ratios. The objective of this research was to evaluate the effect of soil type, soil water use characteristics, and seasonal climatic differences on the WUE and IWUE of grain sorghum grown in the semi-arid climate of the southern Great Plains of the USA. In 1998 and 1999, grain sorghum [*Sorghum bicolor* (L.) Moench 'PIO-8699'] was grown in 0.75-m rows with 16 plants m^{-2} at Bushland, TX in lysimeters containing monolithic soil cores of either the Amarillo, Pullman, or Ulysses soil series. Irrigation treatments in both years were 100%, 50%, 25%, and 0% replacement of ET, simulating deficit irrigation that results from limited water availability such as reduced well capacities. The WUE was significantly higher and ET lower in the milder climatic conditions of 1999 compared with 1998, which had a higher evaporative demand. Once normalized for climatic differences, yield response to ET was similar for both years. Crops grown in the Amarillo soil had significantly higher WUE compared with crops in the other soils, primarily due to reduced ET rather than increased yield. Grain sorghum grown in the Ulysses soil was able to produce higher yields at lower plant available water compared with the other two soils, but the crops in all soils reduced yield when experiencing water stress at a critical growth stage of pollination. At comparable final soil water contents, grain yields of the crop in the Pullman soil were higher in 1999 (lower evaporative demand) compared with yields produced in 1998 (higher evaporative demand), while the crops in the other two soils produced similar yields in both environments. The relationship between irrigation application and yield was more curvilinear in 1998 possibly due to increased soil water evaporation at the higher irrigation applications, while the relationship was more linear in 1999. In general, IWUE declined with increasing irrigation application within each year, but was variable in some irrigation treatments, due to water stress at critical growth stages. No differences among soil types occurred in IWUE in either year, primarily due to variability among replicates.

NUTRIENT MANAGEMENT IN DUAL-USE WHEAT PRODUCTION

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INTRODUCTION

Conservation of our region's natural resources is a major priority at the highest levels of government. Conserving those resources is essential to long-term viability of rural economies. Crop residue on the soil surface is beneficial in terms of reduced soil erosion, rainfall capture, rainfall retention, and seedling protection. Producers in this area have not adopted no-till in a grazing system because of uncertainties about stand establishment, soil compaction, soil fertility, lack of proper equipment, and weed control. Understandably, most do not want to risk their future on an unproven technology. However, a few producers have successfully implemented no-till management in grain-only systems.

The Texas Rolling Plains has very large and diverse wheat/stocker operations which rural economies depend on as a major source of revenue. In these systems, wheat is planted in September under conventional tillage. Numerous field operations with large, expensive equipment along with high operating and labor costs are required to prepare "clean" fields prior to seeding. Unfortunately, soil moisture is lost in the process. Soil erosion by wind and water can cause significant damage on exposed soil. Wheat seedlings are unprotected from desiccating wind and washing out under conventional tillage. Large areas are subject to replanting, creating costly delays in wheat establishment and plant growth needed in a graze-and-grain wheat/stocker system. Conservation tillage (e.g. no-till) holds promise in mitigating soil and moisture losses in wheat/stocker systems through increased soil organic matter, enhanced capture and retention of limited precipitation and decreased risk of reseeding.

Fertilizer requirements in conservation tillage systems for wheat and stocker cattle production in the Rolling Plains are relatively unknown. A high research priority has been placed on no-till and reduced-till systems in a dual-purpose wheat/stocker enterprise, particularly development of efficient nitrogen (N) and phosphorus fertility programs. A key input to all wheat production is N fertilizer. Information on N fertility response of wheat in a no-till grazing system does not exist, although this knowledge is vital to successful implementation of no-till grazing systems.

Our current research indicates that stand establishment in no-till systems can be successful with the proper equipment. Furthermore, soil compaction may not be as serious as previously believed, as long as a reasonable amount of residue is maintained on the soil surface to cushion hoof action and the impacting effect of rain. It may take several years for a new production system to stabilize, particularly when converting from conventional tillage to a conservation tillage system.

The primary objective of this research is to identify N fertility levels that maximize forage and beef yields as well as maintaining grain yield and quality in no-till and conventional-till wheat/stocker production systems.

MATERIALS AND METHODS

The research site is located about 10 miles south of the Vernon Research Center on the Smith/Walker research unit. Approximately 550 acres are devoted to wheat, forage, and stocker cattle research. Pastures are near commercial production size (25 to 35 acres) with individual watering sources. Studies are conducted under dryland conditions. The soil is a clay loam and prone to wind and water erosion when left bare.

One N fertility study was nested in a larger 35-acre pasture with free-ranging stocker cattle (400 to 500 weights). Plots size was 20 ft by 100 ft. All fertilizer was surfaced applied as liquid material. Fertilizer treatments in each tillage system (no-till and conventional-till) included 0, 30, 60, 90, and 120 lb N/ac, with and without 45 lbs N/ac top-dressed in January in a randomized complete block design with 4 replications. The "Cutter" wheat variety was planted mid-September at 60 lbs seed/ac. No-till plots were kept weed free with herbicides. In August of each year, soils were sampled to the 2-foot depth for nitrate determination. Plots were clipped periodically to determine forage production. Cattle were removed (pulled-off) from pastures when wheat reached the 'first hollow stem' growth stage to allow grain production. Wheat was machine-harvested for grain yield.

RESULTS AND DISCUSSION

Forage production in 2003 to February 2004 was virtually non-existent due to record dry weather from November 2003 through January 2004. Therefore, these data are not presented. Rainfall in the fall of 2004 resulted in more normal forage production (Fig.1). There was no significant difference ($P \geq 0.05$) in forage production to March 1, 2005 between conventional tillage and no-till production system. This is promising from a wheat stocker grazing standpoint. Increasing amounts of pre-plant N resulted ($P \geq 0.05$) in increasing amounts of forage (Fig. 1).

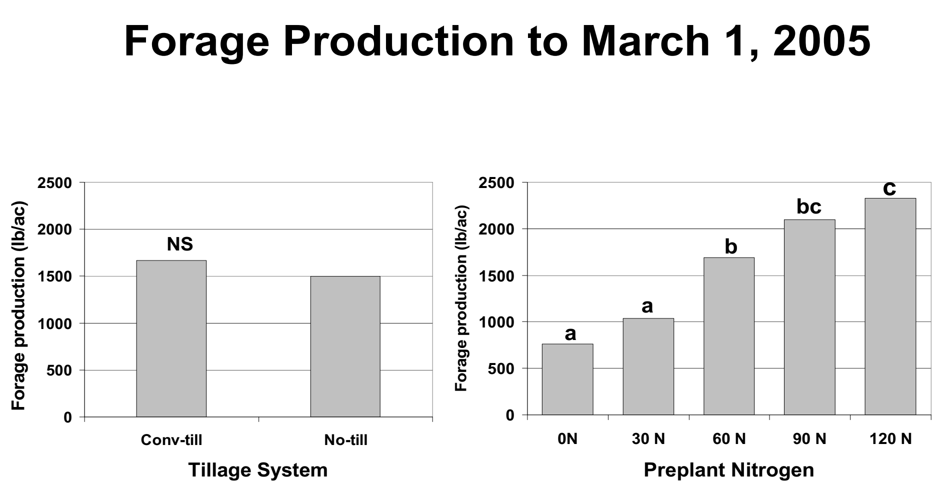

Figure 1. Wheat forage response to tillage and preplant N.

Table 1 shows that among all main effects and interactions, only top-dressed N significantly influenced gain yield ($P \leq 0.05$) both years. Tillage and pre-treatment N were significant in 2004 but not in 2005. The fact that tillage x N and tillage x top-dressed N interactions were not significant indicates that, over time and with proper management, changing from conventional-till to a no-till system may not result in reduced grain yield in a dual-use wheat system. These results must be considered preliminary, however.

Analysis of Variance for Grain Yield

Source	DF	2004	2005
		---Prob (F)---	
Rep	3	0.001	0.152
Tillage (T)	1	0.001	0.215
Nitrogen (N)	4	0.001	0.032
T x N	4	0.545	0.884
Top-dress (TD)	1	0.001	0.000
TD x T	1	0.506	0.735
TD x N	4	0.116	0.162
TD x T x N	4	0.586	0.764

Table 1. ANOVA for wheat grain yield.

Results show that tillage may have some affect on wheat yield (Fig. 2). Yields were significantly higher with conventional tillage than with no-till in 2004 but not in 2005, although grain yield was numerically less under no-till in 2005. Additional research will be needed to verify the effect of tillage on grain yield in a dual-use system. Reduced income from a slight yield reduction may be offset by the increased cost of establishing the wheat crop under conventional tillage.

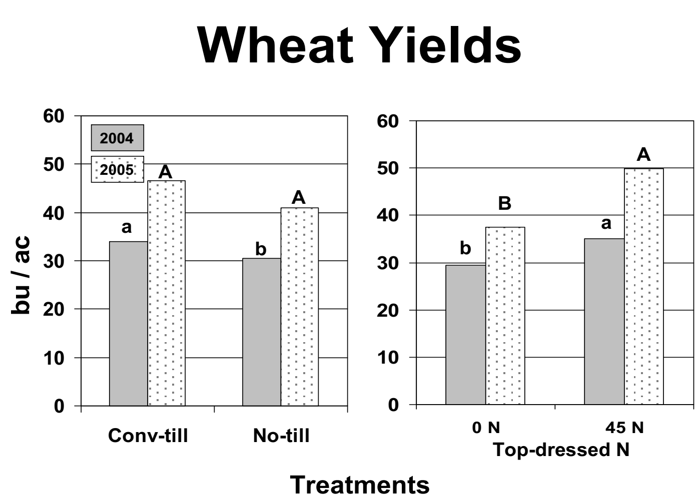

Figure 2. Effect of tillage and top-dressing N on wheat yields.

Top-dressing N significantly increased yield both years of the study, but to a greater extent in 2005 (Fig. 2). It appears that in 2005, no matter what level of pre-plant N the plots received, top-dressing 45 lb N/ac maximized final yield (Fig. 3). It should be recognized that the same N treatment was placed on the same plot in 2004 and 2005. Figure 3 also shows that the greatest increase in grain yield in 2005 occurred when N was top-dressed on plots that received no pre-plant N. From a grain production standpoint, this system may be most economical. However, from a forage standpoint, pre-plant N is essential in a dual-use system (Fig. 1).

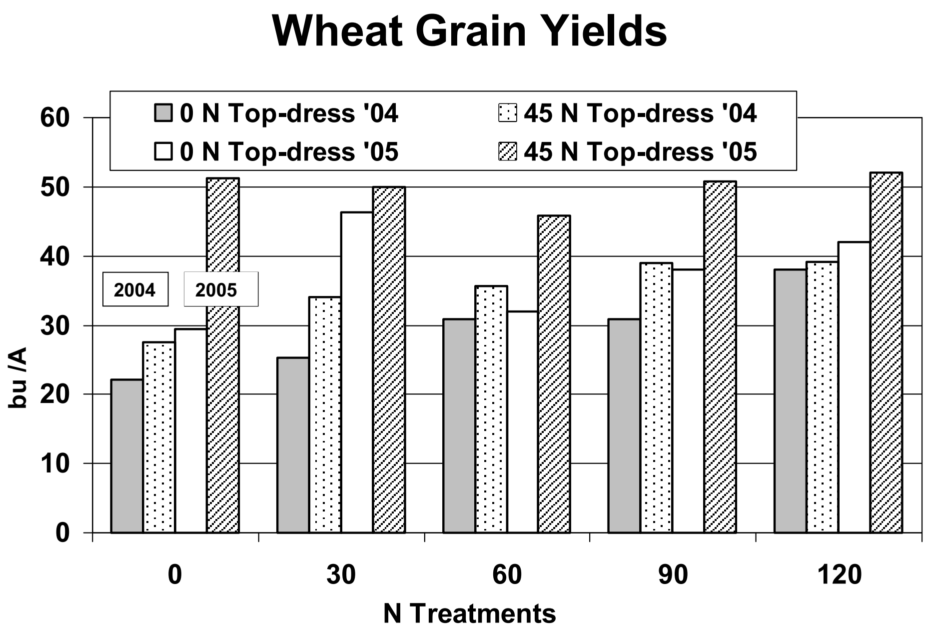

Figure 3. Effect of N treatments of grain yield, 2004 and 2005.

A preliminary economic analysis of top-dressing N to increase grain yield was attempted (Fig. 4). Top-dressing N resulted in a positive net return with all pre-plant N applications, except the highest pre-plant N rate of 120 lbs N/ac. Applying all top-dressed N with zero pre-plant N generated the highest net return. Inputs included the cost of the liquid fertilizer, application costs, harvest costs, and price received for the harvested grain. Seed costs, labor, fuel, maintenance, interest, etc. were not included in developing the net returns.

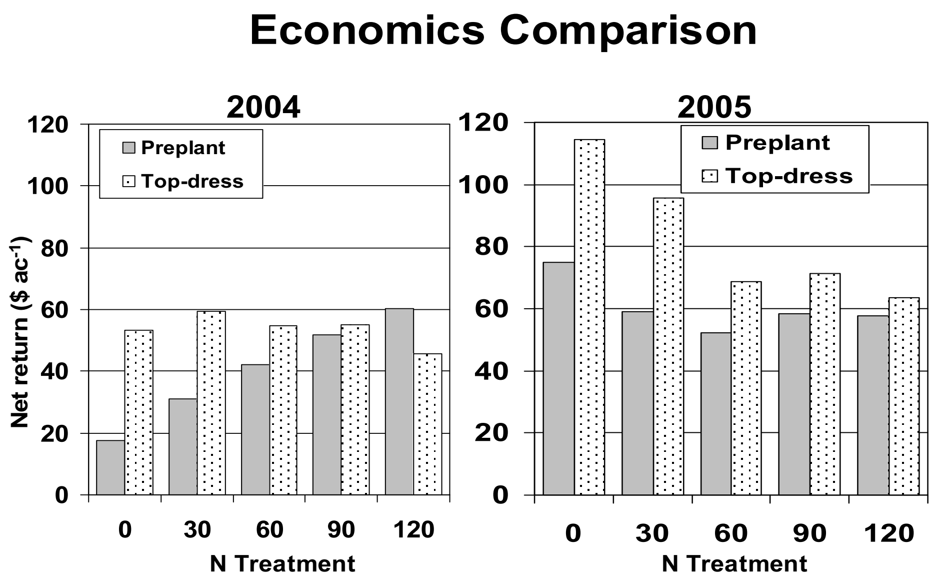

Figure 4. Economic comparison of preplant and top-dressed N application for grain yield.

Figure 5 shows nitrates in the top two feet of soil for the two tillage systems for 2004 and 2005. There were significant ($P \leq 0.05$) differences between the two systems at different depths. In 2005, there was significantly less nitrate in the top foot of soil under no-till. Since 2005 was the wetter year, we hypothesize that nitrates may have been immobilized in the decomposition of organic matter or lost through denitrification.

