Proceedings of the

1993 SOUTHERN CONSERVATION TILLAGE

CONFERENCE FOR SUSTAINABLE AGRICULTURE

Monroe, Louisiana
June 15-17, 1993

"The Evolution of Conservation Tillage Systems"

Louisiana State University
Agricultural Center

U.S.
Soil
Conservation
Service

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1993 Southern Conservation Tillage Conference for Sustainable Agriculture

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The planning committee for the 1993 SCTCSA gratefully acknowledges the special assistance of Dr. William H. Brown, Dr. R. Larry Rogers, Mr. Jack Lord, and Mrs. Sheila Shirley in making plans for the conference. The committee and, especially, the editor also recognize Mrs. Darlene Regan and Mrs. Kim Guidry for the hard work and effort devoted to the assembly of these proceedings.

FOREWORD

Interest in conservation tillage in Louisiana dates back nearly 30 years. In 1964, LSU Agricultural Center researchers experimented with planting cotton into hairy vetch with a mulch tillage planter. Paraquat was applied to kill the vetch and other vegetation. They produced 2,613 pounds with conventional tillage. They repeated the trial again in 1965 with similar results.

But, in the 1960s, fuel and fertilizer were cheap, most tractors lacked the horsepower to pull a mulch tillage planter, and cultivation was essential for control of many weeds, especially johnsongrass. Although these early efforts proved successful, interest in this system did not catch on.

Rising production costs, more powerful tractors, improved herbicide technology, and public concern over soil and water conservation have led to increased interests in conservation tillage. In 1991, Louisiana farmers were practicing conservation tillage on more than 600,000 acres of the state's 3.5 million planted acres of cropland.

Conservation tillage has a wide variety of applications across Louisiana. Intensive residue management is the primary means of controlling erosion and meeting conservation compliance standards on nearly 250,000 acres of highly erodible cropland in the state. Delta row crop farmers employ conservation tillage for soil management and timely planting on their clayey alluvial soils. On the prairies of southwestern Louisiana, rice farmers are using conservation tillage to improve surface water quality.

Growth of conservation tillage in the South has been evolutionary, rather than revolutionary. In 1991, conservation tillage was used on 15 percent of the planted acreage in the Delta states, as compared with 28 percent nationwide. While this is 13 percent below the national average, 31 percent of the Delta states cropland is planted to cotton and rice. Conservation tillage technology has only recently begun to evolve for these two important crops.

The 1993 conference theme, "The Evolution of Conservation Tillage Systems," will focus on the continuing evolution of conservation tillage systems for the Southern Region, which are achieving soil and water conservation goals. We at the Louisiana Agricultural Experiment Station, the Louisiana Cooperative Extension Service, and the USDA - Soil Conservation Service appreciate the opportunity to host the 1993 conference and to further the development of conservation tillage to sustain crop production systems. "Bienvenue en Louisiane, L' etat des bayous."

Richard C. Aycock

CONTENTS

AGRI-21: A COMPREHENSIVE DEMONSTRATION OF PROFITABLE ANDD ENVIRONMENTALLY SUSTAINABLE AGRICULTURE FOR THE 21ST CENTURY

Larry A. Johnson[1]

INTRODUCTION

Farmers in the Tennessee Valley and the nation are faced with economic and environmental issues that are changing traditional agriculture. As legislative bodies impose new environmental and safety regulations on agriculture, the challenges will become more serious. These issues have the potential to adversely impact the economic viability of farmers and threaten their long-term survival.

Adjustments to these issues are complex and are not made quickly. Farmers need information on how to proceed without being subjected to undue risks. A new procedure for bridging the gap between sustainable research findings and their practical application and evaluation under farm conditions is a part of the Agri-21 Farming Systems program. The major component of this program is the whole-farm demonstration, which is used to fully integrate the issues of sustainable agriculture. It takes into consideration the entire farm, the farm family, and their resources and aspirations. These demonstration farms, called Agri-21 Farms, serve as applied research stations where innovative techniques are tested and evaluated. Agri-21 Farms also function as an educational tool for farmers, technical agricultural workers, and the agricultural community. The additional components of the program provide opportunities to test and demonstrate sustainable agriculture technology on an individual enterprise.

OBJECTIVES

The objectives of this program are (1) to develop, test, demonstrate, and evaluate technology that will be required to maintain sustainable (efficient, competitive, profitable, and environmentally acceptable) farming operations in the 21st century and (2) to educate and/or enhance the awareness of professional agricultural workers, farmers and their families the agricultural community, and the general public of critical agricultural issues and alternative solutions.

STRATEGIC METHODS

Major areas of program emphasis include environmental improvement, increased profitability, leadership development and education, and improved family finances and personal lives. Specific activities include:

Environmental

- Best management practices (BMPs) for conservation compliance, including no tillage, minimum tillage, conservation tillage, ridge tillage, winter cover crops, and crop rotations.
- Integrated pest management (IPM).
- Nutrient management on crop, pasture, and forest land.
- Wetlands management, filter/buffer strips, and farmstead environmental assessments.
- Pesticide, fertilizer, and petroleum product handling and storage.
- Livestock and household waste storage and management.
- Farmstead and feedlot stormwater management.

Financial

- The latest computerized farm planning techniques, including FINPACK and Planetor.
- The latest marketing techniques and strategies, including improved market information technologies.
- Strengthening and improving agribusinesses.

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- Exploring economical uses for farm and processing wastes.

- Economical use of pesticides and other chemicals.

- Introduction of alternative enterprises.

Education

- Conduct field days and farm tours on participating farms.

- Conduct workshops and conferences on agricultural/public policy and environmental regulations.

- Prepare brochures, handbooks, newsletters, news releases, and video productions on sustainable agriculture.

- Conduct short courses (formal training) on various aspects of sustainable agriculture.

- Incorporate the sustainability concept in school curriculums.

Leadership Development and Public Awareness

- Foster the leadership skills of participants.

- Participate in the legislative process as environmental policy affecting agriculture is developed.

- Develop partnerships with community and local governing bodies.

- Make the general public aware of the benefits of sustainable agriculture.

- Participate in Leadership Development Training workshops.

DEMONSTRATION AREA AND PROJECT DURATION

The Agri-21 Farming Systems program is conducted in the 201 counties of the seven-state Tennessee Valley region. The Agri-21 Farms are selected, or targeted, in areas that represent significant farming regions or have problems common to many farms. The Agri-21 Farming Systems program extends over a 10-year period beginning October 1, 1992. On-farm demonstrations will be conducted over a 9-year period. The final, or tenth year, is to be used for an overall program evaluation.

PROGRAM SUPERVISION

The overall direction and supervision for this program is provided by the Executive and Management committees. The Executive Committee is comprised of the seven Extension Service deans and directors of the Valley land-grant universities, a representative of a Valley 1890 land-grant institution, and a representative of a state department of agriculture. It also includes USDA agency heads and other government entities, non-profit agricultural organizations, as well as a representative from the Tennessee Valley Region Association of Demonstration Farm Families. The committee meets annually to establish general program guidelines and policy, review progress and plans, assist in securing project funding, and issue special directives to the Management Committee.

The Management Committee is charged with Valley-wide program coordination, implementation, evaluation, and supervision. The role of the Management committee is to provide regional coordination and leadership for the program. It is made up of the co-chairs of the Technical Operations Subcommittee, a representative of each of the seven-state Agri-21 committees, as well as a farmer representative from the Tennessee Valley Region Association of Demonstration Farm Families.

The Technical Operations Subcommittee is a subcommittee to the Management Committee. It is comprised of individuals having expertise in disciplines related to the various assigned functions of the subcommittee and is responsible for formulating a uniform planning procedure for the Agri-21 farm demonstrations. This should include the necessary steps for developing the plan and the tools to be used.

At the state level, the program is directed by the State Agri-21 Committee. The committee is co-chaired by the university supervisor for TVA programs and the TVA regional manager and consists of representatives of state participating agencies. The university program supervisor represents the state committee on the Management Committee. State committees are responsible for implementing the program in their respective states, adhering to the guidelines and directives established by the Executive and Management committees.

Management of the program at the local level is the responsibility of a university Extension staff person with guidance and direction from the state comniittee. In most cases, this person is a state Extension specialist. This individual is responsible for the program at the "grass roots" level and for soliciting the assistance of other specialists, county Extension staff, and other agency personnel.

NUMBER OF FARM DEMONSTRATIONS AND LENGTH OF PARTICIPATION

A major goal of the Agri-21 Farming Systems program is to select and implement approximately 100 whole-farm demonstrations across the Valley (see Table 1). All Agri-21 Farm demonstrations are for a 5-year period. The participation period starts on a fiscal year basis beginning on October 1. The first year of participation is considered a probationary period. Continued participation is contingent upon the successful completion of activities planned for each year of the program.

Table 1. Number of Agri-21 Farm Demonstrations by Program/Project Year.

Project Year	Year of Program Participation 1	2	3	4	5	Total
1	18					18
2	18	18				36
3	20	18	18			56
4	22	20	18	18		78
5	22	22	20	18	18	100
6		22	22	20	18	82
7			22	22	20	64
8				22	22	44
9					22	22
10						0

Evaluation Period

CRITERIA FOR SELECTING POTENTIAL AGRI-21 FARM PARTICIPANTS

1. Be established in a full-time farming operation or part-time operation of which a substantial portion (at least one-third) of the family gross income is derived from farming.

2. Be in a position to obtain access of sufficient resources to implement the farm plan.

3. Have needs in their current farming operation that can be addressed with this initiative.

4. Be committed to addressing the issues of sustainable agriculture (efficient, competitive, profitable, and environmentally acceptable).

5. Be willing to keep detailed records, make their farm available for tours and visits of farmers and professional people, and agree to allow environmental sampling throughout the duration of the project.

6. Be willing to accept advice and guidance and to participate in environmental education and leadership development sessions.

7. Have farming operations representative of agriculture in the area targeted for the demonstrations.

8. Be committed to implement the farm plan, serve as a demonstrator, and be an advocate for the duration of their participation.

9. Where appropriate, priority will be given to cooperators identified in special watershed and other targeted areas by cooperating agencies and organizations, such as state heritage programs, hydrologic units, etc.

PROCEDURE FOR NOMINATING AND SELECTING ACRl-21 FARM CANDIDATES

Nominations originate at the local or county level. An organized group, such as a county rural development conimittee or a similar group, with representatives from all major agricultural agencies may submit a nomination for consideration to the State Agri-21 Committee.

All nominations arc made at least 6 months prior to a farm beginning the program. Representatives of the State Agri-21 Committee review the nominations and make a preliniinary screening of the nominees' qualifications of the nominees, especially as related to farming types to be emphasized, areas of the state to be targeted, etc. Following this screening, representatives of the state committee visit all nominees to interview the operator and the family, observe the current farming operation, and assess the family's potential to be a successful cooperator.

Those selected are notified of their preliminary selection. Final selection is determined when the farm plan(s) is completed and accepted by the candidates.

PLANNING PROCESS AND PROCEDURES

Once the preliminary selection is made, a comprehensive plan is developed in partnership with each prospective demonstrator. The plan includes a full inventory of the farm's resources, as well as the establishment of farm and family goals. A number of alternative plans are prepared so the family can compare these with their current operation. They are expected, however, to implement one that achieves an optimum net farm income subject to environmental and regulatory constraints and fits the family's financial and development goals.

The Overall Farm Plan

The planning procedures and tools necessary to develop the comprehensive plans needed for these farms were determined by the Technical Operations Subcommittee. The overall plan should also provide for farm and family financial planning, including financial simulations, environmental assessments and plans, as well as leadership and education workplans and schedules.

The second thrust of this program is to increase the awareness of professional agricultural workers, farmers and their families, and the agricultural community of critical agricultural issues. Formal plans are developed to accomplish this phase of the program. These plans may range from a general statewide program to very specitic on-farm activities utilizing Agri-21 Farm experiences.

INCENTIVES AND REIMBURSEMENTS

Participants receive cost-share incentives provided certain measures of success or progress are achieved as the plans are implemented. Incentives are MADE available following implementation or accomplishment of a planned activity. The level of incentives for an individual demonstration will be determined during the planning process and may vary according to complexity and risk of the technology being introduced. The nature or type of incentives may also vary from year to year. Generally, incentives will be in the FORM of discounts or a reimbursement for a share of the cost of an approved item or practice. Incentives will be available for all components of the Agri-21 Farming Systems program. Participants, however, may not receive incentives for more than one component. Agricultural and state agencies may assist, as appropriate, in financing the planned changes in the farming operation.

PROJECT BUDGET

The annual cost of the Agri-21 Farming Systems program is estimated at about $2 million. This estimate includes the cost of conducting all components of the Agri-21 Farming Systems program's on-farm activities (Agri-21 whole-farm demonstrations and sustainable practice and alternative enterprise demonstrations); leadership development training; conferences; workshops; field days and tours; program planning, supervision, and management; project evaluation; and promotional and reporting activities. This figure also includes estimates of agency staff salaries and related costs, educational activities, and program incentives, but does not include expenditures to be made by participating farm families as they implement the program. Input from other state and federal agencies, both direct funds and in-kind services, will be sought, especially where their agency objectives and goals mesh with those of Agri-21 Farming Systems program. Efforts will be made to develop new partnerships with industry, private non-profit foundations, special interest groups, and others to provide additional support.

SUMMARY

The Agri-21 Farming Systems program is an initiative designed to continue and strengthen cooperative efforts in order to demonstrate agricultural technology that will be required to conduct a profitable and sustainable agriculture in the 21st century.

The whole-farm demonstration concept (Agri-21 Farms) is used to integrate economic and environmental aspects into one approach for sustainable agriculture. Successful implementation and adaptation of this concept in the Tennessee Valley provide a model for focusing on the farm and the farm family, as well as their resources and personal aspirations. These demonstrations expedite the acceptance of research findings for on-farm utilization. The Agri-21 Farming Systems program provides farmers with methods to enhance the environment without sacrificing agricultural productivity or family income.

BREEDING TROPICAL CORN FOR DROUGHT TOLERANCE

S. Edme and R. N. Gallaher[1]

ABSTRACT

Improving tropical maize (*Zea mays* L.) tolerance for drought stress was initiated in 1991 in a fullsib recurrent selection program. This breeding program was initiated to compare two selection environments and to improve the yield stability of tropical maize under the north Florida drought-prone environments. Rainfed and irrigated plots were used to evaluate 140 fullsib families, along with four checks in a 12 X 12 partially balanced lattice design with four replications. Relative grain yield, plant and ear height leaf area, flower delay, canopy temperature, tassel weight, and drought index were used to select the fullsibs for the recombination phase. Yield reductions, ranging from 2 to 40% in the stress site, were mild due to appreciable rainfall. High variability existed among the fullsibs tested for grain yield. Irrigated grain yield ranged from 3987 to 8039 kg ha^{-1}, and rainfed grain yield from 3066 to 7124 kg ha^{-1}. A 15% selection pressure resulted in the advancement of 21 fullsibs from either site to the recombination process.

INTRODUCTION

Tropical and temperate maize (*Zea mays* L.) yields are both affected by drought resulting from irregular rainfall distribution and low water-holding capacity of soils, as in north Florida. Tropical maize is, however, mostly associated with low-input environments, characterized by water and temperature stresses, among others (Boyer, 1982). Improving tolerance for drought stress is imperative for tropical maize improvement and is a growing concern for multiple cropping and conservatino tillage sustainable agriculture. In north central Florida, low moisture retention by the soil makes even a short period of drought a constraint to grain production, particularly if the stress coincides with flowering time (Claasen and Shaw, 1970; Robins and Domingo, 1953). Observed variation in susceptibility to water stress among genotypes suggests that the trait can be improved (Fischer et al., 1983; Jensen, 1971).

Conflicting results exist as to the choice of best selection environment to be used for greater yield in low-yielding sites. Falconer (1981) suggested selecting in stress conditions while Daday et al. (1973) indicated that selection for yield is more effective under favorable conditions because of greater genetic variance and heritability. The most relevant criteria in breeding corn for drought tolerance were found to be anthesis-to-silking interval, canopy temperature at flowering, leaf area loss, and relative grain yield (Fischer et al., 1983).

This breeding program was initiated to improve the grain yield stability of tropical corn in Florida under drought conditions, to compare synthetics developed under rainfed and irrigated environments for drought resistance, and to develop synthetics as possible sources of drought resistance for future breeding programs. This paper presents the first year evaluation of the fullsib families for selection and subsequent recombination

MATERIALS AND METHODS

The first of the two cycles of fullsib recurrent selection was conducted at Green Acres Agronomy Farm of the University of Florida, Gainesville, Florida in 1991. The experimental site was an area dominated by Arenic and Grossarenic Paleudults soil types (Soil Survey Staff, 1984).

Plant materials

The 140 fullsib families derived from a set of 199 fullsibs under selection for high yield with Florida, Costa Kica, The Dominican Republic, and CIMMYT corn materials involved in their making (R.N. Gallaher, personal communication). Four checks were included in the 1991 evaluation: a temperate hybrid (Pioneer Brand P3320), the tropical hybrid (DeKalb Brand DeKalbXL 678-C, and two tropical Florida synthetics developed by Dr. R.N. Gallaher.

The 144 entries were planted on 21 March 1991 in a 12 X 12 partially balanced lattice design with four rep1ications. This initial evaluation trial was designated to measure the variation in a number of plant characters associated with drought-resistant mechanisms among the 140 fullsib families: leaf area,

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plant height and ear height, anthesis-to-silking interval, yield, drought intensity and index, and canopy temperature at flowering. Drought index was calculated as follows: S = (1-Y/Yp) / (1-X/Xp), where Y=yield under stress, Yp=irrigated yield, and X and Xp are the respective average yields over all fullsibs under stress and nonstress conditions. The drought intensity is defined by the term (1-X / Xp).

The trial was conducted under two different soil water regimes: sprinkler-irrigated and rainfed. Plot size was a single row 3 m long and 0.76 wide, and hills were hand-planted. The sites were managed for maximum production.

RESULTS AND DISCUSSION

Anthesis-to-silking interval

Days to anthesis and silking were affected less in the rainfed site compared with the irrigated site. High variability existed for the anthesis-to-silking interval when both sites were compared (Fig. 1). Delays of 3 to 5 days were observed under the rainfed conditions, with 4 to 5 days more common. Under the irrigated condition, the fullsibs had a range of 2 to 5 days of delay, but the majority had 2 to 3 days of delay.

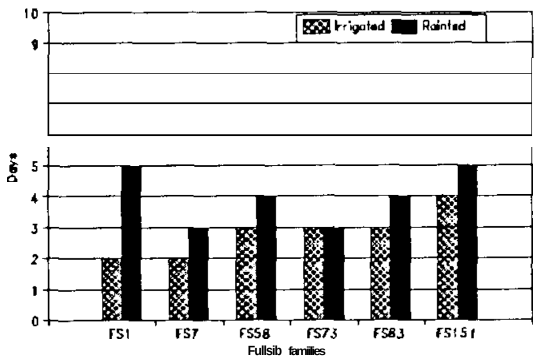

Fig. 1. Anthesis-silking intervals for six of the fullsib families.

Yield

High variability existed for yield in both rainfed and irrigated experiments (Table 1). The grain yields ranged from 3066 to 7124 kg ha^{-1} for the rainfed site and from 3987 to 8039 kg ha^{-1} for the irrigated site. Reductions or increases were observed for some of the fullsib families when their mean performance was compared in both conditions (Fig, 2). Good rainfall (687.6 mm) associated with a better soil moisture retention in the rainfed site resulted in a mild stress (a total of 20 drought-days of which only five occurred at pre-anthesis). Consequently, some higher mean grain yields were registered in the stress environment. Pre-anthesis stress adaptation might also have been a factor.

Table 1. Significance for the traits tested under irrigated and rainfed conditions.

Traits	Rainfed	Irrigated
Yield	***	***
Plant height	***	***
Ear height	***	***
Leaf area	ns	ns
Canopy temperature	ns	
Tassel weight	***	
Index	***	

*** significant at the 0.0001 level
ns nonsignificant at the 0.05 level
· no measurement taken

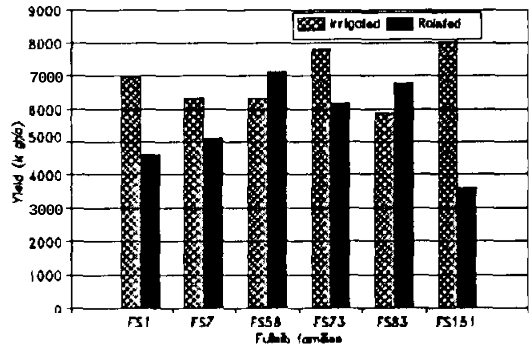

Fig. 2. Grain yield of six of the fullsibs in the rainfed and irrigated sites.

Plant and ear height

High variability also existed among the fullsib families for plant and ear height (Table 1). Plant heights were from 1.95 to 2.46 m in the irrigated site and from 1.00 to 2.45 m for the rainfed site. Reductions in ear height were also observed in the rainfed experiment. Ear height ranged from 0.97 to 1.47 m in the irrigated site and from 0.52 to 127 m in the rainfed site.

Leaf area and tassel weight

No significant differences were obtained for leaf area or other leaf traits in either site. The water stress was not severe enough to show differences among the fullsib families for leaf characteristics. Neither was a significant difference observed for canopy temperature. Frequent cloudy days at the flowering stage made this measurement difficult.

Tassel weight was found to be significant among the fullsib families grown in the rainfed site. The weight ranged from 2.67 to 6.84 g. Selection was practiced for reduced tassel weight in the rainfed site only.

Drought intensity and index

The drought intensities calculated for yield, plant height, and ear height were 020, 039, and 0.41, respectively (Table 2). A drought index based on relative yield was used for the final ranking of the families with respect to drought (Table 3). Some families had both high drought index and high yield potential. Twenty-one families with drought index greater than 1.00 were selected for the recombination phase.

CONCLUSION

High variability existed among the fullsib families for yield, tassel weight, plant and ear height, and drought index. A successful combination of a high yield potential and drought resistant traits from this breeding material should be possible for improved multiple cropping sustainable agricultural systems. The anthesis-to-silking interval was more affected than days to anthesis or to silking in response to the water regimes. Anthesis-to-silking intervals greater than live (5) days may result in incomplete pollination. Good rainfall and mild pre-anthesis stress might have explained the higher yields of some fullsib families in the rainfed conditions. Twenty-one fullsib families were selected from each site and crossed for recombination.

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Table 2. Drought intensities based on grain yield, plant height and ear height in rainfed and irrigated conditions among the 140 fullsib families.

Traits	Drought intensity†
Yield	020
Plant height	039
Ear height	0.41

† Drought intensity= (1-X / Xp), where X = average over fullsibs under rainfed, and Xp = average of fullsibs under irrigated conditions.

Table 3. Drought index based on relative grain yield of rainfed to irrigated conditions among six fullsib families.

Families	Drought index (S)†
1	1.68
73	1.04
151	2.50
7	0.97
58	0.55
83	0.66

† S = (1-Y/Yp) / (1-X/Xp), where Y = yield under stress, Yp = irrigated yield, and X and Xp are the respective average yields over all fullsibs under stress and nonstress conditions.

EFFECT OF WINTER COVER ON SOIL MOISTURE CONTENT IN CONVENTIONAL AND STRIP TILLAGE COTTON

Philip J. Bauer and Warren J. Busscher[1]

ABSTRACT

Moisture stress frequently limits crop productivity on the coarse-textured soils of the Southeastern Coastal Plain. Our objective was to determine the effect of winter cover and tillage on soil moisture levels and cotton (Gossypium hirsutum L.) yield. Cotton was grown following rye (Secale cereale L.) or winter fallow with conventional (incorporation of all surface residues followed by in-row subsoiling) and strip (in-row subsoiling only) tillage in 1991 and 1992. Soil type was Norfolk loamy sand (fine, loamy, siliceous, thermic, Typic Kandiudult). In 1992, soil moisture was monitored daily using gypsum blocks placed at 20 and 46 cm below a center row of each plot. In the strip tillage system, lint yield was 434 and 224 kg ha^{-1} higher following rye than fallow in 1991 and 1992, respectively. No yield differences between the cover treatments occurred with conventional tillage. Soil moisture content in 1992 was higher following rye than fallow in both tillage systems, but the difference was greater with reduced tillage. These results indicate that a rye cover crop in strip tillage on coarse-textured soils increases cotton productivity by increasing available soil moisture.

INTRODUCTION

Current recommendations for cotton production following a winter cover crop include killing the winter cover at least 2 weeks before planting. Part of the reason for the early kill is to prevent the winter cover from depleting seedbed moisture. Low seedbed moisture can reduce seedling emergence and final stands (Karlen, 1989). Though the influence of winter cover crops on seedbed moisture at planting is well understood, less is known about how seasonal soil water supplies are influenced by growing winter crops. Increased surface residue from the winter crop could potentially increase rainfall infiltration and the moisture supplying capacity of the soil throughout the growing season.

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When seedbed moisture does not limit stand establishment, small increases in cotton yield have been found when rye is used as a winter cover on Eastern Coastal Plain soils. For example, in a 3-year study, green-manured rye increased cotton lint yield 140 kg ha^{-1} more than a fallow treatment when both were supplied with 56 kg N ha^{-1} (Bauer et al., 1993). Since some of the more productive soils of the Southeastern Coastal Plain have surface horizons with low available water holding capacities (0.06 to 0.10 g/g) (Campbell et al., 1974), improved soil-water relationships may be partially responsible for these yield increases.

We initiated a study in 1990 to determine the effects of tillage method and cover crop destruction date on cotton grown on a coarse-textured soil. In 1992, soil moisture data were collected from these plots. In this report, we present the results on the effect of a rye winter cover crop on soil moisture in conventional and strip tillage production systems.

MATERIALS AND METHODS

The experiment was conducted on a Norfolk loamy sand at the Clemson Pee Dee Research and Education Center in Florence, SC. Rye (Vita-graze') was seeded with a grain drill at a rate of 122 kg ha^{-1} in the fall of both 1990 and 1991. In 1990, the experimental field was disked and bedded before planting rye. After the cotton stalks were shredded in the fall of 1991, bedders were used to place a small amount of soil (2.5 cm or less) onto the existing beds of all plots before rye seeding.

The conventional tillage treatment consisted of disking to a depth of 15 to 20 cm, reforming the beds, in-row subsoiling, and between-row cultivations after cotton emergence. The strip tillage treatment consisted of in-row subsoiling only.

Total N application in all plots was 78 kg ha^{-1}. Lime and other plant nutrients were applied based on soil test results and Clemson University Extension recommendations. Cotton ('Coker 315') was planted with a four-row Case-IH 900 series no-till planter on May 8,1991 and May 10,1992. Row width was 0.97 m. In the strip tillage plots, paraquat was applied to desiccate all vegetation before planting. Herbicides, applied at recommended rates, were applied to all plots for weed control. Herbicides were applied with a directed sprayer into the midrows of the strip tillage plots when cultivation was used in the conventional tillage treatment. Handweeding was also used in all plots. Pyrethroid and organophosphate insecticides were applied as needed to control insect pests.

Soil moisture was determined with a Delmhorst KS-D1 soil moisture tester in 1992 only. Four gypsum blocks, two at the 20-cm and two at the 46-cm depth, were buried below a middle row of each plot. Measurements were taken daily (Monday through Friday, except holidays) between 7:30 and 900 a.m. Soil moisture was monitored from May 28 through August 29.

Biomass of the winter covers (winter weeds in the winter fallow plots or the rye winter cover) was determined by drying a 1 m^2 sample from two areas of each main plot (winter covers) in late April of each year. Shortly before harvest, plant height was measured on five plants in each plot. Two interior rows were harvested with a two-row spindle picker on October 9, 1991 and October 22, 1992 for yield determinations. Lint yield was calculated after saw-ginning a grab sample from the harvest bag and multiplying seedcotton yield by lint percent.

The experimental design was a randomized complete block in a split-split plot arrangement with winter cover on main plots and tillage on subplots. Sub-subplots were date of winter cover incorporation/desiccation (either 5 or 15 days before cotton planting). The experiment had four replicates. All data collected were subjected to analysis of variance. Since date of incorporation/dessication had no significant ($P<0.05$) impact on any of the dependent variables, data presented were averaged over the incorporation/desiccation dates.

RESULTS AND DISCUSSION

Rye biomass production was similar between years, averaging 2556 kg ha^{-1} in 1991 and 2472 kg ha^{-1} in 1992. Winter weed dry matter production was greater in the second year of the study, averaging 551 kg ha^{-1} in 1991 and 1011 kg ha^{-1} in 1992.

Cotton lint yield was more than two times greater in 1991 than 1992 (Table 1). In 1992, cool spring and early-summer temperatures delayed seedling growth and the eventual crop harvest.

Table 1. Effect of winter cover and tillage on cotton plant height and yield at Florence, SC.

Winter Cover	Tillage	Plant Height 1991	Plant Height 1992	Lint Yield 1991	Lint Yield 1992
		----- cm ------		----- kg/ha ----	
Fallow	**CT**†	**80**	**68**	**1133**	**446**
	ST	**71**	**57**	**952**	**267**
Rye	CT	77	69	1322	**563**
	ST	*a2*	77	1386	491
LSD(0.05)		125	15.5	428	145

† CT = Conventional Tillage, ST = Strip Tillage.

Even though cotton yields in the 2 years differed considerably, the cotton plant responses to tillage and winter cover treatments were similar between years. In both years, plant height was not significantly ($P<0.05$) affected by winter cover treatment in conventional tillage. Under conventional tillage, small numerical but not statisically significant ($P<0.05$) increases were found in both years following the rye cover crop (Table 1). This response is similar to previous findings using rye as a green manure on this soil type (Bauer et al., 1993). In the strip tillage system, cotton following rye grown for a surface mulch had greater lint yield in both years and greater plant height in 1992 than cotton grown following winter fallow (Table 1).

We did not detect a difference in soil moisture among treatments before early July or after mid-August in 1992 (data not shown). Soil moisture contents during an extended *dry* period, which occurred from July 1 (beginning at about first bloom) through August 14, are presented in Figures 1 and 2.

Drying of the surface layer (20-cm depth) occurred a few days earlier in the fallow winter cover treatment than the rye winter cover treatment for both tillage systems (Fig. 1). Within tillage systems, the rate of soil drying was quite similar between the rye and fallow winter cover treatments.