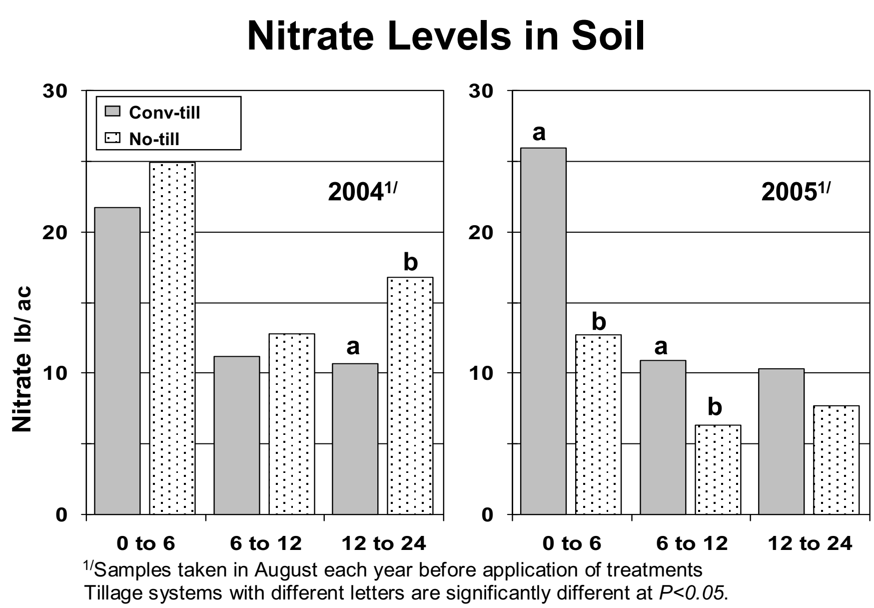

Figure 5. Soil nitrate levels in the upper 2 feet of soil under two tillage systems.

CONCLUSIONS

The past two growing seasons were quite different with 2003-2004 being extremely dry and 2004-2005 being abnormally wet in the fall and early winter. Consequently, fall forage production and grain yields were much higher in 2005. In 2005 there was no significant difference between tillage systems with respect to forage production to March 1, the general cattle pull-off date. Forage production and grain yield had a near linear response to pre-plant N application. Top-dressing 45 lb N/ac resulted in a significant increase in grain yield at all pre-plant N application levels except at the highest pre-plant application of 120 lb N/ac. Grain yields in 2004 were significantly higher with conv-till compared with no-till. However, in the second year of the study, grain yields from conv- till were numerically, but not significantly ($P = 0.22$), superior to those from no-tillage. In 2005, a top-dressed application of 45 lb N/ac resulted in maximum grain yield in all plots regardless of the pre-plant N treatment. This was less evident in 2004. From a grain production stand point, the greatest yield increase occurred when 45 lb N/ac was applied to plots that received no pre-plant N, and those plots also generated the highest economic net return. The economics of beef production were not included in this study. Forage yield to March 1 was minimal in plots receiving no N, and in a dual-use system, this would not be acceptable. We are developing management programs that attempt to find the optimum economic balance between forage production, grain yield, beef production, and reduced animal health risk.

ACKNOWLEDGMENTS

The authors wish to thank the Fluid Fertilizer Foundation, the Potash and Phosphate Institute, and the Texas Wheat Producers Board for financial and in-kind support of this research.

COMPARISON OF NUTRIENT SPATIAL VARIABILITY IN CROPLAND AND RANGELAND

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ABSTRACT

This study evaluated the hypothesis that cropping systems had no impact on nutrient levels and spatial variability relative to rangeland. Elevation, electrical conductivity (EC), pH, soil organic carbon (SOC), total N, P, Mg, Cu, Fe, Mn, and Zn were measured at three depths in a 0.6 ac grid on adjacent 17.3 ac plots of dryland cropland and native rangeland on an Olton clay loam (fine, mixed, thermic, Aridic Paleustolls). The coefficient of variation (CV) ranged from >25% for soil pH, Mn and Cu, to 25 to 60% for SOC, N, Mg, and EC, to more than 40% for P and Fe, to more than 80% for Zn. The P variability below 6 in was ~50% greater in cropland, while the Zn variability below 2 in was ~250% greater in rangeland. The mean rangeland SOC (1.2%) and N (0.13%) were about twice that in cropland. The EC, and Cu, and Mg concentrations were 25 to 40% greater in cropland, while Fe similar in both systems, Mn was about 5% less, P about 30% less, and Zn about 70% less in cropland.. The range of spatial dependence in cropland was 50% less for N, but 140 to 400% greater for Cu, Zn, Mg, P and SOC. Levels of SOC, N, P, Zn, and Mn were lower in cropland, while Cu, Mg, and EC levels were greater in cropland. The relative variability (CV) and spatial dependence were similar for most nutrients across systems, but the range of spatial dependence was much different in the cropland for Zn, P, Cu, SOC, Mg, and N.

IF IT WAS EASY, EVERYBODY WOULD BE DOING IT: WHY CONSERVATION TILLAGE HAS NOT BEEN ADOPTED BY SOUTHERN HIGH PLAINS PRODUCERS

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SUMMARY

Conservation tillage has been widely adopted in many regions of North America. Well documented benefits of energy savings, erosion control, and improved infiltration have profited producers who have adopted conservation tillage systems elsewhere and generated some interest among producers in the southernmost areas of the Southern High Plains (SHP) of Texas. In spite of this interest, few producers have adopted conservation tillage and their neighbors are skeptical of their chances for success. The southern end of the SHP is characterized by sandy loam soils with less than 0.5 % organic carbon formed under a thermic soil temperature regime, less than 19" of average annual rainfall, and a cotton monoculture. Under dryland conditions in the SHP, cotton generally produces less than 1500 lbs ac^{-1} of crop residue which is only about 20 % of the Soil Conditioning Index (SCI) maintenance amount required to maintain steady state soil carbon reserves. Thus, cultivated soils tend to be very low in organic matter, poorly structured, compact easily, and rapidly disperse during rain events effectively sealing the surface and limiting infiltration. Research conducted at the USDA-ARS Big Spring Field Station (BSFS) over the last 5 years indicates that the time required to successfully convert from conventional tillage to no-till systems may be exceptionally long under these conditions.

A field at the BSFS that was planted with native grass for 50 years was deep chiseled and disc plowed in 2000. Since the initial field preparation, it has been maintained in a no-till system. It has been planted with high residue crops such as sorgho-sudan, sorghum, and barley in rotation with cotton every third crop. Cotton yields from this field have been less than half the yield from an adjacent field with the same planting patterns maintained under conventional tillage. Soil compaction problems are evident in this field and sorghum roots have, in some cases, failed to extend beyond the seed furrow. Another field at the BSFS that had been in conventional tillage for 80 years was sub-divided into 24 treatment plots in 2003 following a crop of sorghum. This field was planted with cotton the following year and four tillage treatments were randomly assigned to three blocks. The tillage treatments were: 1.) (CT) a conventional tillage system of shredding residues, disc plowing twice, and listing the tilled soil into beds, 2.) (RT) a modified ridge till system of listing new beds around standing residues, 3.) (NTM) a no-till system where crop residues are shredded post-harvest, and 4.) (NTS) a no-till system where crop residues are left at full harvested height. Two rotations are also a part of the experimental design with a cotton-fallow-sorghum-fallow rotation and a cotton-fallow-cotton-fallow-sorghum rotation. During the three growing seasons since inception, cotton has been grown on at least half the field in all tillage treatments. Record rainfall in 2004 and very timely rainfall in 2005 resulted in record crops of cotton in and around Big Spring. These ideal growing conditions may have partially masked the tillage system effect on the growth and yield of the crops expected in more normal years.

For most growth and yield parameters in most years, the CT and RT treatments have resulted in the highest yields. In 2003, the CT treatment resulted in significantly higher yield that the other 3 treatments. Stand establishment, growth, and phenology data were better and earlier for the RT treatment until 60 days of drought followed by ample rains in September 2003. The extra protection from sandblast injury afforded the seedlings by the roughened beds and standing residue in the RT treatment may be partially responsible for the early response. The higher leaf area at mid-season in the RT treatment and expected greater water use may have reduced soil water to levels resulting in stress from which the RT plants never fully recovered. A large percentage of the cotton bolls in the RT treatment failed to mature and open in 2003.

In 2004, the CT and RT treatments yielded approximately 50 % more cotton TDM and more than twice as much lint yield compared with the NTM and NTS treatments. Although significance for treatment effects on cotton TDM was not found at the $p<0.05$ level, treatment effects were significant at the $p<0.1$ level. Sorghum TDM yields were also larger for the CT and RT treatments.

The 2005 data for cotton and sorghum tend to encourage enthusiasm that we are beginning to see the benefits of reduced tillage or at least beginning to overcome early problems with the conversion process. Lint yields were very similar for all treatments as are sorghum TDM yields. Sorghum mean TDM yield for the NTS treatment was actually greater than for the RT treatment. Cotton TDM yields showed a significant treatment effect at the $p=0.0621$ level and so it can easily be argued that the CT and RT treatments were still resulting in better growth. Hand harvest lint data taken two weeks prior to the mechanical harvest indicated a significant treatment effect with the CT and RT treatment means found not significantly different and the RT, NTM, and NTS treatment means not found significantly different. This indicates that the CT and RT treatments resulted in earlier crop maturity.

This investigation has been in place for 3 years will continue for another 9 years. Soil chemical and physical measurements including soil carbon, soil enzyme activities, wet aggregate stability, bulk density, and infiltration rate will be measured at the end of years 6 and 12. We are also hopeful that other fields at BSFS on which no-till and conservation tillage are being investigated will successfully be converted. Agricultural producers, however, cannot afford the yield losses we have experienced and may continue their resistance to change. It is probable that fuel costs, commodity supports, and market opportunities will remain the primary catalysts for change, or lack of it, in SHP agriculture.

SUPPORTING EFFICIENT IRRIGATION MANAGEMENT THROUGH THE TEXAS HIGH PLAINS EVAPOTRANSPIRATION NETWORK

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SUMMARY

The Texas High Plains is the most intensively irrigated region in the state. With limited and declining water resources in the region, efficiency in irrigation management is especially important. Evapotranspiration (ET) based crop water use estimates are key to optimizing irrigation scheduling. High quality, local meteorological data and ET estimates also are crucial to management and interpretation of results from agricultural research programs and to application of numerous crop management and water use models.

The Texas High Plains Evapotranspiration (TXHPET) Network provides meteorological data and crop water use estimates to support efficient irrigation management and associated research and education efforts throughout the region. The network delivers data by fax or e-mail to subscribers. The primary delivery mechanism, however, is the TXHPET website - http://txhighplainset.tamu.edu/.

Through the website, users can access information from any or all of 17 weather stations in the regional network through one common searchable database. Users can access data from one or multiple weather stations, over any time in the period of record. They can choose to access daily or hourly data and select whether the data are presented in English or metric units. Retrieved data can be presented in graphical, text, or data table formats. These features and online educational materials greatly enhance the utility of the data and simplify data analysis and interpretation. Outreach education efforts targeting traditional and new stakeholders are increasing awareness of TXHPET and promoting application of this valuable information for improved irrigation and water resources management.

WATER SAVINGS AND IMPACTS OF IRRIGATED CONSERVATION STRATEGIES

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ABSTRACT

Irrigation from the Ogallala aquifer in the northern region of Texas accounts for nearly 90% of all water use in the region. The water planning group within that region determined that an analysis of water management strategies that could be potentially implemented over the next 60 years to reduce or slow the rate of irrigation water from the Ogallala aquifer to meet regional water planning goals was warranted. The assessment of conservation strategies analyzed included; evapotranspiration (ET) based irrigation scheduling, changes in crop variety, irrigation equipment improvements, changes in crop type, implementation of conservation tillage methods, precipitation enhancement, and the conversion from irrigated to dryland farming. While all the strategies result in water savings, several are devastating to the regional economy. The strategies of changing crop type and changes in crop variety generated the most water savings but these strategies had the most negative impact on the regional economy. The strategies of precipitation enhancement and irrigation scheduling provide both a substantial water savings and have a positive impact on the regional economy. Even with implementation of the positive impacting strategies, the 60 years demand shortage within the region is not met through conservation alone under the proposed implementation levels of strategies. Either higher implementation levels of the strategies considered and/or regulation of groundwater pumping may be required to meet water conservation goals set by the regional water planning group. Decision makers need to weigh carefully water savings, implementation costs and impacts on the regional economy when developing water conservation policies.

SOIL CARBON CONTENT AFTER A HALF CENTURY OF MANAGEMENT

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ABSTRACT

Management effects on soil physical properties can be difficult to determine because there is often no fixed starting point. Soil organic carbon was determined for central Texas Vertisols (Udic Pellusterts) on archived samples from 1949 and samples taken in 2004. Management records were used to interpret the data. Five fields were sampled, representing an untilled native pasture, two previously tilled soils which had been planted to Bermuda grass (*Cynodon dactylon* (L.) Pers.) for 55 and 39 years before the 2004 sampling period, and two fields which had been continuously cropped for nearly the entire 55 year time interval. Soil organic carbon was determined for depth increments of 0 to 6, 6 to 12, 12 to 24, 24 to 36 and 36 to 42 inches. The tilled soils had been seriously degraded of organic carbon by agricultural activities prior to 1949 compared to the native pasture soil. Agricultural practices since 1949 have increased soil carbon concentration in the surface 6 inches. Returning the soils to grass production increased soil surface carbon contents at a faster rate than the conventional agricultural practices. Having archived samples greatly aided in interpreting the effects on management on the soil. It appears that previous estimates of carbon sequestration rates for the Vertisols may have been under estimated by comparative studies of no-till and conventional tillage practices.

ENERGY BALANCE COMPARISON AMONG TILLAGE PRACTICES IN CORN AND CORN-SOYBEAN SYSTEMS

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INTRODUCTION

There is little information available on the effect of common management practices on the energy balance of corn and soybean cropping systems. This type of information is needed to assess the sustainability of these systems. Such information will also be useful for designing improved cropping systems. The objective of this study was to compare the energy balance among continuous and rotated corn and soybean under six tillage systems using data from a long-term study conducted in eastern Nebraska.

METHODS

The tillage study was initiated in 1986 at the Rogers Memorial Research Farm near Lincoln, NE under natural rainfall conditions. Soil at the site is a Sharpsburg silty clay loam. The experimental design was a completely randomized block with a split-plot arrangement of treatments and six replications. Tillage system (tandom disk, chisel plow, moldboard plow, subsoil tillage, ridge tillage, and no-tillage) was applied to the whole plots and cropping treatment (continuous corn, corn in a corn-soybean rotation, soybean in a corn-soybean rotation, and continuous soybean) to the sub-plots. Cultural practices were similar to those used by local producers. Seeding rates varied from 40,000 to 58,000 seeds ha^{-1} for corn and from 250,000 to 375,000 seeds ha^{-1} for soybean. Varieties/hybrids were changed approximately every four years to take advantage of genetic improvements. Pesticides were used at recommended rates as needed each season. Corn was fertilized with 113 kg ha^{-1} as NH_4NO_3 and no fertilizer was applied to soybean.

Energy inputs included diesel consumption during field operations and energy equivalents for seed, fertilizer, and pesticides. Energy associated with labor was not included as it accounts for <0.2% of total energy in most modern cropping systems. In addition, solar energy was not included as its magnitude would mask variation in other energy inputs (Hülsbergen et al., 2001). Energy inputs for drying, storage, and transportation from the farm to consumers was not included. Fuel use efficiency by machinery and for production of N fertilizer has improved over time and energy consumption was determined for three periods (1986 to 1990, 1991 to 1995, and 1996 to 2001). Fuel use for equipment from these three time periods was obtained from the Nebraska Tractor Test Laboratory. Energy equivalents for N fertilizer were 49.4 MJ kg^{-1} for 1986 to 1990, 35.3 MJ kg^{-1} for 1991 to 1995, and 32.2 MJ kg^{-1} for 1996 to 2001. Calculations were made using a 50 ha field located 5 km away from the farm. Energy output was calculated by converting yields to energy equivalents assuming 15.6 MJ kg^{-1} for corn and 23.8 MJ kg^{-1} for soybean.