In contrast to the surface horizon, little difference in soil moisture content was found between rye and fallow treatments at the 46-cm depth when conventional tillage was used (Fig. 2, top). However, in the strip tillage plots, the rye surface mulch delayed soil

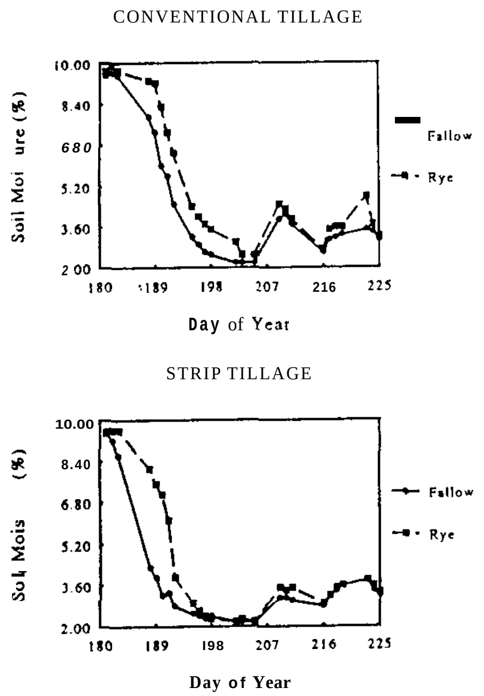

Figure 1. in-row soil moisture content at the 20-cm dcpfh of cotton following wlnter cnvcr treatments of rye or fallow in conventional (top) nnd strip (bottom) tillage systems.

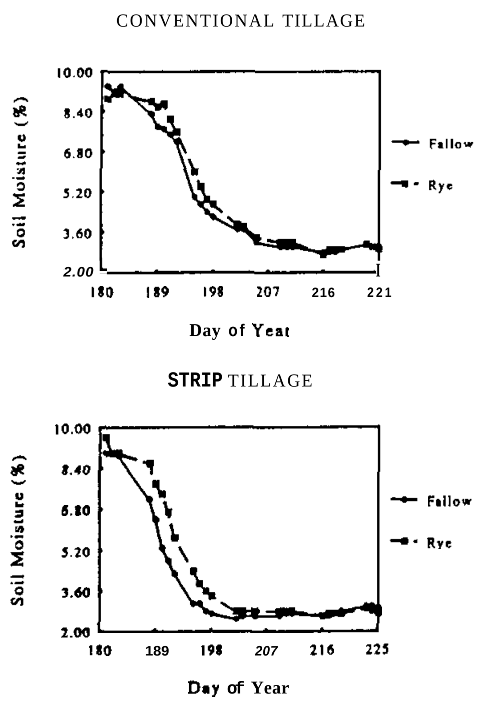

Figure 2. In-row moisture content at the 46-cm depth of cotton following witner cover treatments of rye or fallow in conventional (top) and strip (bottom) tillage systems.

moisture depletion by several days (Fig. 2, bottom). As found in the surface layer, the rate of soil drying within a tillage system was similar between the winter cover treatments. It is unclear why soil moisture differences between the winter covers occurred at the 46-cm depth in the reduced tillage systems but not In the conventional. Differences in root growth patterns or soil physical conditions may have been involved.

In summary, we found greater differences in height and yield between the fallow and rye winter cover treatments in the strip tillage system than in conventional tillage both years of this study. Soil moisture data from one year of study suggest that differences in soil moisture status may be responsible for the greater response in the strip tillage treatment. Delays in moisture stress, especially during the flowering cycle when young bolls are susceptible to shedding, could account for the increased productivity of cotton following a rye winter cover.

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INFLUENCE OF TILLAGE AND COVER CROPPING ON NITRATE LEACHING

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INTRODUCTION

The contamination of water resources by nitrate (NO_3) is a major health and environmental quality issue confronting the U.S. today. Domestic, municipal, industrial, and agricultural sources all contribute to NO_3 loading of streams and aquifers, although the severity of the problem and the source of the NO_3 vary greatly from location to location. Land use and management, biological activity, geology, and climate interact to control how much NO_3 reaches our water supplies and its concentration there.

Heavy use of N resources in corn *(Zea mays* L.) production has been implicated as an extensive source of NO_3 delivered to ground and surface waters in the eastern U.S. (Hallberg, 1989). Since NO_3^- leaching is strongly influenced by soil and crop management (Thomas et al., 1989; Russelle and Hargrove, 1989), there is great need to assess NO_3 leaching losses in the new corn production systems that are gaining farmer acceptance.

No-tillage is a relatively new practice that has undergone widespread adoption in many corn-producing regions of the country (Mannering et al., 1987). Because it profoundly affects the soil moisture regime and soil porosity (Phillips, 1984; Blevins et al., 1984), no-tillage can be expected to impact NO_3 leaching, though often in ways that are not readily predictable Schepers, 1987).

Cover cropping with non-leguminous winter annuals, such as rye *(Secale cereale* L.), is an old practice with great potential for renewed use. Not only does rye help control soil loss during otherwise fallow winter periods, use of a rye cover crop may significantly reduce NO_3 leaching during the fall, winter, and early spring.

Research was undertaken to evaluate the effects of tillage [conventional (CT) vs. no-tillage (NT)] and winter cover cropping (fallow vs. rye) on NO_3 leaching from land devoted to corn production. This report presents first year results of a proposed multi-year study.

MATERIALS AND METHODS

Field Site

This continuing study is being conducted at the USDA-ARS Southern Piedmont Conservation Research Center near Watkinsville, Georgia. The study area is located on Cecil sandy loam soil (clayey, kaolinitic, thermic Typic Kanhapludults), and consists of 12 instrumented, tile-drained plots, each measuring 10 m wide x 30 m long. Each plot is underlain by five 30 m long drain lines spaced 2.5 m apart. Drain lines consist of 10-cm diameter, flexible, slotted PVC pipe installed on a 1% grade. At the lower plot edge, the depth of each drain line is 1 m from the soil surface. To exclude subsurface lateral flow, plot borders are enclosed with polyethylene sheeting that extends from the soil surface to the depth of the drain lines.

The volume of water drained from a plot is measured by tipping bucket, and is recorded digitally with a datalogger. A small portion of the drainage flow (< 3%) is removed by a sampling slot located between tipping-bucket halves. Drainage samples are collected and stored under refrigeration (1.7°C) in the field by lsco Model 3700 FR sequential waste water samplers Isco Inc., Lincoln, NE 68501-3531). Drainage samples are analyzed for NO_3^- by the Griess-Ilosvay method (Keeney and Nelson, 1982), following reduction by Cd to NO_3^-.

Field Operations, Sampling, and Analysis

In preparation for this experiment, conventionally tilled corn, fertilized with 168 kg N ha^{-1}, was grown during the summer of 1991 on the entire plot area. After grain harvest, corn stalks were mowed.

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On 18 October 1991, six plots were no-till planted to rye (cv. Wheeler) at the rate of 112 kg seed ha^{-1}. The remaining six plots were left fallow for the winter.

To assess the inorganic N content of the soil profile, plots were sampled to 90 cm in 15-cm increments on **6** November 1991 and 14 April 1992. Soil was extracted with 2 M KCI (20 g soil:100 mL solution), and soil extracts were analyzed for NH_4-N by the indophenol-blue method (Keeney and Nelson, 1982) and for NO_3-N by the Griess-Ilosvay method (Keeney and Nelson, 1982).

To estimate dry matter production and N uptake by the rye, aboveground tissue samples were taken on **23** April 1992. Rye samples were dried **(65°C),** ground **(< 1** mm), and digested (Nelson and Sommers, 1973); digest N concentrations were determined colorimetrically by the indophenol-blue reaction (Keeney and Nelson, 1982).

On 23 April 1992, the rye was killed, and tillage treatments were imposed: conventional tillage plots were mowed, moldboard plowed and disked; no-tillage plots were mowed, sprayed with paraquat (1,l'-dimethyl-4,4'-bipyridinium ion), and left untilled.

On 24 April 1992, plots were planted to corn (cv. DeKalb 689) at the rate of 60250 kernels ha^{-1}, in rows 0.76 m apart. Fertilizer N (168 kg N ha^{-1} as NH_4NO_3) was broadcast 3 days later. To control weeds, plots were sprayed on 28 April 1992 with atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine] and alachlor [2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide], both applied at the rate of 2.24 kg ai ha^{-1}. Corn on the no-tillage rye plots was replanted on 21 May 1992 because of extensive bird damage.

On 7 October 1992, corn grain was harvested, and corn stover samples were taken from the two center rows of each plot. Corn tissue was analyzed for N as rye tissue had been (described above). The first year of the experiment was concluded on **30** October 1992.

Experimental Design and Statistical Procedures

The experiment was laid out as a split plot design in randomized blocks with three replications. The main plot is tillage (conventional or no-tillage), and the subplot is winter cover crop (fallow or rye). Analysis of variance was performed using SAS (SAS Institute, 1985).

RESULTS AND DISCUSSION

Winter 1991

Drainage. Unusually dry fall conditions (Table 1) delayed soil moisture recharge and virtually eliminated tile drainage until the last days of December 1991 (Figure **1**). By the end of February 1992, winter drainage essentially had ceased. From then on, lower than normal spring rainfall (Table 1) and increasing evapotranspiration combined to prevent significant drainage during the rest of the cover crop/winter fallow period.

Table 1. Monthly rainfall from October 1991 through October 1992 and long-term (1884-1991) average monthly rainfall at Watkinsville, Georgia.

Year	Month	Monthly rainfall at site (mm)	Long-term average monthly rainfall† (mm)	Rainfall deficit (-) or surplus (+) (mm)
1991	October	3.4	75.7	-72.3
	November	17.0	78.0	-61.0
	December	81.5	110.5	-29.0
1992	January	88.2	118.9	-30.7
	February	121.9	120.6	+1.3
	March	101.6	134.4	-32.8
	April	40.1	98.6	-58.5
	May	43.7	96.5	-52.8
	June	165.3	99.3	+66.0
	July	145.1	126.7	+18.4
	August	205.5	107.4	+98.1
	September	194.3	85.6	+108.7
	October	61.7	75.7	-14.0
	Total	1269.3	1327.9	-58.6

† measured 5 kvm from site.

Cumulative drainage was consistently less under rye than it was under winter fallow (Figure **1**). By late April when the rye was killed, the difference in drainage volumes was considerable (41 mm under rye, 60 mm under fallow).

Nitrate Concentrations. The concentration of NO_3-N in the drainage effluent was also consistently lower with the rye cover crop (Figure 1). Under rye, the average NO_3-N concentration of tile flow was 8.8 mg

NO_3-N L^{-1}, just below the U.S. Public Health Service's maximum allowable concentration for drinking water (**10** mg NO_3-N L^{-1}). In contrast, the average NO_3-N concentration measured under winter fallow (**21.6** mg NO_3-N L^{-1}) was roughly two times the Health Service limit.

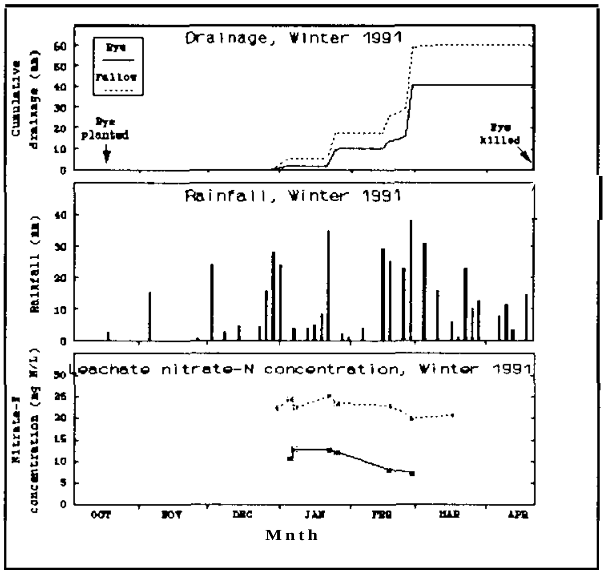

Figure **1**. Cumulative drainage, rainfall, and leachate NO_3-N concentration for winter **1991.**

Nitrate Losses. Measured NO_3 leaching losses were small for both winter cover treatments (Table 2). However, we do not know how completely the tile drains intercepted water leaching through the plots or how much these values underestimate actual NO_3^- leaching losses. Incomplete drainage water inter-ception is suggested by the drainage response of a storm in February. This storm occurred less than a day after drainage from the previous storm had ceased and during a time of year when evapotranspiration was minimal. Thus, the soil was near saturation when the storm began, and under these conditions, tile interception of water draining through the plots should be maximal. For this storm, we calculated that tile drains intercepted an average of 742% (std. dev. 12.8%) of the rainfall. It should be noted, however, that this estimate of tile drain capture efficiency did not take into account the possibility that runoff losses were significant. Runoff was not measured in this study.

Total NO_3-N loss in tile flow was less under rye than under winter fallow (Table 2). Reduction in NO_3^- leaching by cover crops appears related to their use of both water and N (Meisinger et al., 1991). Transpiration by cover crops consumes soil moisture, and this reduces the volume of water available to transport NO_3^- through the root zone. Uptake of N by cover crops removes NO_3^- from the soil solution that otherwise can be leached out of the soil profile.

Table **2.** Total measured leaching loss of NO_3-N during winter, soil profile NO_3-N content on 6 Nov 1991 and 14 Apr 1992, and N content of aboveground rye dry matter on 23 April 1992.

Winter cover	Measured leaching loss of NO_3-N†	Soil profile NO_3-N content‡ 6 Nov 1991	Soil profile NO_3-N content‡ 14 Apr 1992	Rye N content 23 Apr 1992
	kg NO_3-N ha^{-1}			
Rye	**3.6(±2.0)a§**	**80(±27)a**	**14(± 6)a**	**94(±13)**
Fallow	**11.8(±3.2)b¶**	**80(±17)a**	**51(±12)b**	--

† Total from 18 October 1991 through 23 April 1992.
‡ Sampled to a depth of 90 cm.
§ Where letter postscripts differ within **a** column, means are significantly different (***P*** **< 0.10).**
¶ Values in parenthesis are sample standard deviations.

Nitrogen Balance. Rough N balances were constructed for winter 1991. In early November 1991, 80 kg NO_3-N ha^{-1} were found in the root zone of both winter cover treatments (Table 2). By late April 1992, N accounting on the rye plots indicated a total of 112 kg N ha^{-1} had been sequestered in rye aboveground dry matter, intercepted by tile drains, or retained within the root zone as NO_3-N (Table 2). Although variability in field measurements was great, the lack of agreement between fall and spring N-balance estimates raises the possibility that soil N mineralization was appreciable between early November and April.

In contrast, roughly half as much N was accounted for in April on the fallow plots, where a total of 63 kg N ha^{-1} had been captured by tile drains or remained in the root zone as NO_3-N (Table 2). This difference in N-balance estimates between the two winter cover treatments suggests that denitrification was greater on the fallow plots. On the cover-cropped plots, competition by rye for NO_3-N may have reduced denitrification losses.

Summer 1992

Drainage. Despite below normal rainfall in March, April, and May, above average amounts from June through September 1992 (Table 1) generated more summer drainage than expected (Figure 2). From the time of corn planting through 30 October 1992, the trend was for greater cumulative drainage where rye had been grown the previous winter (198 mm after rye, 168 mm after fallow, **$P<0.13$).** During the same period, cumulative drainage was greater where no-tillage was used (200 mm for NT, 164 mm for CT, $P<0.06$). These results are consistent with a mulch effect. Killed cover crops and post-harvest crop residues, left as surface mulch by no-tillage, frequently increase leachate volume by encouraging infiltration and slowing evaporative water loss (Phillips, 1984). Not surprisingly, summer drainage was greatest where residue coverage was greatest: on no-tillage plots that possessed a mulch of both rye and corn residues (Figure 2).

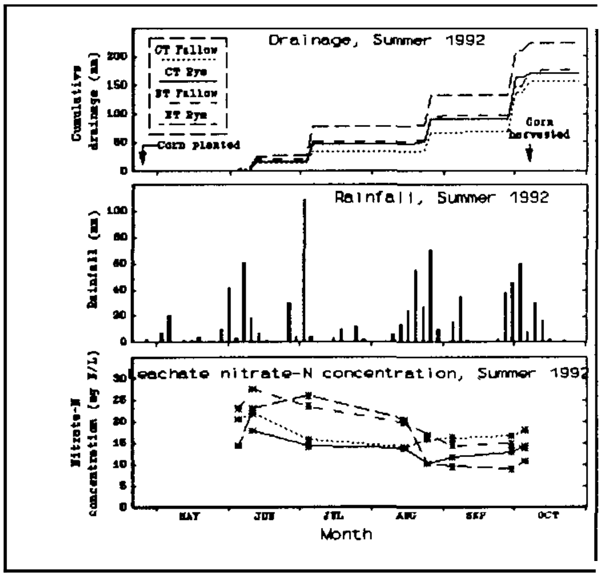

Figure **2.** Cumulative drainage, rainfall, and leachate NO_3-N concentration for summer **1992.**

Nitrate Concentrations. In general, leachate NO_3-N concentrations were higher soon after drainage began in the summer and lower at the end of the corn growing season (Figure 2). This trend probably reflects the seasonal pattern of N use by corn (Magdoff, **1991)** and the fact that N fertilizer was applied in a single application at the beginning of the growing season.

For three of the four treatment combinations, NO_3-N concentrations appeared to increase slightly late in the summer season (Figure 2). These increases may be due to the combined effect of diminished N uptake by corn as it matured and to continuing mineralization of soil organic N (Magdoff, 1991).

In general, leachate NO_3-N concentrations tended to be higher with no-tillage than with conventional tillage during the first half of the summer period (Figure 2). This tillage effect may be due to the presence of more large soil pores (macropores) that are continuous with the soil surface under no-tillage (Tyler and Thomas, 1977). Macropores can conduct large amounts of water and nitrate rapidly through the root zone, deep into the profile, or beyond (Thomas and Phillips, 1979). Intense storms, like the one on 4 July 1992 (Figure 2), usually produce the most macropore flow.

The NO_3-N concentration of the tile flow during the summer was affected by winter management practices. In general, summer NO_3-N concentrations tended to be lower where rye had been grown the previous winter than where the land had been left fallow (Figure 2). When averaged across the summer season, the NO_3-N concentration of tile flow was lower *($P<0.05$)* after rye (13.9 mg NO_3-N L^{-1}) than after fallow **(17.6** mg NO_3-N L^{-1}**).** These differences in summer NO_3-N concentration reflect the difference between the two winter cover treatments in profile NO_3-N at about the time the corn growing season began (Table 2). In addition, N immobilization associated with the decomposition of rye residues could have limited the amount of NO_3-N susceptible to summer leaching.

Nitrate Losses. Total NO_3-N losses during the corn growing season were much greater than they had been during the preceding winter fallow/cover crop period. This can be attributed to above average rainfall from June through September and to the leaching of fertilizer N applied for corn. Between corn planting and 30 October 1992, significantly **($P<0.07$)** more NO_3-N was lost in tile flow with no-tillage **(34 kg** NO_3-N ha^{-1}) than was lost with conventional tillage (25 kg NO_3-N ha^{-1}). Despite tillage differences in measured NO_3-N leaching loss and the fact that corn was replanted on the no-tillage rye plots, there was no significant effect of tillage, cover cropping or their interaction on corn N uptake (99 kg N ha^{-1} for NT rye, **97 kg** N ha^{-1} for CT rye, **95 kg** N ha^{-1} for NT fallow, **92** kg N ha^{-1} for CT fallow).

Winter management did not significantly affect the total quantity of NO_3-N leached during the summer season (29 kg NO_3-N ha^{-1} after rye, and 30 kg NO_3-N ha^{-1} after winter fallow). Similarly, the interaction of tillage and previous cover crop had no significant effect on measured NO_3-N leaching losses during the summer season (35 kg NO_3-N ha^{-1} for NT rye, 23 kg NO_3-N ha^{-1} for CT rye, 34 kg NO_3-N ha^{-1} for **NT** fallow, 27 kg NO_3-N ha^{-1} for CT fallow).

CONCLUSIONS

In climates like Georgia's that possess mild humid winters, use of a rye cover crop appears to have utility for control of NO_3^- leaching from cropland. First year results of this study indicate that a rye cover crop significantly limited NO_3^- leaching loss by reducing both the volume and the NO_3-N concentration of water that leached through the root zone. While quantities of NO_3-N in the drainage were small during both winter and summer, NO_3-N concentrations generally remained above 10 mg NO_3-N L^{-1}, except in winter where a rye cover crop was growing.

Since no-tillage conserves soil moisture from evaporation and promotes macroporosity, it is not surprising that NO_3^- leaching losses were greater with no-tillage corn than with conventional tillage corn. These preliminary results suggest that use of no-tillage in the Southern Piedmont may necessitate a higher level of management if stringent control of NO_3^- leaching is required.

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GRASS HEDGES REDUCE SOIL LOSS ON NO-TILL AND CONVENTIONAL-TILL COTTON PLOTS

K. C. McGregor and S. M. Dabney[1]

ABSTRACT

Stiff grass *(Miscanthus sinesis)* hedges were transplanted across the lower ends of standard erosion plots near Holly Springs, MS on March 27, 1991. The hedges were transplanted about a month before the initiation of research on runoff and soil loss comparisons from conventional and no-till cotton *(Gossypium hirsutum)*. The cotton study, begun on April 25,1991, was designed to compare runoff and soil loss from conventional and no-till cotton. Hedges were located 1.5 ft upslope from the lower ends of 5% sloping plots that were 133 ft wide and 72.6 ft long. The cotton experiment consisted of five treatments: no-till with and without a grass hedge, conventional-till with and without a grass hedge, and no-till without a grass hedge but with a winter cover crop. Hedges reduced soil loss even though completely consolidated hedges were not produced during 1991. Soil loss during the cotton growing season on conventional-till plots with hedges was 14 t/A as compared with 25 t/A for conventional-till plots without hedges. Soil loss from no-till cotton with hedges averaged 0.8 t/A during the growing season as compared with 1.4 t/A for no-till plots without hedges. Soil loss from no-till plots without hedges but on which winter cover crops would be grown was 3.0 t/A. Results show that grass hedges during the first growing season after transplanting can reduce soil losses. Further research is required to determine the usefulness of hedges in field situations.

INTRODUCTION

Vegetated buffer strips that consist of fine-stemmed forage species, planted in 16- to 50-ft wide intervals between cropped areas, can slow runoff and trap sediment (Hayes et al., 1984; Magette et al., 1989; and Line, 1991). These buffer strips also may remove nutrients and pesticides (Dallaha et al., 1989). The flow-retarding and filtering effectiveness is greatly reduced if concentrated flows force the vegetation into a prone state (Kouwen et al., 1981; Dallaha et al., 1989; and Flanagan et al., 1989). Stiff grass hedges in 1.5- to 5-ft wide strips used together with buffer strips should improve resistance to concentrated flow and reduce the width needed for the buffer strips. Reports indicate that grass hedges in the tropics can be effective in retaining sediments, increasing infiltration, and in gradually reducing slopes across the intervening cropland strips (Tefera, 1983; Abujamin et al., 1985; Thomas, G.W., 1988; and Krishnegowda et al., 1990). Tefera (1983) and Thomas, D.B. (1988) reported that 1.5- to 5-ft wide strips of grass reduced soil loss from runoff plots on a 10% slope hy about two-thirds and water loss by about one-half. Line (1991) found 5- to 20-ft wide grass strips had mean sediment trapping efficiencies that ranged from 50 to 90%, depending on flow rate and strip width.

Cotton production in north Mississippi results in high rates of soil erosion. The severity of the erosion is influenced by the previous cropping history. Mutchler et al. (1985) reported soil loss rates of 33 and 17 t/A for conventional-till cotton after 11 years of conventional-till and no-till history, respectively. Soil losses were 8 and 1 t/A for no-till cotton after reduced-till soybeans and after no-till soybeans and wheat double-cropped, respectively.

Quantitative data are needed to evaluate the erosion control effectiveness of grass hedges. The effectiveness of grass hedges in reducing soil loss on erosion plots was evaluated during the first growing season following transplanting of *Miscanthus sinensis*. The effects on soil loss of conventional-till and no-till cotton following grain sorghum also were evaluated.

PROCEDURE

Three accessions of *Miscanthus sinensis* [grass number 128, 'Gracillimus' (PI 387879); number 129, 'Veriegatus' (PI 9064490); and number 130, an unnamed variety (PI 414060)l were transplanted on March 27, 1991 in a single row on 7-inch centers across and 1 5 ft above the lower end of erosion plots, which were located at the North Mississippi Branch of the Mississippi Agricultural and Forestry Experiment Station, Holly Springs, MS. Plots were 133 by 72.6 ft on 5% slopes with predominately Providence silt loam soils (Typic Fragiudalfs). Plants obtained from the USDA-SCS Plant Materials Center, Baton Rouge, LA were about 1-ft high at the time of transplanting and

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had been grown in 1.2-gallon pots from stock maintained by ARS in Beltsville, MD. Plants in each erosion plot were arranged in the same accession pattern, with a single plant of accession 128 at each end of alternating plantings of accession 130 (two plants) and accession 129 (one plant).

Plant growth characteristics (number of total stems, number of dead stems, total height, green height, and clump circumference) were measured approximately every 4 weeks throughout the season from April 23 until October 14. Duplicates of each accession were monitored on each erosion plot. The same plants were observed throughout the season. Clump circumference was measured at a height of 2 inches above ground level.

The erosion plots on which hedges were transplanted also were used to compare runoff and soil loss from conventional and no-till cotton. Cotton was planted on April 25, about 1 month after the three accessions of *Miscanthus sinensis* were transplanted. Conventional-till treatments consisted of disking and harrowing immediately before planting, followed by two cultivations during June to control grass and weeds. Cotton was harvested on all plots, and the stalks shredded in early October. Soil losses and runoff amounts were measured from the plots using FW-1 water level recorders, H-flumes, and N-1 Coshocton-type wheel sampling devices (Carter and Parsons, 1967).

No-till paired plots with and without hedges had a previous 4-year history of no-till grain sorghum *(Sorghum bicolor);* other paired no-till cotton plots without hedges (to be used with a winter cover crop) had a previous 4-year history of minimum-till grain sorghum (McGregor and Mutchler, 1992). In the minimum-till system, tillage was not done at planting time. No more than two cultivations were done during the early growing season for weed control. One plot of each of the conventional-till cotton pairs with and without hedges had previously been in conventional-till grain sorghum; the other plot had previously been in ridge-till grain sorghum. Pairing conventional-till plots in this manner allowed relative comparisons of averages unbiased by the immediate differences in previous cropping history of plots with and without hedges.

RESULTS AND DISCUSSION

Growth Characteristics

All accessions of the transplanted *Miscanthus sinensis* survived a hard frost that occurred only 2 days after transplanting. The frost severely reduced the green height of all accessions; however, in approximately 2 weeks, the grass began to recnver from the damage.

Growth characteristics of individual accessions were not significantly different between tillage treatments, and there were no differences detected between hedges on no-till and conventional-till plots. Hedges grew the most during July and August. The increase in measured growth parameters during the summer months indicated these accessions are warm-season grasses, and should grow well in the mid-South if they have suffcient cold-hardiness to survive the winters. Although all three accessions grew well, gaps as wide as 3 inches existed between some of the plants at the end of the growing season. Obviously, more than one season is needed for these grasses to complete formation of a consolidated hedge with no gaps. In this particular study, grain sorghum residues trapped by unconsolidated hedges caused more deposition to occur above the hedges. The deposition would have been less without the residues. This deposition was probably greater than that which would have occurred with cotton residues.

By September 10, accessions 130, 129, and 128 produced clump diameters of about 8, 5, and 4 inches; plant heights of about 6, 5, and 4 ft; and live tillers of about 400, 500, and 1000 **tillers/ft^2** of ground surface area, respectively. Accession 128, the shortest variety, produced the largest number of tillers and fine leaves. Accession 130 produced the fewest tillers; however, it had the coarsest stems and blades and grew the tallest and widest. Thus, accession 130 should do the best job of filling in gaps between plants. Fine stemmed grasses usually were more susceptible to stem deflection and hedge "failure" or prostration, but all of the accessions were stiff enough to withstand the flows associated with the runoff from these plots.

Plants balance top growth with root development. Furthermore, plants divide top growth into either an increase in height or an increase in number of tillers. Unfortunately, the increase in number of tillers for accession 128 as compared with the other plants did not result in a corresponding increase in clump diameter. Accessions 129 and 130 appear to be better selections for hedge development.

Rainfall, Runoff. and Soil Loss

Rainfall (Table 1) during May and June was high and accounted for 40 and 20%, respectively, of the 31.7 inches of the rainfall from planting on April 25 through September. Likewise, most of the runoff (Table 1) and soil loss (Table 2) during the growing season occurred during May and June on both no-till and conventional-till plots. No measurable soil loss occurred on no-till plots during July, August, and September; and the total soil loss on no-till plots was very low for the entire growing season. Conservation benefits of no-tillage as compared with conventional-till during the growing season were reflected in the much lower runoff and soil loss values from the no-till cotton plots during that period. Low soil loss from conventional-till plots during July through September reflected the combined effects of low rainfall, low runoff, incorporated grain sorghum residues, and cotton canopy.

Soil loss (April 25 through September) for no-till cotton without hedges averaged 1.4 t/A for plots that had previously been in no-till grain sorghum. Evidently, the no-till grain sorghum cropping history caused the soil loss to be much lower than the 3.0 t/A soil loss measured from the other no-till cotton plots that also were without hedges but which had previously been used for minimum-till grain sorghum. Grass hedges during April 25 through September reduced soil loss for no-till cotton after no-till grain sorghum to 0.8 t/A. During this same period, grass hedges on conventional-till plots reduced soil loss from 25.1 to 14.5 t/A. A fully developed hedge during April and May would have made this reduction in soil loss even more impressive. By early August, accumulations of crop residues and sediment about 1.5 inches deep were observed immediately upslope of hedges on conventional-till plots and up to 3.5 inches of crop residues and sediment accumulated immediately upslope of hedges on no-till plots.