RESULTS

During the study period annual precipitation averaged 708 mm and mean annual temperature was 19.9^{o} C. Mean annual grain yield ranged from 2.4 to 10.6 Mg ha^{-1} and averaged 5.8 Mg ha^{-1} for continuous corn. Yields for corn rotated with soybean ranged from 3.1 to 11.0 Mg ha^{-1} and averaged 7.1 Mg ha^{-1}. Averaged over years, corn yields were greatest with plow tillage and least with no-tillage. Yields for soybean ranged from 1.3 to 3.5 Mg ha^{-1} and averaged 2.4 Mg ha^{-1} for continuous soybean. Yields for soybean rotated with corn ranged from 1.6 to 4.0 Mg ha^{-1} and averaged 2.6 Mg ha^{-1}. Averaged across years, soybean yields were similar among the tillage treatments. Seasonal temperature and rainfall patterns influenced corn and soybean yields and the effect of tillage on yields (Wilhelm and Wortmann, 2004.).

There was variation among years in the energy balance due to weather effects on crop yield and therefore on energy output and efficiency. In spite of year-to-year variation there were tillage effects and crop effects on the energy budget. Energy input was similar among tillage practices when averaged across years (7.9 MJ ha^{-1}). Energy output was greatest with plow tillage (96.1 MJ ha^{-1}) and least with no-tillage (90.4 MJ ha$^{-1)}$. Similarly, energy gain was greatest with plow tillage (87.4 MJ ha^{-1}) and least with no-tillage (83.0 MJ ha^{-1}) while the output:input ratio was greatest for no-tillage (12.8) and least for plow tillage (11.2).

Energy input was greatest for continuous corn (9.7 MJ ha^{-1}) and least for continuous soybean (5.9 MJ ha^{-1}). Differences in energy input are due to differences in fertilizer N inputs between the two crops. Energy output was greater for corn (107.5 MJ ha^{-1}) than for soybean (63.8 MJ ha^{-1}). Energy gain was greater for corn (97.8 MJ ha^{-1}) than for soybean (57.8 MJ ha^{-1}), the result of yield differences between the crops. The output:input ratio was greater in corn-soybean rotation (13.1) than in continuous corn (11.4) or soybean (11.4).

CONCLUSIONS

Weather effects on yield influences annual energy budgets.

Averaged across years, crop (differences in applied fertilizer N, yield, and energy content of the grain) influences energy balances more strongly than does tillage in rainfed systems of the western Corn Belt.

While there were significant tillage by crop interactions their effects were small compared to those discussed above.

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PHYSIOLOGICAL AND MORPHOLOGICAL TRAITS FOR SELECTION OF DUAL-USE WHEAT WITH IMPROVED FORAGE PRODUCTION

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ABSTRACT

There are no clearly defined selection criteria for breeding forage-type wheat. In a series of experiments, we determined relationships between early-season forage production and morphological and physiological traits in a range of wheat cultivars and breeding lines under in a grazing system. Tiller number and specific leaf weight were highly correlated with early-season forage production, while leaf width and leaf length were poorly correlated. Growing conditions did affect the correlations. Concentration of phenolic compounds, metabolites that may play a role in preventing frothy bloat in cattle grazing wheat, was highly depended on weather conditions and varied among wheat entries, suggesting potential for manipulating production of these metabolites.

SUMMARY

Wheat historically has been bred for increased grain yield and for tolerance to abiotic (drought, soil mineral imbalance) and biotic (insects, pathogens) stresses. Although grain yield potential of modern cultivars is higher than older cultivars, breeding progress for forage production, forage quality, and grazing has been very limited. Texas A&M University has released only one variety (Lockett) bred exclusively for grazing and one dual-purpose (TAM-202) wheat variety. The lack of adequate selection criteria has hampered breeding efforts to develop improved forage-type and dual-purpose wheat varieties. Because of a lack of clearly defined selection criteria for breeding forage-type wheat, breeders usually rely on forage quantity and quality during the fall-spring growing season as selection tools. Such an approach may not be the most appropriate to develop disease and insect resistant, productive cultivars with a maximal potential to withstand various grazing pressures and climate fluctuations. Recent studies suggest phenolic compounds may be one group of metabolites in wheat forage controlling frothy bloat, a serious digestive disorder of cattle grazing wheat. In an independent series of studies, we evidenced a relationship between rapid changes in solar radiation and temperature (e.g., during passing cold fronts) and phenolic concentration in wheat forage. Frothy bloat incidences usually amplify during conditions of rapid weather changes in the late winter-early spring season. Previous research evidenced the importance of foam stability in the rumen for the potential of frothy bloat. We showed that wheat entries with low phenolic concentrations exhibited an increase in foam strength measured in vitro.

The objective of this study was to determine morphological and physiological traits for selection of dual-use wheat with improved forage productivity. In this presentation we discuss correlations between forage production in the early grazing season (November-December) and wheat plant morphological parameters, and phenolic concentrations in wheat cultivars and breeding lines.

During the 2003-2005 winter growing seasons we evaluated forage and grain yield, grazing tolerance, morphological and physiological traits, and resistance to pests and diseases of a range of breeding lines and cultivars selected from the Texas Elite (TXE) and Uniform Variety Trial (UVT) wheat collections. Each wheat entry was strip-planted on 0.04-ac plots (18 x 100 ft) in blocks repeated 3 times. Seeding rate was 23 seeds/sq ft, which corresponds to 75 lbs/ac of Lockett wheat (check variety). The experimental site was a part of a 35-ac wheat pasture grazed from December through February each year at 0.75 head/ac stocking rate. Forage yield was measured at 28-d intervals from grazed and enclosed, non-grazed areas by harvesting 5.4 sq ft area of each plot. Tillers were counted from 1-ft row. Wheat samples for phenolic compounds assessments were collected in January, February, and March 2005 during periods of sudden weather changes. The experimental design was a completely randomized block replicated three times. All data were analyzed using the Mixed Procedure of the Statistical Analysis System (SAS, 1999). Replications were considered random and wheat entries were considered a fixed factor. Mean separation was performed using the protected least square means (LSMEANS) procedure. Significance was declared at $P < 0.05$.

The 2003 winter growing season was extremely dry until January 2004. Precipitation during October-December 2003 was only 1.10 inches (long-term average is 4.80 inches). Early forage yield was positively correlated (R^2=0.66) with tiller number in the dryland wheat, but not significantly correlated with tiller number in the irrigated UVT (R^2=0.22) and TXE (R^2=0.16) wheat collections. Precipitation during October-December 2004 (11.63 inches) was above normal (4.80 inches). Under such wet conditions, early forage yield was not correlated with tiller number in the dryland study (R^2=0.07) and weakly correlated with tiller number in the non-irrigated UVT (R^2=0.41) and TXE wheat collections (R^2=0.52). Leaf length was not correlated with early forage yield (R^2=0.08 to R^2=0.25), except for dryland wheat in 2003 (R^2=0.88). Leaf width was also not correlated with early forage yield (R^2=0.004 to R^2=0.16. Specific leaf weight (SLW) was negatively correlated with early forage production in dryland wheat in 2003, but there were weak correlations between these traits in irrigated UVT and TXE wheat collections. In 2004, early yield was negatively correlated with SLW in dryland wheat and non-irrigated UVT and TXE collections. Producing leaves with lower SLW enables the construction of more leaf area per unit of leaf mass, which is a typical strategy of fast growing grass species. Phenolic compounds varied among wheat cultivars and breeding lines during the 2004-2005 growing season. Cultivars TAM 100, TAM 111, TAM W-101, Deliver, and a breeding line TX98V9628 had the highest concentrations of phenolics, while cultivars TAM 400, OK 102, Jagger, and breeding lines TX01V5314, TX00V1117 and TX01U2598 had the lowest phenolic concentrations.

Morphological traits such as tiller number or specific leaf weight are easy to measure and they are correlated with early wheat forage production. It is important to conduct the wheat selection process for increased forage productivity under conditions in which the cultivars will later grow. Leaf parameters such as length or width are not useful in selecting lines for high forage productivity. Concentrations of phenolic compounds (which may play a role in frothy bloat prevention) vary among wheat cultivars and breeding lines, suggesting a potential for selection of wheat with high and stable phenolic content.

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CHALLENGES IN INTEGRATING CAFO NUTRIENT MANAGEMENT WITH ENVIRONMENTAL STEWARDSHIP[1,2]

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INTRODUCTION

In general, 70 to 90% of nutrients fed to livestock subsequently end up in manure and can potentially be lost to the environment. Thus, the effects of livestock operations, especially larger concentrated animal feeding operations (**CAFO),** on the environment are a growing concern among many groups. The role of nutrition (i.e. pre-excretion strategies) and manure management (post-excretion strategies) in controlling possible adverse effects on the environment are receiving increased emphasis.

With the advent of the new EPA Clean Water Regulations [USEPA, 2003a, 2003b], all CAFO, and many smaller AFO, must have comprehensive nutrient management plans (**CNMP**) that address factors such as feed management, manure handling, and land application of manure (NRCS, 2000). Manure nutrients must be applied to farm lands at no greater than agronomic rates: thus, meeting nutrient application standards may require CAFO to spread manure over a much larger land area than they currently use. Ribaudo (2003) reported that only 18% of large hog farms and 23% of large dairies currently apply manure on enough cropland to meet a N management plan. Lander et al. (1998) estimated that only 20 (P-based) to 50% (N-based) of AFO operate with enough land to meet new land application requirements. Today at least 2 to 5% of U.S. counties produce more manure than can be assimilated by total crop land and pasture in the county (Kellogg et al., 2000; Lander et al., 1998). New, and potential new, air quality regulations on PM-2.5, PM-coarse, ammonia, and hydrogen sulfide emissions may also lead to requirements for nutritional and management controls. Even pasture-based operations such as cow-calf ranches may be challenged by Total Maximum Daily Load regulations that may limit access to wetlands and alter fertilizer use.

CAFO ENVIRONMENTAL CONCERNS / BACKGROUND

The nutrients of primary environmental concern to agriculture are N and P. Phosphorus concerns revolve primarily around potential contamination of surface waters; whereas, N concerns revolve around both water (nitrates in surface & ground water) and air quality (ammonia, odors) issues. These concerns may be legal (ie. nuisance lawsuits, etc.) as well as regulatory.

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[2]The mention of trade of manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion of other similar products by USDA-ARS.

Water quality. Beef and dairy feeding operations with properly designed and maintained runoff retention ponds and(or) lagoons normally have little, if any, effect on surface or ground water quality, although dry deposition of ammonia may increase N content of waters in close proximity to CAFO. The potential for water contamination generally occurs after the manure leaves the CAFO and is used as a fertilizer on fields or pastures. When applied at P utilization rates, rather than N utilization rates, the quantity of farm land required to dispose of manure is increased by 5- to 10-fold.

Air quality. The major air quality concerns of beef and dairy cattle operations vary with location, but, in general, are dust, odors, and ammonia. Concerns with dust and odors are generally local and revolve around "quality of life," health, and litigation issues; whereas, concerns with ammonia are mainly global or regional and revolve around it's designation as a PM-2.5 precursor (NRC, 2003) or possibly to its listing as a "hazardous substance" under the Emergency Planning and Community Right-to-Know Act (EPCRA).

PROGRESS IN DECREASING CAFO EFFECTS ON THE ENVIRONMENT

Changes in livestock production over the last several decades such as improved genetics, improved feed processing, diet modifications, and growth and lactation enhancers have directly increased production efficiency and indirectly reduced environmental hazards. Today, diets are more digestible and less manure is produced per unit of production. For example, incorporation of new technologies into the beef cattle feeding industry has decreased the amount of feed required per unit of gain from over 7 in the early 1980's, to less than 6 today. Although the driving force for these changes has been economics, these changes have also had a positive impact on many of the environmental issues now facing feedyards. Thanks to these new technologies, the quantity of feed fed annually to feedlot cattle in the southern Great Plains is 5 million tons less and the annual dry manure output is 3 million tons less than without these technologies (Greene and Cole, 2003).

Similar improvements have been noted in the dairy industry. Tylutki et al. (2004) noted that over a 5-year period, by modifying diet nutrient content and better managing manure, a dairy farm in New York was able to increase the proportion of home grown forages used in their diets by 38% and decrease manure N and P per acre by 17 and 28%, respectively. In 1998 the farm was accumulating P at the rate of 7.2 lb/acre; whereas, in 2002 it was accumulating P at only 0.26 lb/acre. At the same time, feed cost per unit of milk produced was decreased 48%. Similarly, in England, Withers et al. (1999) noted that surplus P in a whole-farm dairy system could be decreased from 21 lb/ac to 2.1 lb/ac via changes in the crops grown and dietary P concentration without adversely affecting milk production. From 1975 to 1995, the annual P excess (ie. soil storage) in Wisconsin decreased from 54 million kg to 14 million kg due, in part, to improved nutrition and management of dairy cows (Bundy and Sturgul, 2001).

Today, the livestock industry needs to develop and implement additional feeding and management strategies that continue the trend of improved feed efficiency while at the same time, reducing nutrient excretion to the environment, and producing a "higher quality" manure to be used as a fertilizer.

CHALLENGES

Excessive intake of nutrients by livestock leads to excessive excretion in manure. The term "precision feeding" has been coined to suggest that livestock can be fed with greater precision than currently practiced. However, at the present time, it is still not clear how effectively precision feeding can be applied in the field. It has been said that there are at least four different diets in any livestock operation: 1) the diet formulated by the nutritionist, 2) the diet actually mixed, 3) the diet delivered to the animals, and 4) the diet consumed by the animals. Making diets 1 and 4 the same is difficult.

Most nutritionists incorporate safety margins in their diet formulations to protect against variation in the nutrient content of ingredients and the nutrient requirements of animals. The point at which a safety margin becomes excessive is not clear. Galyean (1996) and Galyean and Gleghorn (2002) reported that beef cattle consulting nutritionists fed diets that varied from 12.5 to 14% (dry matter basis) in formulated crude protein **(CP)** concentration with a mode of 13.5%. Formulated P concentrations ranged from 0.25 to 0.35% with a mode of 0.3%. Surveys of Virginia and Wisconsin dairy herds indicated that, on average, the dietary P concentrations were 45% greater than NRC recommendations (Knowlton, 2002) and that 85% of dairies fed P in excess of NRC (2001) recommendations (Powell et al., 2002).

Some of the factors that limit the use of precision feeding in AFO include 1) variability in animal nutrient requirements, 2) seasonal / climatic effects, 3) variability in composition of feed ingredients, 4) logistics (Cole, 2003). Additional factors such as the low cost of urea and many by-product feeds, and as-yet undetermined ingredient associative effects also are important. Most of these limitations revolve around the risk of adversely affecting animal health or performance.

Animal Variability. Cattle producers are normally faced with large variations in the genetics of cattle within a single lot. Factors such as finished weight (i.e. body weight at 28% body fat), gain potential, stage of production, tolerance to weather extremes, milk production, etc. all affect the nutrient requirements of individual animals within a lot.

When formulating diets for large, genetically diverse, groups of animals, diets can be balanced based on the genetic potential of the best animals in the group or the genetic potential of the worst animals in the group. As an example of the effect of animal growth potential on CP requirements, we calculated the performance and N excretion of 100 hypothetical steers fed diets formulated to meet the CP requirements of the lowest 50%, lowest 84%, or 100% of the animals in the pen (NRC, 1984; Table 1). In addition, we calculated the overall pen performance and N excretion if 100 steers were "precision fed" (fed three different diets – one balanced for the bottom-performing 50 steers, one for the middle 34 steers, and one for the best-performing 16 steers). Restricting the dietary CP concentration to meet the requirements of 50% of the cattle in the pen had adverse effects on animal performance and did not decrease total pen N excretion because more days were required to reach market weight. Feeding to meet the requirements of 84% of the cattle, rather than 100%, had a slight adverse effect on calculated animal performance but a beneficial effect on calculated N excretion. As expected, precision feeding provided the best performance and lowest N excretion but was not "attainable" in a real world situation. Based on these calculations, diets need to be formulated to meet the requirements of at least 84% of the cattle in a pen. Interestingly, these simulated results agree well with results we obtained in feeding and metabolism trials (Gleghorn, et al., 2004; Gueye et al., 2003; McBride et al., 2003; Cole, 2006).

Seasonal /Climatic Variability. Animal performance and ammonia emissions vary with seasons (Erickson et al. 2000, 2003; Cole, 2003). Thus, to more precisely feed cattle, environmental and seasonal factors may need to be taken into account.

Feed Ingredient and Diet Variability. A major factor limiting the use of precision feeding is feed and diet variability. Loads of feed ingredients vary in nutrient composition because of growing conditions, time in storage, etc. Many tabular values are based on "old" and limited data and thus their validity today is questionable. In an 8-year survey of corn CP concentrations at a Texas feedyard, only 6% of corn samples had a CP concentration equal to or greater than NRC (2000) values (Table 2; Figure 1: Cole, 2003).

Many factors affect nutrient composition of diets including the nutrient composition of the ingredients, sampling errors, mixing errors, and laboratory variability/errors. To reduce diet variability employees should receive training in proper feed mixing and sampling, and feed mixers and scales should be tested routinely to be sure that ingredients are mixed properly and to determine the optimal mixing time (McCoy, 1994; Jones, 2001).

The analyses of 110 samples of a finishing diet formulated to contain 13.5% CP based on historical corn composition data (Table 2: Figure 1) demonstrated that although there was some variation in analyzed CP concentrations of the diets, the mean and median values were close to the formulated concentration and over 75% of the samples contained at least 13.13% CP. Only 10% of ration samples had a CP concentration of less than 12.75%. Similarly, Dou et al. (2003) noted that 67% of dairy rations were within 10% of the formulated protein concentration. Thus, if the nutritionist has a good chemical analysis or a history of the composition of feed ingredients, it is possible to mix diets that meet formulated diet specifications at least 75 to 90% of the time.

Chemical Analyses. Chemical analyses of feeds can vary from lab to lab and from method to method. In Table 3 are presented the analyzed CP concentrations of 5 feedyard diet samples sent to 3 different labs. The diet was formulated to contain 13.5% CP and on average analyzed to contain 13.7% CP. However the analyzed CP concentrations ranged from 12.7 to 14.5%. Obviously, the difficulty in obtaining precise feed analyses makes the formulation of diets more difficult.

Logistic challenges. One of the advantages of modern concentrated livestock feeding operations is the economy of scale. However, the sheer size of many operations also makes it more difficult to adapt some technologies. In large operations, modifying feeding practices may require feed mill modifications or may increase the feed truck miles and/or employee time required just to get cattle fed. Requirements of additional fuel, employees, or feed trucks can result in significant costs to the enterprise.

Feed Selection. Ingredient selection can have a major effect on the nutrient concentration in diets. Many by-product feeds such as distiller's grains, corn gluten feed, and high protein meals are high in N, P, S, and(or) other nutrients. Their use may result in diets and manure with excessive P concentrations. For example, Gueye et al. (2003) and McBride et al. (2003) noted that replacing cottonseed meal with urea as the supplemental N source in finishing diets reduced diet P concentration by 29.4% and P excretion by 20.5%. Many of these co-products fit well into beef cow supplements or dairy rations if other supplemental forms of P are removed.

Feed intake. Animals require quantities of nutrients rather than dietary proportions (ie. lbs/day vs. %). However, in most cattle feeding operations animals are provided ad libitum access to complete diets. Therefore diets are formulated to contain designated concentrations of nutrients with the assumption that feed intake will be within a specified range. Overestimating feed intake will lead to under-feeding specific nutrients, whereas underestimating feed intake will potentially lead to feeding excessive quantities of nutrients. For example, a 5% change in the dry matter intake of a dairy cow can affect the required dietary CP concentration by 0.5 to 1% (Chase, 2002).

Feed processing effects. In the newest versions of the beef and dairy nutrient requirements (NRC, 2000, 2001, respectively) diets are balanced based on the quantity of ruminally degradable (**DIP or RDP**) and ruminally undegradable (**UIP or RUP**) protein. Van Horn et al. (1994) calculated that simply balancing the DIP and UIP in the diet of dairy cows would decrease N excretion about 15% compared to NRC (1989) standards.

However, DIP and UIP values of feeds have not been determined experimentally and their requirements vary with other dietary and management factors.

Feedlot studies with dry-rolled corn-based diets suggest the CP requirement of finishing beef cattle is equal to or less than 11.5% of dietary DM (Milton et al., 1997; Shain et al., 1998) and that the DIP requirement is approximately 6.5% . However, results of trials with steam-flaked corn-based diets suggest the optimal CP concentration for finishing cattle performance is closer to 13.0% (Cooper et al., 2002; Gleghorn, et al., 2004) and the DIP requirement is greater than 8%. This difference in DIP (and subsequently CP) requirements is due to greater ruminal starch digestion in cattle fed steam-flaked corn-based diets.

Typically, it is not possible to "balance" DIP and UIP in beef cattle finishing diets because of the high UIP value of the basal ingredients. In an 80% corn beef finishing diet, the corn + forage portion of the diet will usually supply UIP in excess of the animal's requirement. Thus, when supplemental protein is provided to supply required DIP, the "excess" UIP-N in the grain+forage+supplement portion of the diet results in excess total N in the diet. This is in contrast to most dairy diets which require supplemental UIP.

Phosphorus: Most feed grains contain at least 0.30% P. Thus, if fed at 80% of a finishing diet, the basal P content of the diet is 0.25% or more. Erickson et al. (1999) noted that performance of finishing steers was not adversely affected by feeding diets with P concentrations as low as 0.14%. Similarly, in growing beef steers, Greene et al. (2001) noted that decreasing the dietary P concentration from 0.33 to 0.22% decreased P intake 50%, and decreased P excretion by 54% without affecting average daily gain and gain/feed.

Wu et al. (2000; 2001) noted that the P requirement of dairy cows may be substantially lower than concentrations routinely fed in the industry and that any P fed in excess of 0.31% was excreted in the feces.

Availability of feed P has received little attention in ruminant diets because early studies indicated that phytate-P in grains is highly available to ruminants. The current NRC for dairy (2001) assumes a P availability of 64% for forages, 70% for concentrates, and > 70% for most inorganic P sources; whereas, the NRC for beef cattle (2000) assumes a P availability of 68 % for all feeds. Providing supplemental P to dairy and beef cows based on available P, rather than total P, can potentially decrease the quantities of supplemental P fed and excreted by a factor of 3 or more (Table 4).

In general, once beef cattle are adjusted to the high concentrate finishing diet, they are fed a single diet throughout the feeding period. Thus, protein may be deficient early in the feeding period and in excess late in the feeding period. On average, an excess of approximately 2.64 lb of N is fed per animal during a 150 day feeding period (Galyean, 1998). Nitrogen can be conserved by lowering the dietary protein concentration late in the feeding period (phase feeding). To date, most phase feeding studies conducted with beef cattle fed dry-rolled corn-based diets and(or) with moderate implanting strategies suggest that supplemental protein could be partially, or completely withdrawn from finishing diets during the last 30 to 60 days on feed without adversely affecting animal performance (Erickson et al., 2000: Vasconcelos et al., 2006). However, in studies with beef cattle fed steam-flaked corn-based diets, decreasing dietary protein late in the feeding period (from 13.5 to 11.5%) had adverse effects on animal performance (Cole et al., 2006).

Satter and Wu (1999) noted that dairy cows could also be phase fed without adversely affecting milk production. By decreasing dietary CP concentration from 17.9 to 16.0% on week 17 of lactation, N intake was decreased 13%, manure N was decreased 16%, and milk production was not affected.

Because there are a number of obstacles to overcome in using phase feeding systems in commercial feedyards (additional supplements and diets, added time or labor required to feed, possibly increased incidence of acidosis, etc.) the economic practicality of phase feeding under current situations is not clear. With the advent of the new growth promoter, Optiflex (Elanco Animal Health), which will be fed toward the end of the feeding period, the effects of phase feeding will need additional evaluation.

USE OF MANURE AS A FERTILIZER: DIET AND MANAGEMENT EFFECTS

Improper use of organic and/or inorganic fertilizers can result in nutrient accumulation in soils, runoff to surface water or percolation to ground water. Many farmers prefer to use commercial inorganic fertilizers, rather than manure because of factors such as uncertain and inconsistent nutrient content, difficulties in uniform spreading, soil compaction, odor, weed seeds, high salt content, personal opinions, transportation costs, and low N:P ratio. Increased paper work from regulations could potentially further decrease use of manures by farmers.

Most crops require a N:P of 5 to 8:1. However harvested feedlot and dairy manures normally have N:P of 3:1 or less. The major factor affecting the N:P ratio is N volatilization losses. Depending upon weather conditions, pen surface conditions, diet, and other factors, 40 to 60% of N fed may be lost to the atmosphere, primarily as ammonia (Cole 2006; Cole et al., 2005; 2006; Todd et al., 2005, 2006). Decreasing dietary protein concentration from 13 to 11.5% of dry matter decreased potential ammonia emissions by approximately 30% (Cole et al., 2005; Todd et al., 2006). A number of potential soil amendments (Shi et al., 2001) and feed additives (Eng et al., 2003) have the potential to decrease ammonia emissions from feedlot pens. However the economics of these methods have not been clearly determined. More frequent cleaning of dirt surfaced pens will potentially increase N capture in the manure and decrease ammonia emissions (Erickson et al., 2003), especially in the summer months. Although this relationship should hold true for dairy dry lots as well, more frequent scraping of concrete dairy barns does not appear to affect N volatilization losses (Larry Satter, personal communication). Erickson et al. (2003) also noted that increasing dietary fiber (as corn bran) in the finishing diet or adding sawdust to the pen surface decreased the quantity of N volatilized from the pen surface during a winter/spring feeding period. However, these procedures also increase the total quantity of manure than must be removed from the facility.

Application of manure as a fertilizer on pastures is difficult to sustain in the long term because animal product removes less than 30% of the nutrients applied. For optimal utilization of manure nutrients, at least a portion of the forage needs to be removed as hay or silage. In addition, grazing cattle do not distribute manure evenly across a pasture (White et al., 2001).

Thus, fertilizers (organic and inorganic) should not be applied in areas where animals tend to congregate and deposit more nutrients on the land.

The nutrient composition and availability of manures collected from CAFOs vary greatly depending upon animal species, the diet fed, length and type of storage, type of housing, timing and method of manure collection, pen surface, bedding used, application systems, etc. Because many nutrients and trace elements in animal manures are organically bound or contained within structural components, manure may act as a form of "slow release" fertilizer (Loecke et al., 2004). Long-term manure applications may actually help decrease nutrient and soil runoff losses from fields due to increased soil organic matter and improved soil physical properties (infiltration, aggregation, bulk density) (Gilley and Risse, 2000).

Diet and management may also affect nutrient availability of manures. Sorenson and Fernandez (2003) noted that the fiber ($r = -0.73$) and crude protein ($r = 0.53$) content of swine diets affected the subsequent mineral fertilizer equivalent value of slurry N. Similarly, Sorenson et al. (2003) noted that the dietary crude protein ($r = 0.71$) and crude fiber ($r = -0.73$ to -0.82) content of dairy cattle diets were correlated to the subsequent mineral fertilizer equivalent value of slurry N. The plant availability of slurry N was correlated with the ammonium content ($r^2 = 0.53$) and negatively correlated to the slurry C:N ratio ($r^2 = 0.67$) and dry matter:N ratio ($r^2 = 0.58$).

Ebeling et al. (2002) noted that excessive addition of inorganic P to dairy diets (0.31 vs. 0.49%) produced manures with higher P concentrations (0.48 vs. 1.28% P). When applied at equal N application rates, total P runoff was 6 times greater and dissolved reactive P runoff was 10 times greater for the high-P manure than the low-P manure. When applied at equivalent P levels, total P runoff was 2 times greater and dissolved reactive P runoff was 6 times greater for the high-P than low-P manure.

Koelsch (2000) noted that decreasing dietary P concentration of beef finishing diets from 0.45 to 0.22% decreased the corn acres required for manure application by 60%. Powell et al. (2001; 2002) noted that decreasing dietary P concentration of dairy diets from the national average of 0.48% to a concentration of 0.38% (deemed to be adequate by several research studies), would decrease land required for manure application by 39%.

Composting of animal manures can decrease application costs, decrease mass and water content, suppress pathogens, destroy weed seeds and feed additives, and result in smaller and more uniform particle size, and decreased odor emissions. However, during composting there is a 30 to 50% decrease in mass due to losses of C (46 to 62%) and N (19 to 42%) (DeLuca and DeLuca, 1997; Eghball et al., 1997). This decreases the N:P ratio and increases the concentration of other nutrients, salts, and minerals.

Depending upon the type of housing and manure handling system, appreciable quantities of manure nutrients can end up in lagoons or retention ponds. Nutrient concentrations in retention ponds will vary depending upon rainfall, evaporation, changes in pond volume, and N volatilization. In general, the high concentrations of salt, P or other nutrients in many lagoons and retention ponds limit their use as fertilizer (Rhoades et al., 2003).

CONCLUSIONS

The general public is demanding that everyone - and that includes agriculture - be held accountable for their impact on the environment. This means that today, and in the future, we will need to balance animal production with environmental risks. "Safety margins" in diet formulation may have to be decreased. At the present time the biggest "cushion" available is probably toward the end of the feeding period and late in lactation - the time period when we can probably have the greatest effect on both nutrient excretion and ammonia emissions. The use of many technologies such as phase feeding and precision feeding is limited at the present time. Adding a "manure removal charge" to the cost of feed ingredients may be beneficial in limiting the use of feeds that may produce environmental problems. The major factor limiting use of manure nutrients is often farmers' preference for inorganic fertilizers; thus, to make manure more attractive as a fertilizer, livestock producers need to treat manures as a co-product, rather than as a waste to be disposed of at the cheapest price.

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Table 1. Calculated effects of feeding to meet the CP requirements of 50%, 84%, 100%, or of precision feeding on steer performance and N excretion: 100 head of 880 lb., large frame steers (NRC, 1984)

Item	50%	84%	100%	Precision
Ration cost, $ / ton	108	110	112	109
N intake, lb/d	34.8	39.8	45.1	37.4
N excreted, lb/d	27.9	31.9	36.1	29.9
ADG, lb	2.73	3.39	3.52	3.52
Feed/gain	8.00	6.49	6.25	6.25
Cost of gain, $/cwt	43.20	35.70	35.00	34.06
Days to 1,280 lb	146	118	114	114
N excreted, lb/100 steers	4,073	3,764	4,115	3,409

Table 2. Variation in composition (% DM) of sorghum, corn, and complete diets at a commercial feedyard over 8 years (diet formulated to contain 13.5% CP; no supplemental P was added) (Cole, 2003).

Item	Crude protein,%			P,%		
	Sorghum	Corn	Diet	Sorghum	Corn	Diet
Number of samples	69	32	110	68	32	110
Mean	11.15	9.25	13.74	0.28	0.25	0.36
Std. Dev.	1.05	1.14	0.92	0.05	0.04	0.07
Maximum	13.29	12.31	16.34	0.45	0.39	0.64
90%	12.40	10.51	14.96	0.33	0.28	0.42
75% quartile	11.80	9.58	14.33	0.31	0.26	0.39
Median	11.32	9.06	13.68	0.26	0.24	0.35
25% quartile	10.73	8.55	13.13	0.24	0.23	0.32
10%	9.49	8.30	12.75	0.23	0.21	0.30
Minimum	8.29	6.84	11.13	0.19	0.20	0.18
Skewness	-0.63	1.08	0.16	1.11	2.12	1.37
Kurtosis	0.22	2.05	0.54	1.38	6.94	4.58
NRC, 2000	12.6	9.8	--	0.34	0.32	--

Table 3. Variation in crude protein analysis of five feedlot diet samples obtained at unloading from a feed truck (diets formulated to contain 13.5% CP) (Cole 2003).