Rainfall (Table 1) from March 27 to April 25, during the period following transplanting of grass hedges until planting of cotton, was extremely high. Grain sorghum residues remaining on the soil surface kept soil loss low, even for plots that had been in conventional-till. Higher soil loss on the same plots during the early growing season of May and June partially reflected erosion control benefits lost when crop residues are incorporated by tillage during seedbed preparation. Grain sorghum residues left undisturbed on no-till plots after planting of cotton continued to provide erosion control. Residues which accumulated above the hedges on conventional-till and no-till plots contributed to the success of hedges in reducing soil loss.

Discussion of Potential Applications of Hedge Grasses

The usefulness of hedge grasses for erosion control will be greatly enhanced if the hedges can eventually perform in a field situation similarly to terraces. A desirable result of soil accumulating above hedges would be the "bench-terracing" of such fields with a reduction of slope length and steepness between the hedges. Runoff would then be routed through the watersheds in such a manner to provide improved erosion control. Any conservation practice that leaves more of the soil in place on the land also eventually improves the water quality of our streams and lakes. Other structural or vegetative methods (like grass waterways) simultaneously may be needed with use of stiff hedge grasses to control erosion and improve the field topography. Over a long period of time, sediment deposition above hedges may alter flow patterns if hedges are not on true contours, thus concentrating runoff at lower elevations in hedge rows. A potential hazard associated with the use of grass hedges is that in some field situations, and especially during very high intensity rainfall events, serious breakthroughs of hedges may occur at points where concentrated flow occurs. In the latter case, formation of gullies and rills then might reveal greater erosion problems than would have occurred without flow concentration. Future research involving field-size areas is required to answer some of the questions related to the use and limitations of grass hedges in field situations. Such evaluations of advantages and limitations of grass hedges for erosion control also will determine the best applications for their use.

SUMMARY AND CONCLUSIONS

Grass hedges were successfully transplanted on erosion plots at Holly Springs, MS. Three accessions of *Miscanthus sinesis* were used in each of the single rows of hedges that were located across the lower ends of plots. Largest growth rates occurred in July and August. All three accessions grew well, but not well enough for complete formation of a consolidated hedge during the first growing season. Nevertheless, the potential of these hedges for erosion control was very evident during this first year on runoff plots. The developing hedges dramatically reduced soil loss during the growing season on conventional-till and no-till plots

Table 1. Rainfall and runoff (inches) during the growing season of 1991.

	Rain	Runoff: Conventional-till, Without Hedge	Runoff: Conventional-till, With Hedge	Runoff: No-till, Without Hedge	Runoff: No-till, With Hedge	Runoff: No-till, With Cover Crop†
Hedges Transplanted (March 27)††						
March 27 to April 25	12.6	3.8	4.4	5.5	6.8	3.6
Tillage; Cotton Planted (April 25)						
April 25-30	5.6	2.1	2.4	2.7	3.6	2.3
May	12.7	7.7	7.7	3.1	5.0	4.7
June	6.4	2.9	2.9	2.2	2.1	1.6
July	2.4	0.5	0.2	0.0	0.0	0.2
August	3.3	1.0	0.5	0.3	0.2	0.6
September	1.4	0.1	0.1	0.0	0.0	0.0
April 25 to Sept. 30	31.8	14.3	13.8	8.3	10.9	9.4

† Also without hedges, but will have winter cover crop. Differs from other no-till plots without hedges by having minimum-till rather than no-till history.

†† Conditions on plots during April reflected previous grain sorghum cropping history.

Table 2. Soil loss (t/A) during the growing season of 1991.

	Runoff: Conventional-till, Without Hedge	Runoff: Conventional-till, With Hedge	Runoff: No-till, Without Hedge	Runoff: No-till, With Hedge	Runoff: No-till, With Cover Crop†
Hedges Transplanted (March 27)††					
March 27 to April 25	0.3	0.6	0.2	0.3	0.3
Tillage; Cotton Planted (April 25)					
April 25-30	0.7	0.5	0.1	0.1	0.2
May	9.4	8.9	0.4	0.4	1.7
June	13.0	4.9	0.9	0.3	1.0
July	0.6	0.0	0.0	0.0	0.0
August	1.3	0.2	0.0	0.0	0.1
September	0.1	0.0	0.0	0.0	0.0
April 25 to Sept. 30	25.1	14.5	1.4	0.8	3.0

† Also without hedges, but will have winter cover crop. Differs from other no-till plots without hedges by having minimum-till rather than no-till history.

†† Conditions on plots during April reflected previous grain sorghum cropping history.

as compared with similar plots with no hedges. Differences were detected in soil loss between no-till plots without hedges where the cropping history had included a greater amount of tillage. Further research on plots and field-size areas will improve evaluations of the advantages, limitations, and applications of grass hedges in practical farming situations.

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NON-SELECTIVE AND RESIDUAL HERBICIDE TANKMIXES IN NO-TILL RICE

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ABSTRACT

No-till rice production is becoming increasingly popular in Louisiana. A current limitation is the lack of registered herbicides for use in no-till rice. Two studies were conducted in southwestern Louisiana to evaluate a number of burndown herbicides when used alone and in'combination with residual herbicides in tank-mix applications. In 1991, paraquat and glyphosate were applied singly and in combination with either oxyfluorfen or quinclorac 6- and 3-weeks preplant. Weed control was greater and grain yields were significantly higher with both 3-week preplant applications and the residual tankmixes. In 1992, diquat, glyphosate, and glufosinate were applied either singly or in Combination with either quinclorac or thiobencarb 3- and 1-week preplant. Weed control and grain yields were higher with a 1-week preplant application and with the residual tankmixes. These studies indicate the importance of both timing of burndown applications and the use of residual herbicides in combination with burndown herbicides for effective weed control.

Nomenclature: rice, Oryza sativa; paraquat, 1,1'-dimethyl-4,4'-bipyridinium ion; glyphosate, N-(pbosphonomethy1)glycine; oxfluorfen, 2-chloro-l-(3-ethoxy-4-nitrophenoxy)-4-(trifluromethyl) benzene; quinclorac, 3,7-dichloro-8-quinoline-carboxylic acid; diquat, 6,7-dihydrodipyrido[1,2-∝:2',1'-c]pyrazinediium ion; glufosinate, 2-amino-4-(hydroxymethylphosphinyl)-butanoic acid; thiobencarb, S-[(4-chlorophenyl)methyl]-diethylcarbamothioate

INTRODUCTION

Conservation tillage practices are slowly being adapted by rice producers in the south. Increased awareness of the importance of soil and water conservation, reducing sediment loss during field drainage, the judicious use of pesticides and other agronomic inputs, and the need to reduce production costs have led to greater interest in no-till or stale seedbed rice production. Since 1987, studies have been conducted in Louisiana to evaluate conservation tillage practices in water- and drill-seeded rice (Bollich, 1991, 1992; Feagley et al., 1992). There is considerable potential for the use of conservation tillage practices in commercial rice production.

Control of existing vegetation prior to no-till rice establishment is critical to successful stand establishment and resulting weed control after seeding. Glyphosate was the only herbicide registered for burndown in rice through 1992. While it does possess broad-spectrum activity, it is ineffective on some semiaquatic broadleaf weed species such as smartweed *(Polygonum pensylvanicum* L.), knotweed *(Polygonum aviculare* L.), and cutleaf evening primrose *(Oenolhera laciniata* Hill). Paraquat and glufosinate are non-selective contact herbicides that give more rapid burndown of preplant vegetation but are not registered for use in rice. Paraquat is registered for use as a burndown in corn, cotton, and soybeans. Glufosinate is not registered for use in any crop at the present time, but is widely used for this purpose outside the U.S. The residual herbicides quinclorac and tbiobencarb are registered for use in rice, but only thiobencarb can be applied in combination with glyphosate as a preplant burndown. Oxyfluorfen is registered for use in fallow bed cotton.

The objective of these two studies was to compare burndown herbicides when used alone and in combination with residual herbicides in no-till rice.

MATERIALS AND METHODS

The experiments were conducted at the Rice Research Station in Crowley, Louisiana, on a Crowley silt loam (fine, montmorillonitic, thermic, Typic Albaqualf). The test area was laser levelled in August of the preceding year for each study. No other soil-disturbing activities occurred until the studies were planted the following spring.

Herbicides and rates of application for both studies are listed in Tables 1 and 2. In 1991, glyphosate and paraquat were applied alone and in combination with either oxyfluorfen or quinclorac at 6

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or 3 weeks prior to seeding. In 1992, glyphosate, diquat, and glufosinate were applied alone and in combination with either quinclorac or thiobencarb either 3 weeks or 1 week prior to seeding. The experiments were designed as randomized complete blocks with herbicide by application time treatment combinations. Rice (cv. Lemont in 1991 and Mayhelle in 1992) was drill-seeded at the rate of 110 Ib/acre in 7-inch rows on 24 April 1991 and 19 April 1992. The test areas were flush irrigated as needed to establish stand and facilitate seedling growth. Fertilizer applications of 90-0-0 and 150-40-40 (N-P-K) were applied preflood in 1991 and 1992, respectively. A shallow, permanent flood was established after fertilizer application. An additional midseason application of 58-0-0 was applied in 1991.

An application of molinate and bensulfuron was required after permanent flood establishment in 1991 due to severe weed pressure. In 1992, the test area was treated with bentazon before permanently flooding to control aquatic broadleaf weeds.

Weed control, days to 50% heading, plant height, and grain yield were determined each year. In 1992, stand density was also determined.

RESULTS AND DISCUSSION

Time of burndown application in relation to planting significantly influenced weed control. Control was increased when herbicides were applied 3 weeks preplant in 1991 (Table 1). The 6-week applications did not provide adequate weed control prior to planting. Weed control improved when residual herbicides were applied in combination with either glyphosate or paraquat. No difference in weed control was observed between oxyfluorfen and quinclorac when tank-mixed with either burndown herbicide.

Grain yields were also influenced by time of burndown application and herbicide. Yields were significantly reduced when the burndown herbicides were applied 6 weeks preplant. Regrowth of weeds not controlled by the burndown applications or additional weed reinfestation prior to planting limited their effectiveness. Reduced grain yields appeared to be related to weed competition and possible stand reduction. The 3-week preplant applications were more effective in extending control or suppression of weeds beyond seeding. Yields were also higher when residual herbicides were applied in combination with either glyphosate or paraquat, especially with the 3-week preplant application. Highest grain yields resulted from quinclorac tank-mix combinations.

Stand density was not affected by either time of application or herbicide treatment in 1992 (Table 2). Annual grass control at 30 days after planting (DAP) was increased as time of burndown was decreased to 1-week preplant and residual herbicides were applied in tank-mix combinations. Separate ratings were taken for barnyardgrass *(Echinochloa* spp.) and sprangletop *(Leptochloa* spp.) at 60 DAP. Weed control was also increased with a 1-week preplant application and when residual tank-mix Combinations were applied. Quinclorac and thiobencarb were equally effective in offering residual grass control.

Grain yields in 1992 were influenced by time of burndown application. Yields were significantly higher with a 1-week preplant timing. Yields were also higher when residual herbicides were applied in combination with the burndown herbicides. Yields were similar for quinclorac and thiobencarh when applied as tank-mix combinations.

Results of these studies indicate that preplant weed control is more effective when the time elapsed between herbicide application and planting is minimized. Even when no residual herbicides are included with a burndown application, weed control before and after planting is increased when shorter delays between herbicide application and planting occur. More effective weed control resulted in higher grain yields in each study.

Timely application of burndown-residual herbicide tank-mixes allows the opportunity to reduce application costs in no-till rice. The performance of all of the non-registered herbicides evaluated in these two studies indicates potential for their use in no-till rice establishment. Additional herbicides registered for burndown use in rice would greatly increase the potential for widespread adaptation of conservation tillage practices in southern rice production.

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Table 1. Preplant burndown evaluation in no-till, drill-seeded Lemont rice. Rice Research Station, South Unit. Crowley, LA. 1991.

Eerbicide	Time of application	Rate	1 Control	Days to 501 heading	Plant height	Grain yield at 121 moisture
	(weeks preplant)	(lb ai/A)			(cm)	(lb/A)
Glyphosate	6	1.0	64	81	65	2822
Paraquate	6	.63	33	81	65	3155
Glyphosate + Oryfluorfen	6	1.0 + .25	79	81	67	3363
Paraquat + Oryfluorfen	6	.63 + .25	70	81	70	4257
Glyphosate + Quinclorac	6	1.0 + .5	83	81	71	5012
Paraquat + Quinclorac	6	.63 + .5	65	82	73	5374
Glyphosate	3	1.0	98	82	71	4726
Paraquat	3	.63	95	82	70	4831
Glyphosate + Oryfluorfen	3	1.0 + .63	98	83	72	5271
Paraquat + Oryfluorfen	3	.63 + .25	95	82	73	5336
Glyphosate + Quinclorac	3	1.0 + .5	99	83	79	6408
Paraquat + Quinclorac	3	.63 + .5	97	83	74	6159
C.V.Z			12.38	0.77	5.70	13.5
			Main effects			
Time of application:						
6 week preplant			65	81	69	4020
3 week preplant			97	83	73	5455
LSD (0.05)			6	1	2	376
Herbicide:						
Glyphosate			81	82	68	3841
Paraquat			64	82	68	3993
Glyphosate + Oryfluorfen			88	82	70	4317
Paraquat + Oxyfluorfen			82	82	72	4797
Glyphosate + Quinclorac			91	82	75	5710
Paraquat + Quinclorac			81	82	J4	5766
LSD (0.05)			10	ns	4	651
Contrasts:						
Burndown			72	82	68	3883
Burndown tankmix			86	82	72	5147
			•	ns	*	*
Oxyfluorfen			85	82	70	4557
Quinclorac			86	83	74	5738
			us	ns	*	*

* = significant at P = 0.05.
ns = nonsignificant

Table 2. Preplant burndown evaluation in no-till, drill-seeded Maybelle rice. Rice Research Station. South Unit, Crowley, LA. 1992.

Herbicide	Time Of application	Rate	Stand density	2 Grass control' 30 DAP AG	60 DAF' BYG	ST	Days to 502 heading	Plant height	Grain yield at 122 moisture
	(weeks preplant)	(lb ai/A)	(plants/ft²)					(cm)	(lb/A)
Diquat	3	.5	19	85	80	70	77	101	7113
Diquat + Quinclorac	3	.5 + .375	17	80	77	72	77	100	7743
Diquat + Thiobencarb	3	.5 + 3.0	20	87	82	77	77	101	7436
Glyphosate	3	.75	18	72	72	82	77	101	7722
Glyphosate + Quinclorac	3	.75 + .375	22	85	87	75	77	97	7283
Glyphosate + Thiobencarb	3	.75 + 3.0	21	85	90	82	77	101	7913
Glufosinate	3	.75	21	60	67	57	77	100	7230
Glufosinate + Quinclorac	3	.75 + .375	21	92	87	75	77	103	7944
Glufosinate + Thiobencarb	3	.75 + 3.0	20	85	85	80	77	102	7873
Quinclorac	3	.375	20	95	85	82	78	99	7675
Thiobencarb	3	3.0	19	95	82	87	79	96	7242
Diquat	1	.5	22	90	82	85	77	99	7519
Diquat + Quinclorac	1	.5 + .375	20	97	90	90	77	103	7916
Diquat + Thiobencarb	1	.5 + 3.0	21	100	90	90	77	102	7869
Glyphosate	1	.75	23	95	87	87	77	100	7971
Glyphosate + Quinclorac	1	.75 + .375	21	100	90	85	77	99	8110
Glyphosate + Thiobencarb	1	.75 + 3.0	22	100	90	90	77	99	8098
Glufosinate	1	.75	21	90	80	77	77	100	7600
Glufosinate + Quinclorac	1	.75 + .375	22	97	90	87	76	100	7653
Glufosinate + Ibiobencarb	1	.75 + 3.0	23	97	87	90	76	97	7948
Quinclorac	1	.375	18	97	90	87	79	98	7706
Thiobencarb	1	3.0	18	97	90	90	78	97	7936
c.v.2			16.31	12.41	6.49	11.86	0.64	3.41	5.92
Time of application:									
3-week preplant			20	84	82	77	77	100	7561
1-week preplant			21	97	88	87	77	99	7848
LSD (0.05)			ns	5	2	4	ns	ns	194

Continued.