Sample #	Lab 1	Lab 2	Lab 3	Mean	Std dev
1	14.3	14.2	14.1	14.2	0.10
2	13.4	14.0	13.0	13.5	0.50
3	13.2	14.5	13.0	13.6	0.81
4	13.6	14.4	12.7	13.6	0.85
5	13.5	13.9	12.8	13.4	0.56
Average	13.6	14.2	13.1	13.7	--
Std dev.	0.42	0.25	0.56	0.61	--
CV,%	3.1	1.8	4.3	4.45	--

Table 4. Effects of P bioavailability on dietary needs and P excretion of a 1,000 lb beef cow on native range and 1,500 lb dairy cow in dry lot.

Item	Defluor. Rock Phosphate	Dicalcium Phosphate	Monocalcium Phosphate	Phosphoric acid
% P in source	18.0	18.5	21.0	25.0
Absorption coefficient	65%	75%	75%	90%
Cost, $/ton	370	350	360	262
Beef Cow				
P excreted, g/d	3.33	2.06	2.06	0.69
P source needed, g/d	52.81	44.53	39.23	27.46
Fecal P from supplement, lb per 100 cows per yr	267.5	165.6	165.6	55.2
Cost, $/100 cows per yr	785.41	626.5	607.1	289.2
Dairy cow				
P excreted, g/d	3.63	2.25	2.25	0.75
P source needed, g/d	57.6	48.6	42.8	30.0
Fecal P from supplement, Lb/100 cows per year	291.7	180.6	180.6	60.2
Cost $/100 cows per yr	856.51	683.20	662.06	315.38

Assumes beef cow requires 6.2 g of absorbable P /d in supplement and dairy cow requires 6.7 g/d.

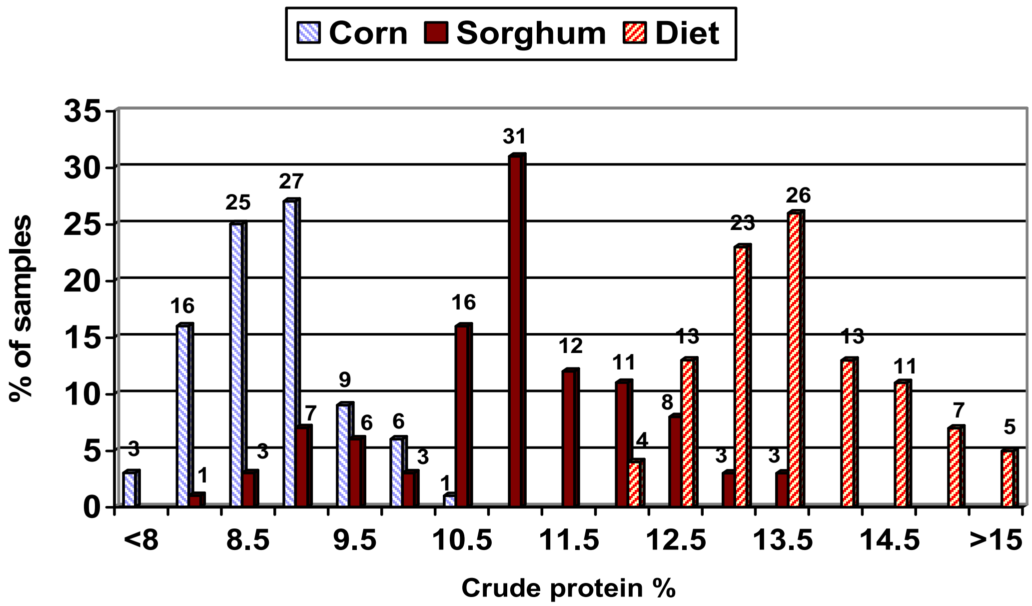

Figure 1. Distribution of crude protein concentrations in feed grain and diet samples (% of samples with designated CP concentration - rounded to nearest 0.5%). Diet formulated for 13.5%CP.

CONSERVATION VS CONVENTIONAL TILLAGE, FALL DOUBLE CROPPING AND COVER CROP EFFECTS ON CROP WATER USE IN SUBTROPICAL SOUTH TEXAS

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ABSTRACT

Water for irrigation is becoming increasingly restricted, and production costs continue to rise in subtropical South Texas. Conservation tillage offers potential advantages in both areas, but requires effort to implement successfully. A study is currently underway in the Lower Rio Grande Valley to compare conservation vs conventional tillage and to evaluate fall double cropping and cover crops compared to fall fallow under conservation tillage. The cropping program being used is a cotton / sorghum biannual rotation. Soil water loss is reduced somewhat when crop residues are retained on the soil surface, but in-season crop water use by a spring crop is not affected by tillage method. In the fall, double cropping and cover crops withdraw significant water from the soil compared to fallow. In a single year, cotton yields were not affected by tillage method, but were lower following a fall double crop or cover crop compared to fall fallow. Grain sorghum production showed some improvement due to conservation tillage compared to conventional tillage for both fall fallow and fall double crop, but for an unknown reason, not for fall cover crop. Soil organic matter content has risen from 0.8% to 1.17% over a 4 year period, but shows no affect due to the cropping treatments applied. Some water savings have been found for conservation tillage, but the effects are not great and depend on rainfall patterns. Planting and weed control are major challenges, but substantial reductions in cost can be achieved.

INTRODUCTION

Water availability for irrigation has become a major concern for South Texas. Conservation tillage offers the advantage of reduced field operations compared to conventional tillage which should result in lower costs, better yields and reduced risk (Ribera et al., 2004; Smart & Bradford, 1999). Water loss is reduced, soil structure improves (Wright & Hons, 2005), and oxidation of organic residues is not as rapid (Salinas-Garcia et al., 1997) as tillage is reduced. Hopefully this will result more efficient water use as well as lower costs. No studies, however have thus far reported any water savings due to reduced tillage, and Licht & Al-Kaisi (2005) reported that soil moisture storage and crop water use efficiency were not affected by tillage system in Iowa. Double cropping and cover crops offer the potential to increase organic matter accumulation improving soil properties, but will increase initial water requirements. Planting and weed control are major challenges for implementing conservation tillage. The objective of this study is to compare conservation vs conventional tillage, and also to evaluate fall double cropping and cool season cover crops compared to fall fallow under conservation tillage.

MATERIALS AND METHODS

The study is being conducted in Lower Rio Grande Valley of Texas, an area with a climate that is subtropical (average daily temperature ranges from a high of 84^{o}F in July to a low of 60^{o}F in January), and semiarid (average annual rainfall <24 in.). A biannual cotton sorghum rotation is being grown, and four cropping treatments are being applied: 1) conventional tillage - fall fallow; 2) conservation tillage - fall fallow; 3) conservation tillage - fall double crop; 4) conservation tillage - fall cover crop. The double crops are corn following cotton, and soybean following sorghum; and the cover crops are black oats following cotton, and hairy vetch following sorghum. Spring crops are being furrow irrigated as required, and fall crops are being grown without irrigation. Treatments are being applied in plots16 rows wide spaced 40 in. apart by 150 ft in length, and are replicated 4 times in a randomized block design. The study was initiated in the fall of 2002 and is currently in the 4th spring crop, which will be the completion of the 2-year rotation for the 2nd time.

Conventional tillage consists of shredding following crop harvest, disking several times, deep chisseling in 2 directions, disking several times again, then bedding up the land. The field is cultivated as required to control any weeds until the next crop is planted, and as the crop is grown. Conservation tillage attempts to leave previous crop residues on the soil surface as long as possible, and to reduce tillage operations. Cultivation is typically performed prior to any furrow irrigation in order to maintain raised beds to facilitate furrow irrigation. Weed control is performed using herbicides.

Parameters being measured include various crop responses, irrigation requirements and changes in soil properties. Data was analyzed statistically using analysis of variance and mean comparisons using Duncan's multiple range test.

RESULTS AND DISCUSSION

The primary differences in soil water use between the tillage & cropping treatments in this study occurred during the fallow periods due to differences in the cover that was left on the soil surface, and in the fall due to differences in water use by the crop being grown (Fig. 1). Water use by the spring crops was affected only slightly by tillage and soil cover, cotton using between 30.6 and 32.4 inches and sorghum using between 17.6 and 18.5 inches of water. Water loss during the fallow periods was reduced 25% by the retention of crop residue on the surface.

Where no fall crop was grown, conservation tillage resulted in an average 11.5% reduction in water use compared to conventional tillage. The fall cover crops used an average 11.3 inches of additional water, but over half of that was recovered through savings from the reduced water loss due to the surface residue. Fall double crops use an additional 15 to 24 inches of water. Only about a third of this is recovered by reduced losses due to the crop residues. These differences are reflected in the amount of irrigation water required to furrow irrigate the cropping treatments the following spring (Fig. 2).

Cotton yields were not significantly affected by conservation tillage compared to conventional when left fallow in the fall, but both fall double cropping and a cover crop reduced cotton yields (Fig. 3). Grain sorghum production showed some improvement due to conservation tillage compared to conventional tillage for both fall fallow and fall double crop, but for an unknown reason, not for fall cover crop (Fig. 4).

Soil NO_3^--N levels measured in January were highest for fall fallow (conservation and conventional tillage) compared to fall double cropping and cover crops, which may reflect immobilization of soil N by the fall crop (Fig. 5). Soil N availability has been reported in other studies to be reduced by plant additions in the short term but enhanced in the long term (Franzleubbers et al., 1995). Organic matter contents rose from 0.8% at the initiation of this study to 1.17% after 3 years, but show no statistically significant differences due to the tillage treatments applied. Other studies have reported increases in organic C particularly near the surface at some point in time under no-till (Franzluebbers et al., 1995; Salinas-Garcia et al., 1997; Wright & Hons, 2005), but no increase in organic matter levels have been reported for any reduced tillage system that involves at least some tillage.

CONCLUSIONS

Conservation tillage in subtropical South Texas offers advantages over conventional tillage, but also poses significant challenges. New procedures and equipment modifications are required. Planting and weed control are difficult, but adequate yields can be maintained. Water savings are erratic depending on rainfall pattern, but improved soil moisture status at any given time would improve the changes of making a crop when drought conditions occur. Differences in soil water status so far have been due only to crop and surface residues, and not due to any long term changes in soil properties. Substantially lower costs, however, due to fewer field operations would be a definite benefit of conservation tillage.

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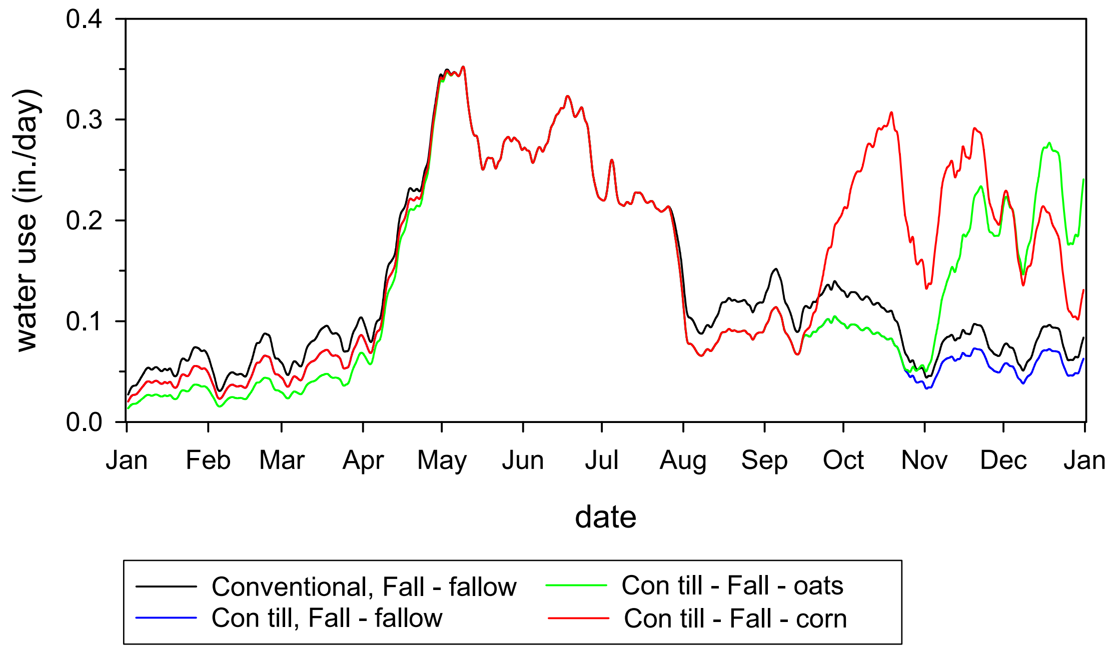

Figure 1. Daily crop water use based on evapotranspiration for the 4 cropping treatments in the cotton – corn/oats year.

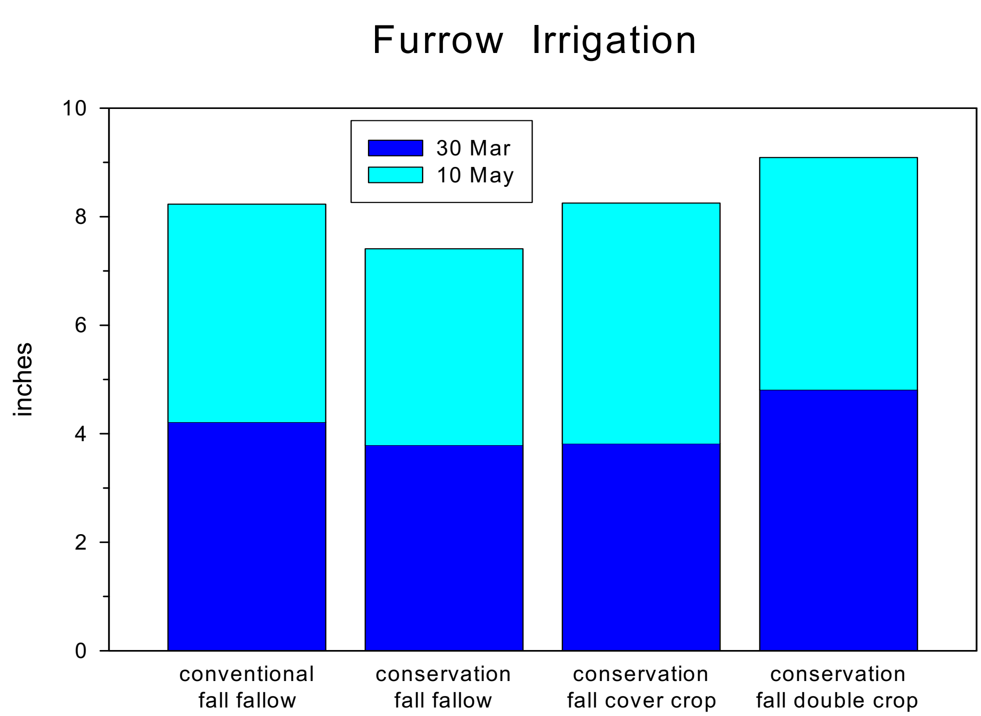

Figure 2. Amount of irrigation water applied to the 4 cropping treatments on 2 dates.