Table 2. Continued

Eerbicide	Time of application	Rate	Stand density	% Grass control[1] 30 DAP AG	60 DAP BYG	60 DAP ST	Days to 502 heading	Plant height	Grain yield at 122 moisture
	(weeks preplant)	(lb ai/A)	(plants/ft^2)					(cm)	(lb/A)
Herbicide:									
Diquat			21	87	81	77	77	100	7316
Diquat + Quinclorac			19	89	84	81	77	101	7829
Diquat + Tbiobencarb			21	94	86	a4	77	102	7652
Glyphosate			20	84	80	a5	77	101	7846
Glyphosate + Quinclorac			21	92	89	80	77	98	7697
Glyphosate + Thiobencarb			21	92	90	86	77	100	8005
Glufosinate			21	75	74	67	77	100	7415
Glufosinate + Quinclorac			21	95	89	81	77	101	7799
Glufosinate + Thiobencarb			22	91	86	a5	77	100	7910
Quinclorac			19	96	a7	a5	78	99	7691
Thiobencarb			19	96	86	89	79	96	7589
LSD *(0.05)*			ns	11	05	1	1	ns	ns
Contrasts:									
Burndown			21	82	78	76	77	100	7526
Burndown tankmix			21	92	a7	83	77	100	7815
			ns	*	*	*	ns	ns	•
Quinclorac			21	92	87	81	77	100	7775
Thiobencarb			21	92	87	85	77	101	7856
			ns	ns	ns	ns	ns	ns	ns

[1] DAP = days after planting. Rating for 30 DAP is overall grass rating. Separate ratings were assigned for barnyardgrass and sprangletop 60 DAP.

• = significant at P = 0.05.

ns = nonsignificant

POPULATION DENSITIES OF ROOT-KNOT NEMATODES FOLLOWING CORN AND SORGHUM IN CROPPING SYSTEMS

R. McSorley and R.N. Gallaher[1]

ABSTRACT

Densities of the root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood, were compared following summer crops of tropical corn *(Zea mays* L.) and sorghum *(Sorghum bicolor* L.) at several locations in north Florida. Densities of *M. incognita* remained low ($\leq$ **34/100** cm^3 soil) following the sorghum cultivars DeKalb FS25E and DeKalh BR64 and the sorghum-sudangrass *(S. sudanense* [Piper] Stapf) hybrid DeKalb SX-17, and were lower ($P \leq 0.05$) than population densities following any of the corn cultivars tested. Results were consistent, regardless of location, planting date, or tillage practices. Densities of *M. incognita* following the sorghum cultivar Asgrow Chaparral were not consistently lower than those following corn. Sorghum can be an effective rotation crop for keeping *M. incognifa* populations low, but cultivar choice is critical.

INTRODUCI'ION

Root-knot nematodes (Meloidogyne spp.) have been recognized for many years as the most serious nematode pests of many commercial crops grown in Florida and other southeastern states (Christie, 1959; Johnson, 1982; Taylor and Sasser, 1978). Recently, increased emphasis has been placed on developing crop rotations or sequences that minimize buildup of serious nematode pests, such as root-knot nematodes (Dickson and Gallaher, 1989; Johnson, 1982; McSorley et al., 1991). For example, a winter cover crop of rye *(Secale cereale* L.) was better than vetch *(Vicia villosa* Roth.) for lowering population densities of *Meloidogyne incognita* (Kofoid and White) Chitwood (McSorley et al., 1991). Densities of *M. incognita* were greatly increased following summer crops of corn *(Zea mays* L.) compared with sorghum (Sorghum *bicolor* L.) in both conventional and no-tillage plots (Dickson and Gallaher, 1989). This and other recent observations (McSorley and Gallaher, 1991a) suggest that sorghum and sorghum-sudangrass *(S. sudanense* [Piper] Stapf) hybrids may be excellent rotation crops for limiting root-knot nematode densities. The objective of the current research is to verify these results across a range of sites, tillage practices, planting dates, and cultivars of corn and sorghum.

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MATERIAIS AND METHODS

Separate experiments involving selected corn and sorghum cultivars were established at several locations in Alachua and Marion counties in north Florida. At all locations, the crop treatments were arranged in a randomized complete block design, but the number of replications varied among the sites. Winter cover crops also varied with site and included rye, vetch, wheat *(Triticum aestivum* L.), lupine *(Lupinus angustifolius* L.), or crimson clover *(Trifolium incarnatum* L.), as well as double-cropped corn or sorghum. Tillage practices also varied with location. Previous crops were mowed and removed for silage, and in conventional tillage plots, crop residues were incorporated by plowing and discing before planting. In no-tillage sites, herbicides were '.applied to kill any living plant material, and seed was planted between the old crop rows. In all cases (conventional and no-tillage), corn and sorghum seed were planted in rows 75 cm apart with a two-row Brown-Harden Super Seeder (Brown Mfg. Co. Banks, AL).

In 1990, corn and sorghum cultivars were planted at the Green Acres Agronomy Research Farm in Alachua County on 20 May. Individual plots consisted of four rows, 5 m long. The soil was an Arredondo sand (94% sand, 35% silt, 25% clay; pH 6.7; 2.0% organic matter). The site at the Dairy Research Unit in Alachua County was on Scranton fine sand (90% sand, 3.5% silt, 6.5% clay; pH 6.8; 43% organic matter), and planted on 21 July 1991. Plots consisted of 30 rows, 70 m long. Plots at the Pine Acres Research Farm in Marion County contained four rows, 9 m long. The soil type was an Arredondo sand-Gainesville loamy sand association (92% sand, 3% silt, 5% clay; pH 5.6; 2.8% organic matter). Three different plantings of corn and sorghum were made at this location in 1990 2 April, 20 May, and 20 July. The 20 July planting was a double crop following the same cultivars in the 2 April planting. In 1991, experiments comparing corn and sorghum were established at seven different locations on the Green Acres Farm. Sites differed in their previous crops, but all were planted in May, and plot size at all sites was four rows, 3 m long.

Cultural practices, fertilizers, and herbicide usage at all of these sites are described in detail elsewhere (Gallaher et al., 1991; McSorley and Gallaher, 1991b; McSorley and Gallaher, 1992). Plots were sampled for nematodes at the harvest of each corn and sorghum crop. Each soil sample consisted of six cores 2.5 cm in diameter and 20 cm deep, collected within plant rows in a systematic pattern. From this, a 100-cm^3 subsample was removed for nematode extraction, using a modified sieving and centrifugation procedure (Jenkins, 1964). Nematode count data were log-transformed ($\log_{10}\{x+1\}$) before analysis of variance, and single degree of freedom orthogonal contrasts (Freed et al., 1987; Sokal and Rohlf, 1969) were determined for corn vs. sorghum.

RESULTS AND DISCUSSION

At all locations in 1990, population densities of the root-knot nematode *M. incognita* were lower ($P < 0.05$) following sorghum than following corn (Table 1). This result occurred regardless of tillage practices or whether the crop was first crop or a double crop. Across all sites, average nematode densities on sorghum were all $\leq$ 34/100 cm^3 soil, whereas the lowest nematode density observed after corn was 147/100 cm' soil. These results are consistent with previous observations (Dickson and Gallaher, 1989; McSorley and Gallaher, 1991a) that sorghum was a better rotation crop than corn for keeping population densities of *M. incognita* low.

In 1991, *M. incognita* population densities following sorghum were lower ($P \leq 0.05$) than those following corn at two sites, were not significantly different at four sites, and were higher than populations following corn at one site (Table 2). Results were different from those obtained in the previous season, but a different sorghum cultivar (Asgrow Chaparral) was used, which supported relatively high (mean densities $\geq$ 91/100 cm^3 soil) numbers of *M. incognita* at harvest.

It is evident that, while the preference of sorghum over corn as a rotation crop to limit *M. incognita* densities is not affected by tillage practices, planting date, or location, the choice of a sorghum cultivar is critical. The sorghum or sorghum-sudangrass cultivars DeKalb FS25E, DeKalb BR64, and DeKalb SX-17 were effective in keeping *M. incognita* low. However, relatively few sorghum cultivars have been tested for their effects on root-knot nematode population densities, and much research will be needed to determine the range of response of available sorghum germplasm to these nematode pests.

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Table 1. Population densities of root-hot nematodes (*Meloidogyne incognita*) following crops of corn or sorghum at several locations in 1990.

Location	Tillage[1]	Previous crop	Current crop	Cultivar	Root-knot nematodes per 100 cm^3 soil[2]
Green Acres	No	Winter rye	Corn	Pioneer X304C	152
			Sorghum	DeKalb FS25E	5*
			Sorghum	DeKalb BR64	2*
Dairy Unit	No	Spring corn	Corn	Pioneer X304C	1,872
			Corn	Florida SYN-1	950
			Corn	DeKalb XL678C	884
			Sorghum	DeKalb FS25E	34*
Pine Acres	Conv.	Winter rye	Corn	Pioneer 3320	437
			Corn	Northrup King 508	409
			Corn	Pioneer X304C	762
			Corn	Florida SYN-1	654
			Sorghum	DeKalb SX-17	6*
			Sorghum	DeKalb FS25E	10*
Pine Acres	No	Spring corn	Corn	Pioneer 3320	191
		Spring corn	Corn	Northrup King 508	162
		Spring corn	Corn	Pioneer X304C	234
		Spring corn	Corn	Florida SYN-1	249
		Spring sorghum	Sorghum	DeKalb SX-17	0*
		Spring sorghum	Sorghum	DeKalb FS25E	5*
Pine Acres	Conv.	Winter rye	Corn	Pioneer 3320	375
			Corn	Northrup King 508	147
			Corn	Pioneer X304C	437
			Corn	Florida SYN-1	306
			Sorghum	DeKalb SX-17	4*
			Sorghum	DeKalb FS25E	13*

[1] No = No tillage; Conv. = Conventional tillage.

[2] Asterisk (*) indicates nematode densities on corn and sorghum at the same location are significantly ($P \leq 0.05$) different, according to the orthogonal contrast of corn vs. sorghum. Data are means of 4-8 replications, depending on loeation.

Table 2. Population densities of root-knot nematodes *(Meloidogyne incognita)* following crops of corn or sorghum under conventional tillage during 1991 at seven sites with different winter cover crops.

Previous crop	Current crop	Cultivar	Root-knot nematodes per 100 cm^3 soil[1]
Wheat	Corn	Pioneer 3098	759
	Sorghum	Asgrow Chaparral	91*
Fallow	Corn	Pioneer 3098	265
	Sorghum	Asgrow Chaparral	318*
Rye	Corn	Pioneer 3098	1,076
	Sorghum	Asgrow Chaparral	166*
Lupine	Corn	Pioneer 3098	782
	Sorghum	Asgrow Chaparral	248
Lupine	Corn	Pioneer 3098	1,244
	Sorghum	Asgrow Chaparral	467
Clover	Corn	Pioneer 3098	706
	Sorghum	Asgrow Chaparral	541
Vetch	Corn	Pioneer 3098	1,262
	Sorghum	Asgrow Chaparral	815

[1] Asterisk (*) indicates nematode densities on corn and sorghum are significantly ($P \leq 0.05$) different, according to the orthogonal contrast of corn vs. sorghum. Data are means of 4-5 replications, depending on site.

NO-TILL CO'ITON GROWTH CHARACTERISTICS AND YIELD IN *ALABAMA*

C.H. Burmester, M.G. Patterson, and D.W. Reeves[1]

ABSTRACT

Two field experiments in northern Alabama were used to compare cotton (Gossypium hirsutum L.) growth and yields in two no-tillage systems with conventionally tilled cotton. The two no-tillage systems evaluated were: 1) planting into old cotton residue and 2) planting into a wheat (Triticum spp.) cover crop. All cotton was planted flat with a burn-down herbicide applied to kill any vegetation at least 2 weeks prior to planting. The soil type in each test was a Decatur silt loam, which is one of the predominate cotton soil types in northern Alabama.

Cotton yields from all tillage systems were evaluated at one test site from 1988 through 1992. Another test site, established in 1991, was used to evaluate the effect of starter fertilizer rates and placement on cotton growth and yield, as well as differences in soil strength and soil water due to tillage systems.

Cotton yields measured from 1988 through 1992 in cotton no-tilled into old cotton residue or no-tilled into wheat were 90 and 95%, respectively, of the yields from conventionally tilled cotton. Most of these yield differences occurred during the dry seasons of 1988, 1990, and 1991. Little yield differences were found when rainfall was more adequate in 1989 and 1992.

The starter fertilizer test conducted in 1991 and 1992 also indicated increased yields with starter fertilizers in the no-till systems in the dry 1991 season, but not when rainfall was abundant in 1992. Little response to starter fertilizer was measured in conventionally tilled cotton either year. Cotton height measurements made in the starter fertilizer test area found cotton grown no-till into cotton residue produced a much more compact plant than any of the other tillage systems in 1991 and 1992. Soil penetrometer readings taken in 1992 may explain part of these differences; soil strength was greater in cotton residue plots than soil in plots conventionally tilled or no-tilled into wheat. Restricted root growth or decreased water infiltration could possibly be the reason for decreased no-till cotton yields in cotton residue during dry seasons.

Planting a wheat cover crop on these soils seems beneficial to cotton grown with no-tillage. Preliminary research indicates this may be due to better cotton rooting or perhaps better water infiltration than when cotton is no-tilled into cotton residue.

INTRODUCTION

Alabama's most intense cotton production area is located on silty clay Limestone Valley soils located in the northern part of the state. Many of these soils are considered highly erodible and, therefore, must have approved soil conservation plans to meet requirements of the 1985 Farm Bill. Research into conservation tillage systems for cotton grown on these soils has been conducted since the early 1980s. However, only in recent years have many acres of conservation tillage cotton been grown in this region.

Two conservation tillage cover systems used by most north Alabama cotton farmers are: 1) planting no-till into old cotton residue and 2) planting no-till into a wheat cover killed at least 2 weeks prior to planting. Essentially, all cotton is planted flat with very little cotton planted on raised beds.

Planting into old cotton residue is preferred by most farmers because of the ease of stand establishment and time and costs involved in planting wheat in the fall. Research by Brown et al. (1985), however, indicated possible weed control and cotton growth problems when cotton was planted into old cotton residue. Reduced cotton stalk height has often been measured when cotton is planted into old cotton residue compared with cotton planted into a small grain cover or conventionally tilled soils (Burmester, unpublished data). The reasons for these reductions have not been explained.