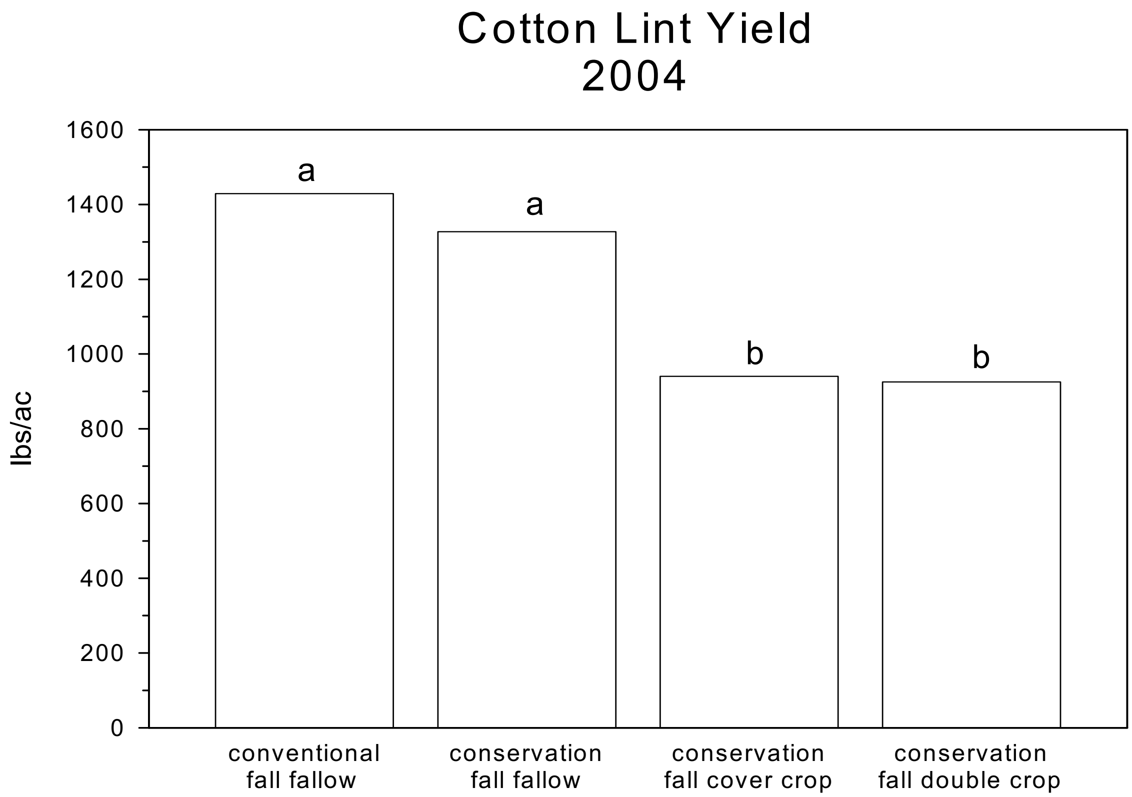

Figure 3. Cotton yields for the 4 cropping treatments.

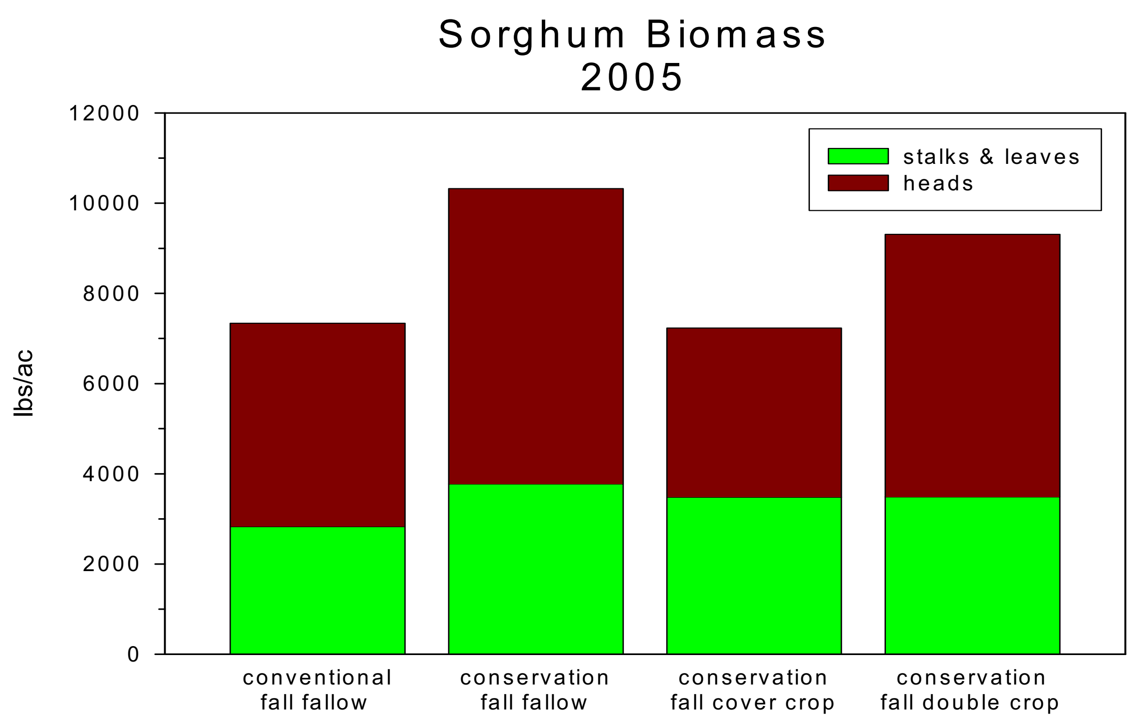

Figure 4. Grain sorghum stalk, leaf and head production for the cropping treatment.

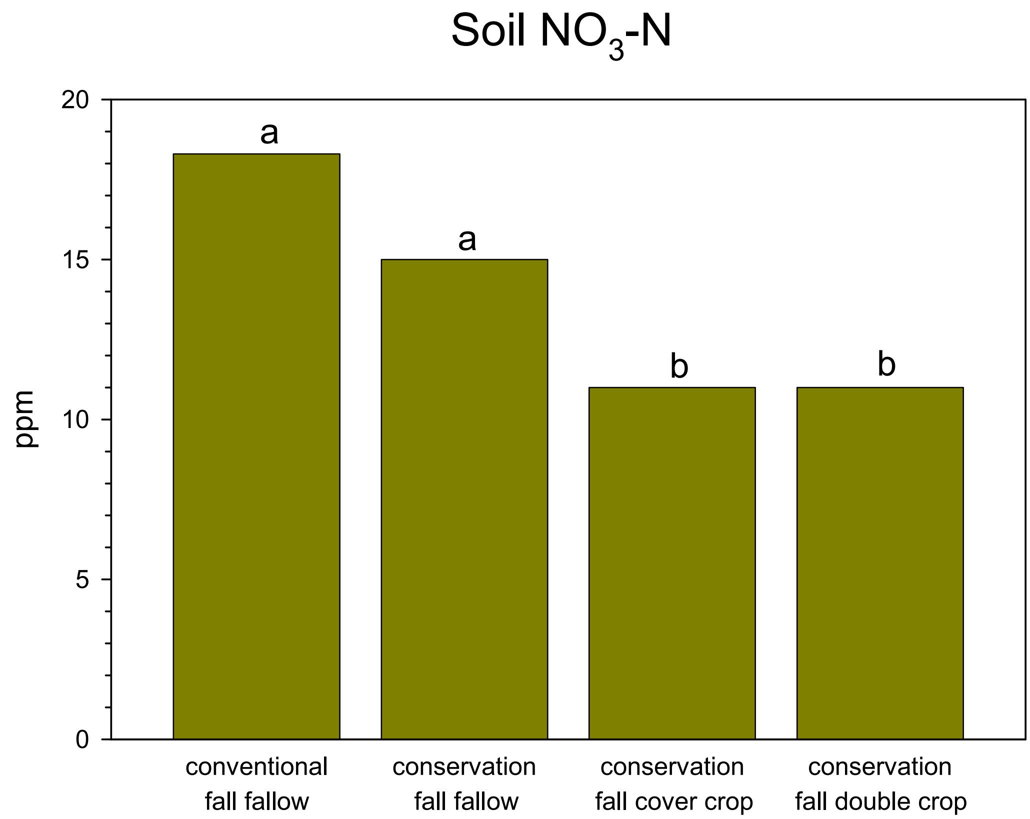

Figure 5. Soil nitrate-N levels for the 4 cropping treatments following the 2nd full crop year (cotton – corn/oats).

SOUTHERN HIGH PLAINS CONSERVATION SYSTEMS EFFECTS ON THE SOIL CONDITIONING INDEX AND OTHER SOIL QUALITY INDEXES

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ABSTRACT

The Soil Conditioning Index (SCI) has been proposed to predict the consequences of management actions on the state of soil organic carbon (SOC). The index was developed based on research in humid, temperate, loamy soils but has not been tested for many other conditions. In this project, we determine the effects of management on SOC in semiarid, thermic, sandy soils. Study sites were located in the Southern High Plains of west Texas (SHP) where long-term native range or grasslands were adjacent to cropland. Agroecosystems studied included native rangeland, conservation grassland, cotton, wheat, wheat-cotton rotations, high residue sorghum/forages, and a sunflowers wildlife planting. The cropland included irrigated and dryland, conventionally-tilled and no-tillage systems. Three replications were sampled on each field. Soil properties measured in the upper 10 cm were soil texture, bulk density, pH, phosphorus, nitrate and total nitrogen, total organic and particulate organic matter carbon, and wet aggregate stability. The SCI was determined using RUSLE2. Soil conditioning index values varied from -1.49 for conventionally-tilled dryland cotton to 2.29 for the conservation grassland. The SCI was negative for all conventionally tilled sites and positive for the native rangeland, conservation grassland and all no tillage sites with the exception of a low production, no tillage dryland wheat site. The SCI was most strongly correlated with the average residue production ($r=0.67$) as estimated in RUSLE2 and particulate organic matter ($r=0.53$). In this study, the OM sub-factor of SCI was not correlated with SOC mass but was correlated with particulate organic matter carbon ($r=0.42$; $P<0.007$) and was most strongly correlated with the average residue production ($r=0.71$; $P<0.0001$).

INTRODUCTION

The USDA, Natural Resources Conservation Service has adopted the SCI to evaluate cropland management systems in the US. The SCI is a tool used to predict the consequences of management actions on the state of SOC, a soil quality indicator. Organic matter is a primary indicator of soil quality and an important factor in carbon sequestration and global climate change.

The index predicts qualitative changes in SOC in the top 10 cm (4 inches) of soil based on the combined effects of three determinants of organic matter using the following equation:

$$SCI = [OM \times (0.4)] + [FO \times (0.4)] + [ER \times (0.2)] \quad [1]$$

where OM represents the organic material or biomass produced and returned to the soil, FO signifies field operations including tillage and other field procedures, and ER corresponds to the influence of wind and water erosion (NRCS, 2003). Note that OM and FO each account for 40% of the final SCI value and wind and water erosion represent 20%.

The SCI is an important soil management index and is required by several criteria of practice standards, including the Conservation Crop Rotation (328) practice standard and as an additional criteria in the Residue and Tillage Management - No Till/Strip Till/Direct Seed (329) practice standard, and is specified for use in the Conservation Security Act of 2004. However, only one study testing the SCI for various conservation systems has been reported.

The SCI was developed based on research conducted from 1948 to 1959 in a humid region with high clay soils at Renner, Texas, USA. Further testing of the concept was provided using data from Iowa and Montana. An evaluation of SCI using nine long-term carbon studies found that positive trends in carbon followed positive trends in SCI and negative SCI trends were associated with negative carbon trends (Hubbs et al., 2002). Correlations of carbon and SCI were improved when data were separated by states.

The SCI assumes tillage reduces SOC and that maintaining organic residues will maintain and increase soil organic levels. The amount of reduction of SOC due to tillage and erosion depends on the native level that may be sustained for a given site and region. Research studies have evaluated the amount of SOC and other soil quality indicators for loamy SHP soils (Potter et al., 1997; Unger, 2001) but little data is available for sandy soils. Previous research from a sandy soil in the SHP of Texas has shown that tillage of long-term grassland will reduce SOC levels by 50% (Zobeck et al., 1995). In a companion study to this study (Bronson et al., 2004), the total soil carbon in the upper 30 cm was 34 Mg ha^{-1} for native rangeland and 23 Mg ha^{-1} for cropland soils. Total soil C in conservation grassland land was greater than cropland soils only in the 0- to 5-cm layer, and was 24 Mg ha^{-1} in the upper 30 cm. However, considerable uncertainty still exists in the application of the SCI concept and its relation to SOC and other soil quality parameters in warm, semiarid regions, particularly in sandy soils such as those that occupy millions of acres in the SHP. In this study, we relate SCI values with other soil quality parameters for a wide variety of SHP land management systems in sandy soils of this semi-arid, hot region.

MATERIALS AND METHODS

We identified 54 field sites in six counties (Crosby, Cochran, Hockley, Howard, Lubbock, and Terry) across the SHP that represented major cropping systems, and conservation planted and native grasslands (Fig. 1). Twelve agroecosystems were sampled (Table 1). Most conservation grassland sites had been in grassland for at least 10 years and are adjacent to conventionally

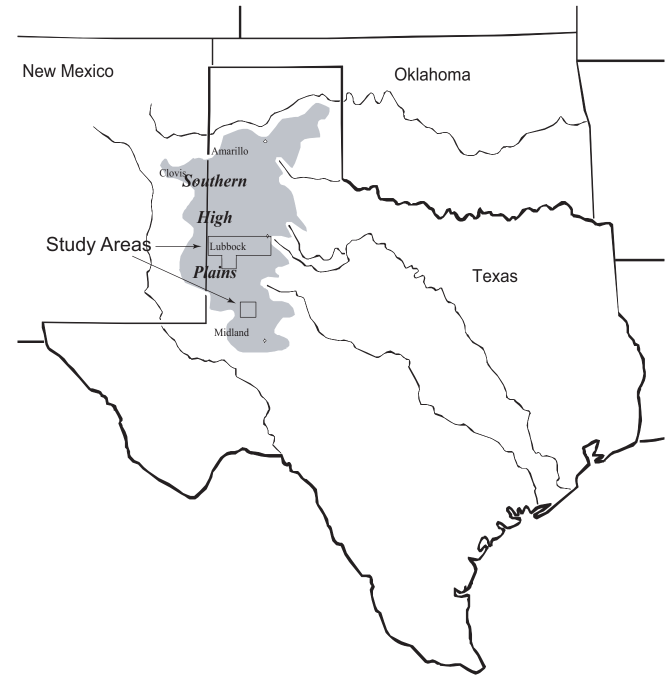

Figure 1. Location of study sites.

managed fields with the same soils. We also located conservation systems (such as no tillage systems) nearby in the same soil when available.

Each field site was sampled at the following depths: 0-5, 5-10, 10-15, 15-30, and 30-60 cm. This study reports the average or cumulative sums of soil properties from 0-10 cm, corresponding to the depths modeled by the SCI (Tables 1 and 2). Three replications were sampled in each site. Samples were collected with a Giddings probe, sampling five cores per replication. Bulk density was determined using the soil cores (Blake and Hartge, 1986). Bulk samples were collected using a shovel for determination of the wet aggregate stability. Soil subsamples were air-dried, ground overnight in a roller mill and total C and N were determined using the Vario Max Elementar[1] CN analyzer (D-63452 Hanau, Germany). Soil texture was determined using a Beckman-Coulter LS230 (Zobeck, 2004). Wet aggregate stability was measured on 2-g of 1 to 2-mm diameter aggregates by the method described by Kemper and Rosenau, (1986). The pH values were determined on air-dried soil (<2.mm) using a 1:1 soil:water ratio (Watson and Brown,1998). Nitrate nitrogen was determined by flow injection analysis (Lachat Instruments., 2000). Phosphorus was measured using the Olsen ($NaHCO_3$) procedure (Frank et al., 1998). Particulate organic matter carbon (POMC) was determined according to the method of Gregorich and Ellert, 1993.

The SCI values and sub-factors were determined using RUSLE2 version 1.25.8 (Dec, 2005) (http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm). Individual field management practices were established using producer surveys. Values for specific SCI sub-factors (Eq. 1) for organic matter (OM), field operations (FO), erosion (ER), a soil tillage factor (STIR), and water erosion were determined by RUSLE2 (Table 3). Wind erosion estimates are also needed to determine SCI, for fields where wind erosion is active, but wind erosion is not determined by RUSLE2 and must be provided by another method. Wind erosion was estimated using an MS Excel spreadsheet program, written by USDA-NRCS agricultural engineers and agronomists, based on the Wind Erosion Equation (Woodruff and Siddoway, 1965). The program calculates erosion using the management period method. The observed values for the crop/plant residues for each management system were determined by clipping rangeland and grassland plots and using producer survey crop yield results for cropped fields (Table 3). Plot clipping followed the

[1]Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA-ARS, USDA-NRCS, or Texas A&M University.

Table 1. Selected average soil physical properties by agroecosystem (0 to 10-cm depth).

Agroecosystem	Obs.	Sand	Clay	Texture	Bulk Density	Aggregate Stability
		----- % -----			lbs ft^{-3}	%
Native Rangeland	22	61.6 (2.6)†	19.7 (1.4)	FSL	82.4 (1.2)[H]	39.4 (2.8)
Conservation Grassland	27	74.7 (2.7)	14.5 (1.2)	FSL	88.6 (1.2)	23.3 (2.9)
Dryland Cotton CT‡	41	74.5 (2.1)	15.2 (1.1)	FSL	82.4 (0.6)	9.6 (0.9)
Dryland Cotton NT	3	79.9 (1.5)	12.7 (0.8)	FSL	82.4 (1.9)	6.3 (0.1)
Irrigated Cotton CT	6	82.4 (2.9)	11.4 (1.3)	LFS	84.3 (1.2)	7.0 (1.3)
Dryland High Residue	3	82.4 (0.6)	10.7 (0.2)	LFS	83.7 (0.6)	14.8 (2.9)
Terminated Wheat/Cotton CT	2	73.3 (6.7)	15.7 (2.7)	FSL	78.7 (3.1)	10.8 (-)
Terminated Wheat/Cotton LT	8	82.3 (2.7)	11.4 (1.4)	LFS	84.3 (0.6)	9.7 (1.9)
Dryland Wheat NT	3	73.6 (1.6)	15.5 (1.1)	FSL	80.5 (2.5)	8.7 (0.7)
Wheat/Cotton Rotation CT	10	74.4 (4.4)	16.7 (2.7)	FSL	85.5 (1.9)	8.1 (2.2)
Wheat/Cotton Rotation NT	9	70.8 (5.8)	14.6 (2.1)	FSL	84.9 (1.2)	12.3 (2.1)
Sunflowers for Wildlife	3	51.3 (2.0)	24.0 (1.5)	SCL	83.0 (1.9)	32.6 (3.5)

† - Sandard errors in parentheses; FSL fine sandy loam; LSF loamy fine sand; SCL sandy clay loam

‡ - CT Conventional tillage; NT No tillage; LT Limited tillage.

procedures outlined by the USDA-NRCS National Range and Pasture Handbook, Chapter 4 (http://www.glti.nrcs.usda.gov/technical/publications/nrph.html).

RUSLE2 calculates the average annual residue production based on the observed residue values (Ave-Res in Table 3) and the amount of residue assumed in SCI to maintain constant levels of organic matter in a given climate and soil texture (Main-Res in Table 3), but the results are not shown. These annual residue production and maintenance values were determined using previous versions of an MS Excel-based SCI calculation program called the Soil Conditioning Index Worksheet, Version 24 (March 2003) or Version 25 (April 2003). Statistical analyses were performed using procedures of SAS ver. 9.1 (SAS, 2002).

RESULTS AND DISCUSSION

The agroecosystems in this study were dominated by fine sandy loams and loamy fine sands (Table 1). Only one agroecosystem, the plot that had a wildlife sunflower planting in a conservation grassland field (sun flowers for wildlife), had a sandy clay loam texture.

The no tillage and limited tillage sites had the highest phosphorus content, probably related to surface application of fertilizers (Table 2).

The SCI was negative for all conventionally-tilled sites and positive for the native rangeland, conservation grassland and all no-tillage sites with the exception of the dryland wheat no-tillage site (Fig.2). The no-tillage dryland wheat field had a hay yield of 0.75 tons/acre, resulting in a low negative SCI value (-0.045). The SCI did not exceed 0 until the hay yield was changed to 1.4 tons/acre.

Since the SCI is a tool used to predict the consequences of management actions on the state of SOC, it is expected that the SCI values would be correlated with organic carbon/matter-related properties. The SCI was most strongly correlated with the average residue production as estimated in RUSLE2 and particulate organic matter (Table 4).

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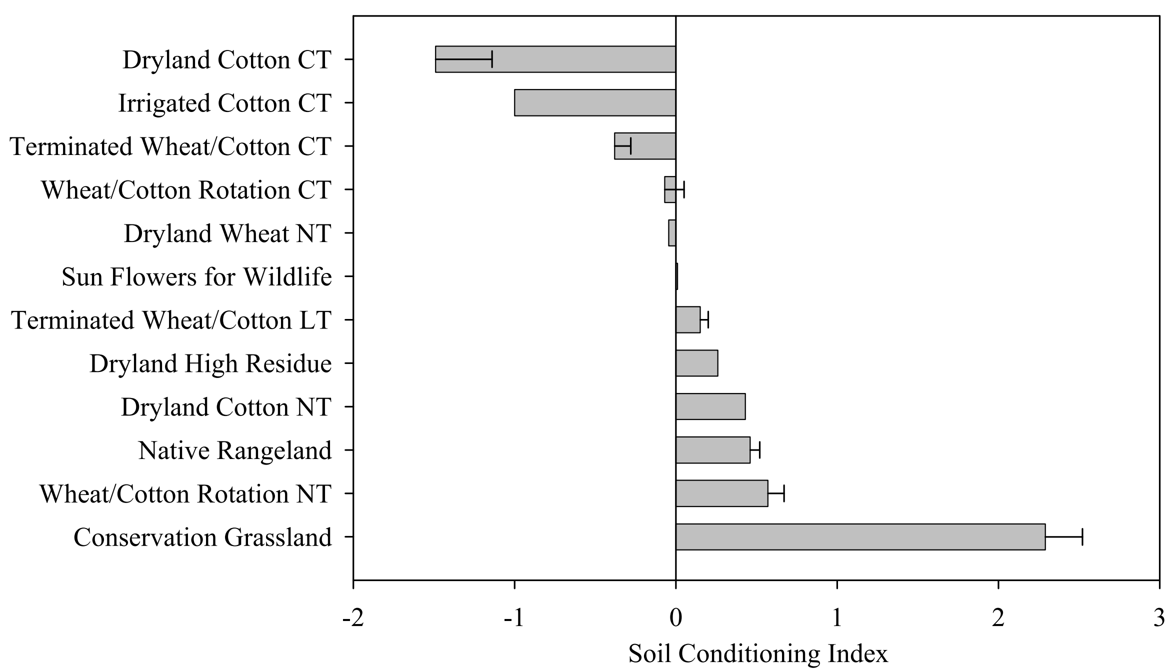

Figure 2. Soil conditioning index by agroecosystem. Error bars are standard errors.

Table 2. Selected average soil chemical properties by agroecosystem (0 - 10-cm depth).

Agroecosystem	Obs.	pH	NO^3-N	Olsen-P	Total Nitrogen ------ Sum 0-10cm -----		Total Organic Carbon		Particulate Organic Matte
					%		Mean 0-10cı	Sum 0-10cm	Sum 0-10cm
			------- ppm -------		%	lbs ac^{-1}	%	------- lbs ac^{-1} -------	
Native Rangeland	22	7.2 (0.1)†	4.7 (1.4)	5.0 (0.4)	0.08 (0.01)	902 (80)	1.0 (0.1)	11279 (1081)	4019 (625)
Conservation Grassland	27	7.4 (0.1)	1.6 (0.3)	7.6 (1.0)	0.06 (0.01)	705 (80)	0.6 (0.04)	8082 (911)	2858 (625)
Dryland Cotton CT‡	41	7.4 (0.1)	9.3 (1.4)	12.3 (0.8)	0.04 (0.0)	482 (45)	0.5 (0.06)	5724 (750)	893 (179)
Dryland Cotton NT	3	6.3 (0.1)	10.2 (1.0)	52.0 (2.0)	0.02 (0.0)	205 (9)	0.2 (0.01)	2724 (89)	-
Irrigated Cotton CT	6	7.7 (0.1)	5.9 (1.3)	6.8 (0.7)	0.04 (0.01)	527 (152)	0.5 (0.10)	5679 (1313)	893 (357)
Dryland High Residue	3	7.9 (0.1)	4.5 (0.4)	13.7 (1.6)	0.04 (0.01)	509 (89)	0.4 (0.04)	4340 (455)	-
Terminated Wheat/Cotton CT	2	7.8 (0.2)	18.5 (10.4)	8.5 (1.0)	0.05 (0.01)	572 (134)	0.5 (0.2)	6072 (1831)	804 (-)
Terminated Wheat/Cotton LT	8	7.8 (0.1)	4.4 (1.2)	25.4 (3.5)	0.03 (0.01)	402 (71)	0.5 (0.2)	6037 (2152)	982 (0.0)
Dryland Wheat NT	3	7.4 (0.3)	9.3 (1.8)	9.3 (1.1)	0.06 (0.01)	652 (63)	0.6 (0.1)	7474 (964)	1875 (-)
Wheat/Cotton Rotation CT	10	7.8 (0.1)	6.5 (1.2)	17.9 (2.1)	0.05 (0.01)	589 (80)	0.5 (0.05)	6081 (625)	893 (0.0)
Wheat/Cotton Rotation NT	9	7.2 (0.1)	15.3 (3.4)	38.5 (4.6)	0.05 (0.01)	607 (152)	0.5 (0.12)	6019 (1375)	2143 (536)
Sunflowers for Wildlife	3	6.8 (0.04)	12.1 (2.0)	3.7 (0.9)	0.08 (0.00)	920 (27)	1.0 (0.2)	11618 (1920)	-

† - Standard errors in parentheses

‡ - CT Conventional tillage; NT No tillage; LT Limited tillage.

Table 3. Soil conditioning index (SCI) subfactors by agroecosystem.

Agroecosystem	Obs.	OM†	FO	ER	STIR	Wind Eros	Water Eros	SCI	-------- Ave-Res --------		------- Main-Res -------	
						------ tons ac^{-1} -----			lbs ac^{-1}	Mg ha^{-1}	lbs ac^{-1}	Mg ha^{-1}
Native Rangeland	8	-0.31 (0.15)‡	1.00 (0.00)	0.95 (0.02)	0.49 (0.00)	0.0 (0.0)	0.14 (0.04)	0.46 (0.06)	5195 (1042)	5.82 (1.17)	6616 (284)	6.90 (0.32)
Conservation Grassland	11	4.22 (0.58)	1.00 (0.00)	1.00 (0.00)	0.15 (0.00)	0.0 (0.0)	0.0 (0.0)	2.29 (0.23)	7369 (1176)	8.25 (1.32)	6970 (144)	7.81 (0.16)
Dryland Cotton CT††	17	-0.41 (0.13)	0.08 (0.06)	-6.79 (1.67)	92.3 (6.4)	18.1 (4.3)	1.7 (0.2)	-1.49 (0.35)	1492 (158)	1.67 (0.18)	7014 (186)	7.85 (0.21)
Dryland Cotton NT	1	-0.17	0.97	0.58	3	1	0.07	0.43	2856	3.2	7834	8.77
Irrigated Cotton CT	2	-0.52 (0.03)	-0.28 (0.01)	-3.55 (0.05)	129.0 (1.0)	10.3 (0.0)	1.3 (0.2)	-1.00 (0.00)	1735 (1492)	1.94 (1.67)	7656 (0.0)	8.57 (0.0)
Dryland High Residue	1	-0.48	0.75	0.78	25.5	0	0.57	0.26	1060	1.19	8240	9.23
Terminated Wheat/Cotton CT	2	-0.62 (0.07)	0.63 (0.03)	-1.85 (0.25)	37.8 (2.7)	5.4 (1.6)	1.9 (0.9)	-0.38 (0.10)	4757 (1034)	5.33 (1.16)	7182 (474)	8.04 (0.53)
Terminated Wheat/Cotton LT	4	-0.20 (0.07)	0.52 (0.01)	0.07 (0.28)	48.2 (0.6)	0.8 (0.5)	0.6 (0.2)	0.15 (0.05)	3969 (754)	4.45 (0.84)	8299 (371)	9.29 (0.42)
Dryland Wheat NT	1	-0.88	0.93	-0.33	6.8	2.1	1.3	-0.05	409	0.46	6708	7.51
Wheat/Cotton Rotation CT	3	-0.32 (0.20)	0.59 (0.07)	-0.87 (0.32)	42.1 (6.6)	3.9 (0.4)	0.9 (0.4)	-0.07 (0.12)	1499 (277)	1.68 (0.31)	7340 (316)	8.22 (0.35)
Wheat/Cotton Rotation NT	3	0.05 (0.24)	0.93 (0.04)	0.89 (0.08)	6.9 (3.8)	0.03 (0.03)	0.25 (0.18)	0.57 (0.10)	4121 (641)	4.61 (0.72)	8285 (789)	9.28 (0.88)
Sunflowers for Wildlife	1	-0.65	0.65	0.05	34.9	0.3	2.1	0.01	1279	1.43	6708	7.51

† - OM=SCI organic matter factor; FO=SCI field operations factor; ER=SCI erosion factor; STIR=SCI tillage factor; Ave-Res=average observed residue mass; Main-res=maintenance residue amount required for SCI.

‡ - Standard errors in parentheses.

†† - CT Conventional tillage; NT No tillage; LT Limited tillage.

Table 4. Pearson correlations of the soil conditioning index with selected study variables.

Source	Aggregate Stability	Particulate Organic Matter	Nitrogen Mass	Carbon Mass	Ave-Res	Wind Erosion	Water Erosion
SCI Pearson Correlation r	0.46	0.53	0.40	0.29	0.67	-0.83	-0.59
SCI Prob > r	0.0006	0.0005	0.003	0.036	<0.0001	<0.0001	<0.0001

Particulate organic matter carbon represents a fraction of the total SOC in soils. Particulate organic matter carbon by agroecosystem was less than about one-third the amount of total SOC (Table 1 and Fig. 3). The native rangeland, conservation grassland and wildlife planting had the highest SOC and POMC values (Fig 3), although there was much overlap among agroecosystems. (Due to experimental constraints, POMC was not measured on all sites.) The mean POMC of the upper 10 cm was significantly correlated with SOC mass ($r=0.40$; $P<0.0.02$) but was more highly correlated with wet aggregate stability ($r=0.71$; $P<0.001$) and nitrogen mass content ($r=0.66$; $P<0.0001$). The average residue production had about the same correlation with POMC ($r=0.37$; $P<0.02$) as SOC.

The SCI has an organic matter sub-factor (SCI-OM) that represents 40% of the final SCI value (Eq. 1). In this study, the SCI-OM was not correlated with SOC mass but was correlated with POMC ($r=0.42$; $P<0.007$) and was most strongly correlated with the average residue production ($r=0.71$; $P<0.0001$).