Increased cotton yield responses to starter fertilizer have been reported by Touchton et al. (1986) in conservation tillage cotton systems in Alabama. Higher nitrogen fertilizer rates are usually needed by cotton planted into a small grain cover compared with cotton planted conventionally or into old cotton stubble, (Brown et al., 1986).

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To help explain differences in cotton response to no-tillage systems, a cotton crop rotation test was modified in 1987 to include the two most common no-tillage systems used in this area. Yields from cotton planted no-till into wheat cover and into old cotton residue were compared with conventionally tilled cotton from 1988 to 1992. The use of starter fertilizers in conservation-tillage cotton was also evaluated in another test area in 1991 and 1992. Soil penetrometer and soil moisture readings were also taken in this test area during 1992.

MATERIALS AND METHODS

Replicated field studies located on the Alabama Agricultural Experiment Station, Belle Mina, AL, were used to evaluate cotton conservation-tillage systems for the area of northern Alabama. Conservation-tillage treatments in tests included cotton planted no-till into a wheat cover or into old cotton residue. All no-till plot areas received a 1 quart burndown application of Roundup herbicide to kill all vegetation at least 2 weeks prior to planting. Conventionally tilled areas were turned in the fall with leveling and smoothing in the spring. Wheat areas were lightly disked in the fall before wheat was planted with a grain drill. Nitrogen as ammonium nitrate was applied at rates of 60 and 30 lb/A at planting and at mid-squaring, respectively, to all plots. The soil type was a Decatur silt loam (Rhodic Paleudult) and is the predominate soil type on which cotton is grown in northern Alabama.

In 1987, a cotton crop rotation experiment established in 1979 was modified to include plots of continuous no-till cotton planted into either a wheat winter cover or an old cotton residue. All plots were eight rows, 50 ft long. Cotton yields were obtained from 1988 to 1992 by mechanically picking the middle four rows from each plot.

In 1991 and 1992, placement of starter fertilizers was evaluated in another test area. Liquid fertilizers, 11-0-0 and 11-37-0, were applied to supply N and P_2O_5 rates of 0-0, 15-0, and 15-50 Ib/A. These starter fertilizers were placed in a 4-inch band over the seed furrow or placed 2x2 at planting in all tillage treatments. The experimental design was a split plot with three replications. Tillage was in whole plots and starter fertilizer treatments were in split plots. The cotton variety DPL 50 was used both years. Cotton stand counts were taken approximately 4 weeks after cotton planting each season. Cotton height measurements were taken approximately 5 and 10 weeks after planting each year. Cotton yields were determined by mechanically picking the two center rows from each plot.

In 1992, soil compaction and soil moisture content were measured in the no-starter check plots in each tillage treatment. Fifteen soil penetrometer readings were made in nontrafticked middles 2 weeks after cotton emergence and in mid-August. Measurements were made using a hand-held Bush recording soil penetrometer (Mark I Model 1979; Findlay, Irvine Ltd., Penicuik, Scotland). Soil volumetric moisture content was measured at three depths (8, 16, and 24 inches). Parallel-paired, stainless steel rods, 0.25 inches in diameter, were installed in-row, 20 inches from the row in a traffic middle and 20 inches from the row in a nontrafficked middle. A Tektronix 1502B cable tester was used to measure soil water using the time-domain reflectometry (TDR) method as developed by Topp and Davis, (1985). Four measurements were made during the boll development period in 1992.

RESULTS AND DISCUSSION

Rainfall and degree day (DD) 60 accumulation differed greatly during the north Alabama growing seasons of 1988 through 1992 (Table 1). Three of the years (1988, 1990, and 1991) are eonsidered drought years with at least one of the summer months being extremely dry. The DD60 accumulations during the summer months were generally consistent except for 1992 when only 81% of average (previous 4 years) DD60s were accumulated.

Seed-cotton yields, measured in the cotton rotation plot area, followed the rainfall pattern closely, with extremely low yields during the 1988, 1990, and 1991 seasons. Cotton yield differences between tillage systems were greatest during these dry seasons (Table 2). Seed-cotton yields of cotton planted no-till into old cotton residue were consistently lower than cotton no-tilled into wheat or conventionally tilled in all three drought years. Cotton yields planted into wheat residue were equivalent to conventionally tilled cotton yields in 1988 and 1990 but lower than conventional cotton yields in 1991 and 1992. Little cotton yield differences were found between tillage treatments during the wetter 1989 season.

Cotton stand counts made in the starter fertilizer test revealed that starter fertilizer source or placement had no effect on final stand (Table 3). Tillage treatments had no effect on final cotton stand in 1991, but in 1992, conventionally tilled cotton plots had slightly higher plant populations than either no-till

Table 1. Rainfall and DD60 accumulation (June-August) for 1888 to 1992 growing seasons.

	Rainfall (in.)				DD60			
Year	June	July	Aug.	Total	June	July	Aug.	Total
1988	**0.29**	**3.89**	**1.56**	**5.74**	**525**	**609**	**655**	**1789**
1989	**12.64**	**5.52**	**1.61**	**19.77**	**434**	**568**	**536**	**1538**
1990	**3.54**	**3.66**	**1.22**	**8.42**	**520**	**587**	**626**	**1733**
1991	**1.57**	**1.98**	**3.69**	**7.24**	**527**	**607**	**597**	**1731**
1992	**8.34**	**5.64**	**3.80**	**17.78**	**389**	**569**	**421**	**1379**

Table 2. Seed-cotton yields in conservation tillage systems and conventional planted cotton at the Tennessee Valley Substation, 1988-1992

	Seed Cotton Yields (1b/Al					
Tillage System	**1988**	**1989**	**1990**	**1991**	**1992**	Avg.
Conventional	**1400**	**2780**	**1700**	**1110**	**3160**	**2030**
No-Till Cotton Stubble	**1140**	**2440**	**1510**	**920**	**3150**	**1830**
No-Till Wheat	**1380**	**2490**	**1840**	**960**	**2990**	**1930**
LSD (0.10)	**140**	**430**	**140**	**30**	**160**	

Table 3. Effect of tillage systems and starter fertilizers on cotton stand in 1991 and 1992.

Fertilizer		Conventional		Stubble		Wheat	
N P_2O_5	Placement	**91**	**92**	**91**	**92**	**91**	**92**
lb/A		----------	----------	plants/ **6** ft	----------	----------	----------
0-0		**23**	**33**	**23**	**29**	**27**	**29**
15-0	Band	**28**	**32**	**30**	**27**	**19**	**22**
15-0	**2x2**	**24**	**30**	**23**	**26**	**23**	**26**
15-50	Band	**22**	**33**	**19**	**31**	**24**	**25**
15-50	**2x2**	**23**	**33**	**24**	**25**	**21**	**27**
LSD (0.05)		**NS**	**NS**	**NS**	**NS**	**NS**	**7**

system (Table 3). These differences in 1992 were due to wetter soil conditions in the no-till areas at planting, which caused greater soil crusting than found on the drier conventionally planted cotton.

Starter fertilizer had no consistent effect on early-season cotton heights (Table 4). However, a consistent cotton height difference caused by starter fertilizers was measured in cotton no-tilled into wheat cover each year at early bloom (Table 4). In both years, the starter fertilizer 15-50 placed 2x2 or banded and the starter fertilizer 15-0 placed 2x2 increased cotton heights compared with no-starter treatment. Also, at early bloom, cotton no-tilled into cotton residue was consistently shorter than cotton planted into conventional tillage or cotton planted no-till into wheat (Table 4). In 1992, early-season height of cotton planted into wheat was about 1 inch taller than conventional or no-till cotton planted into stubble, regardless of any starter fertilizer.

Early-season soil penetrometer readings (Fig. 1) revealed higher resistance to penetration from 0 to 12 inches in the no-till cotton stubble and wheat cover areas than in the soil areas conventionally tilled. However, below 12 inches, the soil in the wheat cover consistently showed less resistance to penetration (2 to 6 bars) than soil conventionally tilled or no-tilled with cotton residue.

Soil penetrometer readings in August were much higher due to the drier soil conditions, and measurements could only be taken to a depth of 12 inches. The no-till with cotton residue plots again had much higher resistance to penetration at all depths compared with the no-till wheat soil areas or conventionally tilled cotton areas. No-tillage into wheat had greater soil resistance to penetration from 0 to 8 inches than soil conventionally tilled. However, at 10 to 12 inch depths, soil in the no-till wheat areas averaged 11 and 16 bars less resistance compared with the conventional tillage.

Volumetric soil moisture readings in 1992 were high most of the growing season due to abundant summer rainfall. The average of four summer measurements indicated a trend toward lower moisture at the 8-inch depth in the conventional tillage row middles compared with the no-tillage systems (Table 5). This was due either to greater cotton root concentration or, more probably, to moisture loss from cultivations. At the 16-inch depth in the nontrafficked middles, conventionally tilled soil again had lower soil moisture than either no-till cover system (Table 5). This was apparently due to greater concentration of cotton roots in this region. At the 24-inch depth, soil moisture in the no-till wheat areas tended to be lower than either the no-till cotton residue area or conventionally tilled soil (Table 5). Greater cotton root density and water extraction at these soil depths agreed with soil penetrometer readings and indicated less compaction at lower depths in the no-till wheat areas.

Cotton lint yields in the starter fertilizer test area averaged about 1 bale in 1991 and 2 3 bales in 1992. Starter fertilizers in 1991 increased cotton yields in both no-tillage systems while starter fertilizers had no effect on conventionally tilled cotton (Table 6). In 1991, all starter fertilizers and placements increased cotton yields in the wheat cover system while only starter fertilizer placed 2x2 increased cotton yields in the cotton residue cover system compared with no-starter. In 1992, no consistent responses to tillage or starter fertilizers were found, although the 15-50 starter fertilizer banded increased cotton yields in the conventionally tilled areas.

Results of these two studies indicate growth differences between cotton planted no-till into wheat or cotton residue compared with conventionally tilled cotton planted in northern Alabama. Cotton grown no-till into cotton residue produced a much more compact cotton plant than in all other tillage systems. Cotton yields measured from 1988 to 1992 also indicated up to a 10% yield reduction when cotton was planted no-till into cotton residue compared with conventionally tilled cotton. Greatest yield reductions with no-tillage cotton planted into cotton residue seem to have occurred during dry seasons. Preliminary results indicate starter fertilizers to be beneficial in increasing no-tillage cotton yields, especially in dry years. Penetrometer readings in 1992 also indicated that soil in the no-tillage stubble area was more compact, possibly limiting root growth or water infiltration. However, with a wheat cover system, lower soil penetrometer readings and lower soil moisture measurements indicate better cotton root development at soil depths below 12 inches.

Table 4. Effects of tillage systems and starter fertilizers on cotton height in 1991 and 1992.

Starter Fertilizer			Heights (in.) 1991		Heights (in.) 1992	
N P_2O_5 lb/A	Place- ment	Tillage	June 4	July 2	June 1	July 16
0-0	-	Conv.	8.0	24.0	3.8	31.3
15-0	Band	Conv.	8.0	25.3	4.3	32.0
15-0	2x2	Conv.	8.0	26.0	3.9	32.3
15-50	Band	Conv.	8.0	27.0	4.1	31.3
15-50	2x2	Conv.	9.0	24.3	4.3	32.3
0-0	-	Stubble	7.7	21.3	4.2	30.0
15-0	Band	Stubble	8.0	21.0	4.2	28.3
15-0	2x2	Stubble	7.3	21.7	4.0	30.3
15-50	Band	Stubble	8.0	21.3	4.3	30.3
15-50	2x2	Stubble	8.0	22.0	4.3	31.0
0-0	-	Wheat	9.0	23.0	5.2	31.0
15-0	Band	Wheat	9.0	24.0	4.9	31.0
15-0	2x2	Wheat	8.0	26.0	5.2	34.3
15-50	Band	Wheat	8.0	27.0	5.3	33.0
15-50	2x2	Wheat	9.0	26.0	5.3	35.6
LSD (0.05)			0.8	2.2	0.3	3.1

Table 5. Effect of tillage systems on volumetric soil moisture at three depths and three positions from the cotton row.

		Volumetric soil moisture (%)		
Position	Depth (in)	Conv.	Wheat	Stubble
In Row	8	22.4	22.5	21.5
Non-Traffic Middle	8	20.6	24.4	25.8
Traffic Middle	8	23.1	27.1	24.9
In Row	16	30.7	32.1	28.4
Non-Traffic Middle	16	26.8	30.1	29.0
Traffic Middle	16	32.1	29.6	29.8
In Row	24	32.4	30.6	34.7
Non-Traffic Middle	24	35.6	31.0	32.5
Traffic Middle	24	31.8	33.1	36.5

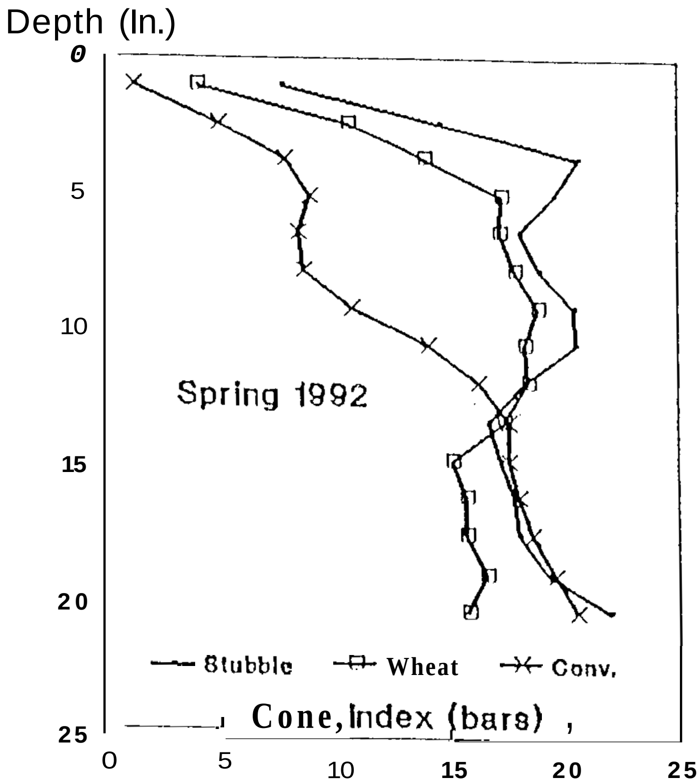

Figure 1. Penetrometer readings in spring 1992 for no-starter treatment in each tillage system.