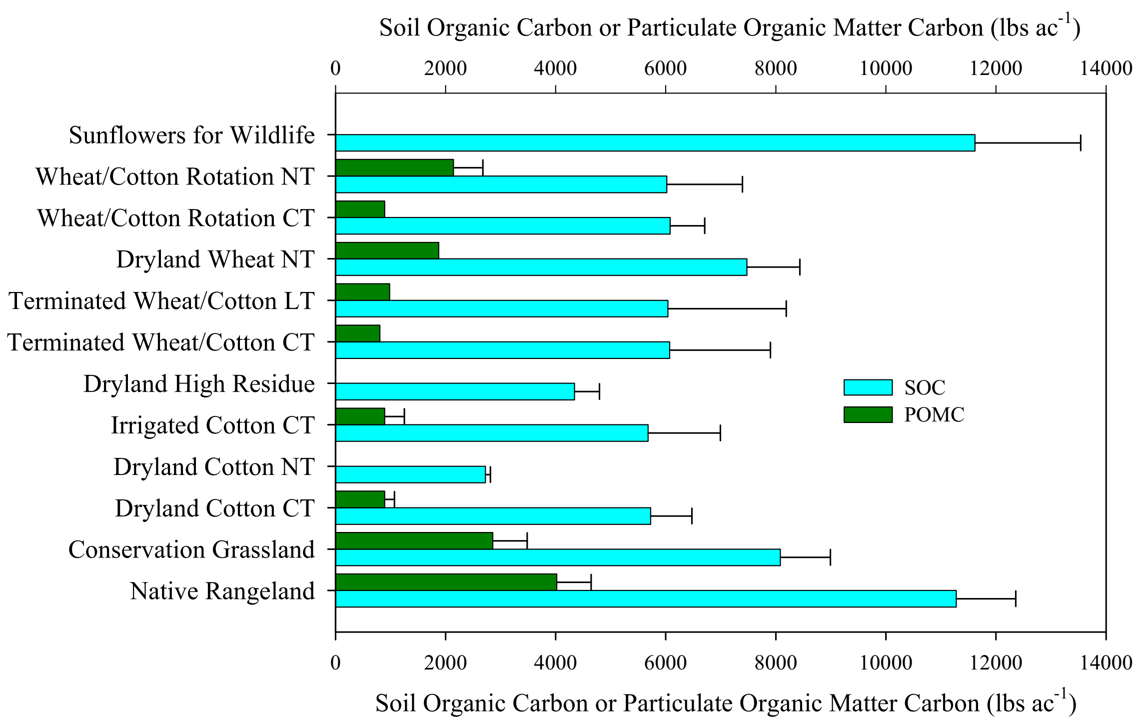

Figure 3. Soil organic carbon (SOC) and particulate organic matter carbon (POMC) by agroecosystem.

CONCLUSIONS

The SCI program implemented in RUSLE2 successfully associated the conservation grasslands, native rangelands, and no-tillage, limited (minimum) tillage and high residue croplands with positive SCI values and the conventionally-tilled fields with negative SCI values. In addition, the general trends seemed reasonable, for most situations. The conservation grasslands had the highest SCI value and the conventionally-tilled dryland cotton had the most negative SCI value.

One exception was the no-tillage dryland wheat field that had a slightly negative SCI value. This was attributed to the low residue produced in this dryland field, resulting in the lowest SCI OM sub-factor of all agroecosystems tested. The SCI value was very close to 0 (-0.05), but was still negative. To accept borderline conditions that clearly provide residue for soil cover, it may be advisable to have a buffer of plus or minus 0.1 considered as equal to 0 when assigning SCI values. This buffer may be particularly necessary in western states where the OM sub-factor in SCI may often be less than 0, even in situations with adequate cover. For example, in this study only the conservation grassland and no-tillage wheat/cotton rotations had positive SCI OM sub-factors.

Although the SCI did identify conservation systems, the stated reason for the association is not clear. Although the stated purpose of the SCI is to predict the consequences of management actions on the state of soil organic carbon, the SCI values were not strongly correlated with total SOC. The SCI values were more strongly associated with a specific form of soil organic carbon, POMC, a relatively more labile form of soil organic carbon. The SCI was even more strongly correlated with the residue production, which serves to add organic matter to the soil and protect the soil from the forces of erosion. Finally, the SCI was most strongly correlated (negatively) with wind erosion, even though the erosion sub-factor was weighted half the amount of the other SCI sub-factors. Further more detailed analysis of this data set is planned. In addition, further field testing of SCI over a wide range of climatic and agroecosystems is recommended.

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CHARACTERIZATION OF PRECIPITATION TRENDS IN THE OGALLALA AQUIFER REGION

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ABSTRACT

Ideally, researchers and practitioners would like the ability to forecast precipitation patterns so that strategies can be developed to manage limited water resources. This is particularly important for regions where depleting aquifer is the main source of water for irrigated crops. Precipitation trends affect crop growth and management practices, yet current precipitation forecasting capability is limited. Given the demand for such information, it seems timely that the regional and spatial variability as well as annual distribution variability should be thoroughly examined. A long-term dataset of daily precipitation at 22 stations located between -104° to -100° W longitude and 33° to 42° N latitude was used to characterize the precipitation trends within the Ogallala Aquifer Region from Nebraska to Texas Panhandle. A detailed analysis identified precipitation trends, number of events and amounts and events by class across the Ogallala Aquifer Region. More than 50 percent of the annual precipitation occurs during the cropping season (May-September). Spatial analysis indicated annual precipitation increases with decrease in longitude (west to east). The smaller precipitation events (0.25-5 mm) account for more than 50 percent of the events per year, but produce only 13.7 percent of the annual average precipitation. Events with 5 to 50 mm account for 41 percent of the total events per year, but produce about 77 percent of the total annual precipitation. Results indicate there has been an increase in the number of precipitation events, mainly due to increase in the number of low to moderate intensity events. This trend is consistent irrespective of rain-gauge location. It was observed that annual average precipitation has been increased but was not statistically significant.

NITROGEN FERTILIZATION AND TILLAGE INFLUENCE ON SELECTED SOIL MICROBIOLOGICAL PROPERTIES

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ABSTRACT

Soil microbes play a key role in plant nutrient availability and act as a nutrient source (N) upon their decomposition. The quantity of soil biomass and conversion of biomass N into plant-available inorganic N may be affected by soil management and fertilization practices. Increased knowledge of physical environment interactions with biological and chemical transformation affecting indigenous soil and fertilizer N is essential to a better understanding of N use efficiency by crops. Long-term tillage and N fertilization studies evaluated no-till (NT), minimum till (MT), and conventional till (CT) systems under N rates of 0, 20 and 60 kg N ha^{-1} for effects on soil microbial biomass C (SMBC) and N (SMBN) and mineralizable C and N in a long-term corn-cotton rotation. The Victoria clay (fine, hyperthermic, montmorillonitic Pellusterts) was sampled at three soil depths and at cotton planting, flowering and harvest. Because of crop residue accumulation and limited incorporation, microbial biomass C was greatest under MT followed by NT and CT. Generally, SMBC decreased with soil depth for all tillage systems. As the growing season progressed the NT consistently maintained the higher SMBC compared to the CT system. A decrease in labile C substrate quality and availability tended to decrease SMBC and SMBN through the season. Mineralizable N was higher in NT than in CT only in the surface layer regardless of N fertility rates. In all tillage systems and N fertility rates mineralizable N decreased with soil depth. Nitrogen fertilization caused increases in mineralizable N in all tillage systems but non significant increases in mineralizable C. Inorganic N averaged over N rates was some 35% higher in NT soil compared to CT at planting and 26% higher at harvest. Generally, reduced tillage such as NT and MT affected soil microbial properties in surface soils and thereby, influenced plant availability dynamics of N.

QUANTIFYING INCIDENCE OF WSMV AND IT'S IMPACT ON WATER USE AND YIELD

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ABSTRACT

Wheat streak mosaic virus (WSMV) is the predominate viral disease of hard red winter wheat in the Texas panhandle. The virus can cause significant reduction in yield. Little has been done to quantify disease incidence over a large area or investigate its impact on water use efficiency (WUE). In 2005 – 2006, a disease survey of all 26 counties in the Texas panhandle was conducted using Landsat satellite imagery. Preliminary results showed that 42,000 acres were infected with WSMV. A separate study was conducted to determine the effects of WSMV on wheat root development and water use. Two varieties of wheat, were grown in large containers under three different water regimes**,** 30, 60, and 80 percent pot capacity. Half of the plants were inoculated with WSMV and half were non-inoculated controls. The total amount of water added to each experimental unit was recorded and after approximately 12 wk plants were harvested to obtain root and top weights to calculate WUE for each treatment. During the first trial, significant differences (p=0.0001) in biomass of infected and non infected plants within the three different water treatments were recorded. In the non-inoculated treatments, biomass increased significantly with increasing water. Biomass of inoculated treatments were significantly lower and had no significant increase with increasing water. At full irrigation, infection by WSMV resulted in a 45 percent reduction in water use. These results demonstrate that WSMV is extremely widespread in the Texas panhandle and more research on irrigation scheduling of infected wheat is needed.

FORAGE PRODUCTION FOR THE HIGH PLAINS BEEF AND DAIRY INDUSTRIES

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SUMMARY

The cattle industry in the High Plains is very diversified ranging from extensive beef cattle ranching operations to intensive grazing and confinement operations in both the beef and dairy industries. Forages are an important part of all of these systems; in some, forages are the main source of nutrients while in others, forages contribute less to the daily nutrient supply but are essential for maintaining health and productivity of the cattle. The forage production systems range from perennial or annual forages fed by precipitation with little if/any other inputs to perennial or annual forages managed with irrigation and soil fertilization.

The diverse cattle production systems create a diversity of needs in terms of the seasonality of forage production, the nutritional value of the forage, and the means by which forage is harvested (grazing, hay, silage). Knowing these needs helps define the forage management practices – forage type, nutrient and water inputs, harvest requirements - required to fulfill the needs of the markets.

In extensive grazing systems based on perennial forages (native or introduced), primary management objectives are to maintain the health of the plant community and capture precipitation to support plant growth. Grazing management and suppression of undesirable plants are the primary management tools used in these systems; soil fertility may be a consideration with some introduced forages. Intensive grazing or hay systems based on perennial forages utilized introduced forages. The management objectives are similar to those mentioned previously but with added emphasis on soil fertility and irrigation inputs to efficiently enhance forage yields and nutritive value. In systems based on annual forages, a primary focus is on stand establishment and hence soil moisture, timing, plant populations become issues in addition to fertility and irrigation inputs. Producing forage for harvest (hay and silage) requires one to balance inputs to produce desired yields but also harvest timing to produce a desired nutritive value for the targeted use of the forage.

DEVELOPMENT OF A GROUND DRIVEN ROTARY SUBSOILER FOR CONSERVATION TILLAGE SYSTEMS

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ABSTRACT

Compacted soil hard-pans restrict crop growth by limiting root access to nutrient and moisture in the subsoil. Subsoiling is the main annual soil tillage practice for conservation systems which should be performed without excessively disturbing the soil surface. Various types of subsoilers are being investigated for this purpose. The objective of this study was to develop an effective subsoiler for conservation tillage systems that minimized soil disturbance and energy requirements. For these purposes, a ground-driven rotary subsoiler was designed and manufactured by dividing a 1.2 m diameter coulter into multiple shanks. Minimizing the sliding soil resistance on the side of the coulter was one of the main considerations in forming the shape of the shanks and the number of shanks. An experiment was conducted in the soil bins of the National Soil Dynamics Laboratory in Auburn, AL with different operating conditions to determine the effect of the subsoiler on soil disturbance and energy consumption. Treatments were three different subsoiler surface areas, which consist of different numbers of shanks (5, 7 and 9), different tilling depths (0.3, 0.4 and 0.5 m) and different forward speeds (5.4, 7.2 and 9 km/h). Soil cone index, bulk density and draft force were measured and statistical analysis was applied to obtained data.

TILLAGE AND GRAZING EFFECTS ON SOIL PHYSICAL PROPERTIES AND CROP YIELD

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ABSTRACT

Water conservation using deficit irrigation and dryland cropping systems are being implemented where the Ogallala aquifer limits irrigation capacity. Decreased crop productivity and profitability has encouraged integration of cattle grazing to supplement crop income, but potential soil compaction may reduce infiltration, limit root growth, and depress yield. Our objectives were to quantify the effects of grazing and tillage practices on ponded infiltration, soil density and penetration resistance with depth, crop yield, and cattle gain. Dryland wheat (*Triticum aestivum* L.) and grain sorghum [*Sorghum bicolor* (L.) Moench] were grown in a 3-year wheat-sorghum-fallow (WSF) rotation with all phases duplicated for grazed or ungrazed plots on a 40 ac. area that we split with no- or stubblemulch- tillage within three blocks (replicates). Cattle gain, crop growth and yield, and measured soil properties were compared with a randomized complete block split-split plot analysis of variance. Dryland wheat forage was sufficient for 32 days grazing with a mean gain of 120 lbs acre^{-1}, which offset the reduced wheat grain yield of 20 bu. acre^{-1} for grazed plots compared with 23 bu acre^{-1} for ungrazed wheat. With timely removal of grazing cattle from wheat, residues for fallow were unaffected by grazing and the subsequent sorghum yielded a uniform 37 bu acre^{-1}. Soil density and penetration resistance measured during fallow after wheat increased with grazing, but were unaffected during fallow after sorghum. Grazing generally depressed infiltration rates for all tillage and cropping phase combinations with the exception of the fallow after wheat no-tillage plots. Limited grazing of dryland wheat successfully increases overall productivity of the WSF cropping system by maintaining wheat grain production and adding cattle gain, but soil compaction reduces infiltration.

MONITORING TILLAGE EFFECTS ON SOIL WATER DYNAMICS USING AUTOMATED TIME-DOMAIN REFLECTOMETRY

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ABSTRACT

Tillage modifies soil physical properties near the surface, which can influence evaporation and how water is redistributed within the profile. The objective of this study was to evaluate the effects of sweep tillage soil water dynamics at a high temporal resolution. Plots were established in a fallow field under stubble-mulch tillage on a Pullman clay loam (Fine, mixed, superactive, thermic Torrertic Paleustolls). Half of the plots were periodically tilled to a depth of .08 m using a sweep plow. The remaining plots were not tilled throughout the duration of the study. Plots were kept weed free and devoid of residue throughout the study period. Soil water contents were monitored at half-hourly intervals using time-domain reflectometry at 0.05, 0.1, 0.15, 0.2, and 0.3 m. During a 123 day period from April to August, tillage decreased net water storage by 10 mm ($P < 0.05$) at 0 to 0.3 m as compared with no-tillage. Higher water contents at 0.05 and 0.1 m depths under no tillage persisted throughout the summer despite greater rainfall infiltration amounts under sweep tillage (21 mm) and the absence of residues in both treatments. Maximum daily net radiation of the tilled surface after DOY 203 ranged from 4 to 19% greater than that of the no tillage surface and these differences diminished with time after tillage. Increased soil water depletion under tillage was likely due to a change in soil hydraulic properties accompanied by enhanced vapor flow near the surface and greater absorption of radiation by a tilled surface with reduced albedo.

SOIL COMPACTION IMPACTS FROM CONSERVATION-TILLAGE IN A STOCKER/WINTER WHEAT PRODUCTION SYSTEM

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ABSTRACT

Winter wheat grown in the southern Great Plains can be used in the fall and winter as forage for beef cattle. While, fallow is a common summer practice associated with winter wheat, summer forage can possibly extend the grazing season and increase profits. But little is known about the increase grazing on soil compaction, particularly with conservation-tilled winter wheat. Soil compaction determined from two summer practices associated with winter wheat production systems (summer fallow and summer forage) were evaluated on 4 experimental paddocks at the USDA-ARS Grazinglands Research Laboratory at El Reno, Oklahoma from 1998 to 2000. Two exclosures were located in each paddock and were used as ungrazed control sites. Soil compaction impacts were determined by calculating a cone index using resistance to penetration methods. Results show that soil surface cone index values were higher in both grazing production systems as compared to the ungrazed control sites. However, as compared to ungrazed summer paddocks, the additional summer grazing of the legumes did not further increase soil compaction. The results from this study suggest that fall and winter grazing increased soil compaction, but additional summer grazing during the fallow period does not further increase soil compaction.