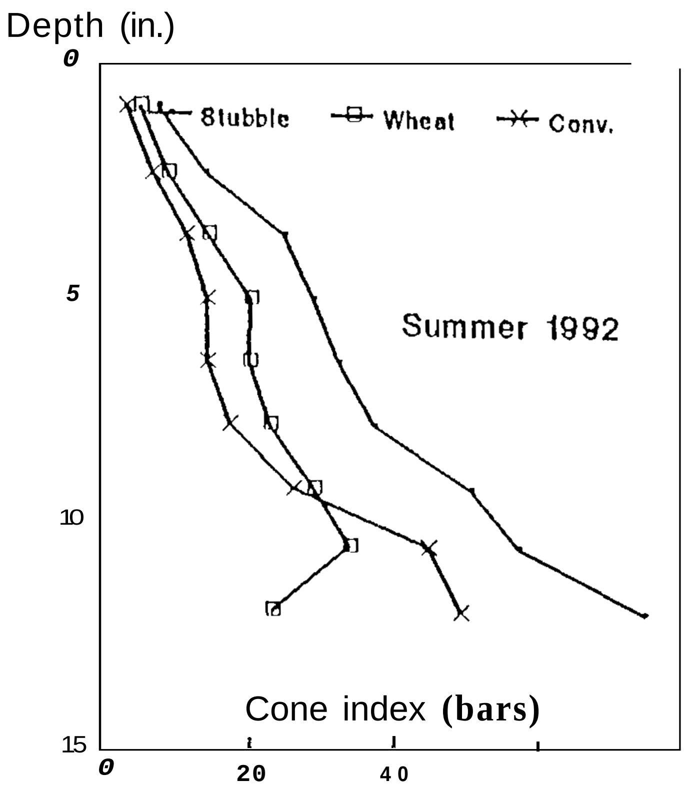

Figure 2. Penetrometer readings in summer 1992 for no-starter treatment in each tillage system.

Table **6.** Effect of tillage systems and starter fertilizers on seed-cotton yields.

Starter fertilizer			Seed Cotton yield	
N P_2O_5	Placement	Tillage	1991	1992
			------lb/A-------	
0-0	-	Conv.	1436	3307
15-0	Band	Conv.	1550	3376
15-0	2x2	Conv.	1450	3550
15-50	Band	Conv.	1410	3717
15-50	2x2	Conv.	1583	3318
0-0	-	Stubble	1353	3129
15-0	Band	Stubble	1463	3314
15-0	2x2	Stubble	1647	3267
15-50	Band	Stubble	1526	3314
15-50	2x2	Stubble	1647	3387
0-0	-	Wheat	1450	3176
15-0	Band	Wheat	1670	2842
15-0	2x2	Wheat	1670	3187
15-50	Band	Wheat	1620	3398
15-50	2x2	Wheat	1773	3423
LSD (0.10)			165	375

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REPLACING HERBICIDES WITH HERBAGE: POTENTIAL USE FOR COVER CROPS IN NO-TILLAGE

J. P. Yenish and A. D. Worsham[1]

INTRODUCI1ON

Recent changes in farm legislation require up to 50% ground cover after planting to qualify for subsidies. Leaving previous crop residue will not meet ground cover requirements in many cases. Cover crops are needed to meet subsidy requirements.

Weed-suppressing cover crops may allow reduction of herbicide use within no-tillage production systems. Using allelopathic cover crops where needed to meet conservation requirements could reduce herbicide use with essentially no additional cost. Additionally, cover crops could potentially replace preemergence herbicides in areas where ground water contamination risk is high. Much work has been done on weed suppression by certain cover crops. Weed suppression by cover crops has ranged from poor to good.

The objectives of these experiments are to determine weed suppression by several species of cover crops and their potential use as a herbicide replacement or supplement in no-tillage corn and cotton production.

MATERIALS AND METHODS

Winter annual cover crops of rye, crimson clover, subterranean clover, and hairy vetch were established on bedded plots in the fall of 1991 at Clayton and Rocky Mount, North Carolina. The soil types were Johns sandy. loam at Clayton and Norfolk loamy sand at Rocky Mount. Additional treatments of no-tillage without cover and conventional tillage were also established. Corn and cotton were planted in separate experiments at both sites in the spring of 1992. Cover crops were killed in all experiments with 2.0 Ib/A glyphosate + .25% X-77 applied 2 weeks prior to planting. Glyphosate was also applied to the no-tillage without cover plots to desiccate weedy vegetation. Conventionally tilled plots were disked and bedded immediately prior to planting. Treatments of preemergence (PREE), postemergence (POST), PREE plus POST, and untreated herbicide applications were established in cover crop plots after corn and cotton were planted. The PREE herbicide treatment for the corn experiments was 1.2 lb/A atrazine + 2.0 lb/A metolachlor. The POST treatment was 1.5 lb/A ametryn + 25% X-77directed when corn was 18 to 30 inches tall. The PREE treatment for cotton at Clayton was 15 lb/A metolachlor + 1.5 lb/A fluometuron. The PREE treatment for cotton at Rocky Mount was 2.0 lb/A metolachlor + 1.5 lb/A fluometuron. The POST treatment in cotton at both locations was an early postemergence directed application of 2 lb/A MSMA + 2 lb/A fluometuron + 5% surfactant and a late postemergence directed application of 1 lb/A cyanazine + 2 lb/A MSMA + 5% surfactant. The POST treatment also included an over-the-top application of .188 lb/A sethoxydim + 1 qt/A surfactant at both postemergence application timings. The resulting experimental design was a 6x4 factorial randomized complete block split plot design with four replications. Whole plots were the cover crop treatments and subplots were the herbicide treatments.

Weed control ratings in the corn experiments were taken approximately 45 days after planting and 21 days after postemergence applications. Yields were taken in the fall of 1992.

Weed control ratings in the cotton experiments were taken approximately 30 and 90 days after planting. Yields were taken in the fall of 1992.

Predominant broadleaf weeds at both locations were pigweed species and common lambsquarters. Predominant grass species were large crabgrass at Clayton and broadleaf signalgrass at Rocky Mount.

RESULTS AND DISCUSSION

Early-season weed control was good to excellent for both broadleaf and grass weed species in cotton and corn at both locations with the PREE treatment (Table 1). Rye was the only cover crop species to consistently provide fair to good weed suppression without additional herbicide. Subterranean clover and crimson clover also provided weed suppression, although inconsistent across locations and crop. Hairy vetch provided little or no weed suppression and was not

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Site	Cover Crop	Corn: Herbicide Treatment[1] PREE Brdlf.	Corn PREE Grass	Corn Untreated Brdlf.	Corn Untreated Grass	Cotton: Herbicide Treatment PREE Brdlf.	Cotton PREE Grass	Cotton Untreated Brdlf.	Cotton Untreated Grass
		Weed Species[2]				Yeed Species			
		Percentage Control				Percentage Control			
Clayton	Rye	100.0	100.0	85.0	78.8	100.0	99.3	87.5	76.3
	Crimson Clover	100.0	92.5	67.5	67.5	91.8	***88.8***	***68.8***	75.0
	Sub. Clover	100.0	93.3	95.0	**75.0**	94.3	95.5	67.5	57.5
	Hairy Vetch	97.8	90.0	17.5	17.5	97.3	95.3	21.3	30.0
	Yo-Tillage	98.8	95.0	22.5	20.0	98.5	**88.0**	0.0	0.0
	Conventional	99.3	**95.8**	**0.0**	**0.0**	99.3	**95.5**	**0.0**	**0.0**
	LSD (p = 0.05)	Broadleaf = 9.5 Grass = 11.0				Broadleaf = 10.0 Grass = ***8.8***			
Rocky Mount	Rye	96.3	97.0	***88.8***	92.5	95.5	95.5	77.5	85.0
	Crimson Clover	95.0	92.0	63.8	60.0	93.8	87.5	71.3	46.3
	Sub. Clover	98.8	98.8	***75-0***	63.8	96.5	93.8	75.0	71.3
	Hairy Vetch	97.5	98.8	***68.8***	70.0	93.8	91.3	42.5	10.0
	No-Tillage	96.3	97.5	28.8	30.0	97.8	96.5	**36.3**	45.0
	Conventional	93.8	98.8	0.0	**0.0**	95.3	**88.0**	0.0	0.0
	LSD (p = **0.05)**	Broadleaf = 10.2 Grass = 13.2				Broadleaf = 11.5 Grass = 14.0			

[1] PREE herbicide treatments include metolachlor (1.5 lb/A at Clayton; 2 lb/A at Rocky Moult) + 1.5 lb/A fluometuron applied preemergence in cotton and 1.2 lb/A atrazine + 2.0 lb/A metolachlor applied preemergence in corn.

[2] Broadleaf **ueed** species at both sites uere predominantly pigweed species and common lambsquarters. Predominant grass ueed species uere large crabgrass at Clayton and broadleaf signalgrass at Rocky Moult.

significantly better than no-tillage without a cover crop in half of the experiments.

All PREE, POST, and PREE + POST applications provided good to excellent late season broadleaf weed control at both locations in corn (Table 2). POST and PREE + POST treatments also provided excellent grass weed control. Late-season grass weed control was reduced in the crimson clover, subterranean clover, and hairy vetch at the Clayton location with the PREE herbicide treatment only compared with other herbicide treatments. Rye and subterranean clover were the only cover crops providing better than 50% suppression of broadleaf weeds without any PREE or POST herbicide application. These two cover crops also provided late-season grass suppression at the Rocky Mount location.

Only POST and PREE + POST herbicide treatments gave good to excellent control of both grass and broadleaf weeds across all cover crop treatments in cotton at both locations (Table 3). Grass and broadleaf control with the PREE only treatment were poor to fair at the Clayton location in all cover crop treatments. Broadleaf weed control in PREE treatments at the Rocky Mount location was good to excellent in all cover crops except rye and grass control, which was acceptable only in the no-tillage treatment. Broadleaf weed control was inconsistent across locations in untreated herbicide plots, and grass control failed.

Untreated herbicide plots gave no cotton lint yield at either location (Table 4). Highest yields within all cover crop treatments were with the PREE + POST herbicide application at both locations except hairy vetch at the Rocky Mount location, Consistently highest yields were in the conventional-tillage plots.

Interactions between cover crops and herbicide treatment were not significant for corn yield. Corn yields in PREE, POST and PREE + POST herbicide plots were significantly higher than the untreated plots at both locations (Data not shown). Yields were not significantly different between cover crops at either location.

SUMMARY

Cover crops continue to be inconsistent in weed-suppressing abilities. Cover crops may he detrimental to herbicide activity in some situations. Additional mechanical or chemical weed control must be applied to provide effective control and profitable yields.

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Table 2. Late-season weed control ratings in corn at Clayton and Rocky Mount, NC.

		Herbicide Treatment[1]							
		PREE		POST		PREE + POST		UNTREATED	
		Weed Species[2]							
Site	Cover Crop	Brdlf.	Grass	Brdlf.	Grass	Hrdlf.	Grass	Brdlf.	Grass
		Percentage Control							
Clayton	Rye	983	95.0	993	96.8	100.0	100.0	83.0	36.3
	Crimson Clover	93.0	66.0	993	96.0	100.0	98.5	413	33.8
	Sub. Clover	88.8	68.8	99.0	98.8	99.0	99.8	66.3	32.5
	Hairy Vetch	Y63	77.5	97.5	92.8	100.0	98.8	10.0	25.0
	No-Tillage	98.8	92.3	96.8	96.0	100.0	100.0	10.0	18.8
	Conventional	97.3	88.0	90.0	91.3	99.8	99.5	0.0	0.0
	LSD (p = 0.05)	Hroadleaf = 9.4				Grass = 12.5			
Rocky Mount	Rye	98.8	94.8	98.0	943	99.5	98.0	68.8	725
	Crimson Clover	96.0	94.8	97.3	94.8	99.8	100.0	46.3	22.5
	Sub. Clover	95.8	96.0	98.0	95.5	100.0	100.0	67.0	61.8
	Hairy Vetch	99.0	98.5	98.5	96.8	99.3	98.5	36.3	50.0
	No-Tillage	99.3	99.5	99.0	97.5	99.5	97.8	17.5	18.8
	Conventional	99.3	98.8	97.5	95.0	100.0	100.0	0.0	0.0
	LSD (p = 0.05)	Broadleaf = 13.2				Grass = 17.5			

[1] Herbicide treatments include 12 lb/A atrezine + 2.0 lb/A metolachlor applied preemergence (PREE) and 1.5 lb/A arnetryn + .25% surlactant applied postemergence directed (POST).

[2] Broadleaf weed species at both sites were predominantly pigweed species and common lambsquarters. Predominant grass weed species were large crabgrass at Clayton and broadleaf signalgrass at Rocky Mount.

Table 3. Late-season Weed control ratings in cotton at Clayton and Rocky Mount, YC.

		Herbicide Treatment[1]							
		PREE		POST		PREE + POST		UNTREATED	
		Weed Species[2]							
Site	Cover Crop	Brdlf.	Grass	Brdlf.	Grass	Brdlf.	Grass	Brdlf.	Grass
		Percentage Control							
Clayton	Rye	62.5	63.8	99.8	99.8	99.8	100.0	85.0	32.5
	Crimson Clover	52.5	18.8	89.5	98.3	100.0	100.0	40.0	18.8
	Sub. Clover	56.3	26.3	92.3	95.3	99.8	99.8	65.0	16.3
	Hairy Vetch	56.3	27.5	89.3	98.8	100.0	100.0	10.0	6.3
	No-Tillage	70.0	23.8	88.3	96.5	100.0	100.0	12.5	0.0
	Conventional	71.3	41.3	95.3	97.8	100.0	99.8	12.5	0.0
	LSD (p = 0.05)	Broadleaf = 14.5				Grass = 10.0			
Rocky Mount	Rye	67.5	40.0	100.0	100.0	100.0	100.0	40.0	27.5
	Crimson Clover	87.5	36.3	100.0	100.0	100.0	100.0	41.3	13.8
	Sub. Clover	86.3	60.0	99.8	99.8	100.0	100.0	57.5	15.0
	Hairy Vetch	88.8	66.3	95.0	100.0	100.0	100.0	50.0	12.5
	No-Tillage	100.0	95.0	100.0	100.0	100.0	100.0	25.0	0.0
	Conventional	90.0	62.5	100.0	99.8	95.0	100.0	0.0	0.0
	LSD (p = 0.05)	Broadleaf = 16.7				Grass = 13.1			

[1] Herbicide treatments include metolachlor (1.5 lb/A at Clayton; 2 lb/A at Rocky Mount) + 1.5 lb/A fluometuron (PREE) and sequential applications of 2 lb/A MSMA + 2 lb/A fluometuron + .5% surfactant applied early postemergence directed and a late postemergence application of 1 lb/A cyanazine + 2 lb/A MSMA + .5% surfactant (POST). POST treatments included -188 lb/A sethoxydim + 1 qt/A surfactant applied at both postemergence application timings.

[2] Broadleaf weed species at both sites were predominantly pigweed species and common lambsquarters. Predominant grass wed species were large crabgrass at Clayton and broadleaf signalgrass at Rocky Mount.

Table 4. Cotton lint yields at Clayton and Rocky Moult. NC.

Site	Cover Crop	Herbicide Treatment[1] PREE	POST	PREE + POST	UNTREATED
		Cotton Lint Yield (lbs./a)			
Clayton	Rye	739	931	1088	0
	Crimson Clover	0	301	430	0
	Sub. Clover	0	608	981	0
	Hairy Vetch	0	947	1148	0
	No-Tillage	0	621	1467	0
	Conventional	243	1206	1612	0
	LSD (p = 0.05) = 312				
Rocky Mount	Rye	337	414	419	0
	Crimson Clover	293	345	409	0
	Sub. Clover	757	625	921	0
	Hairy Vetch	779	639	748	0
	No-Tillage	1236	1364	1460	0
	Conventional	433	1159	1254	0
	LSD (p = 0.05) = 313				

[1] Herbicide treatments include metolachlor (1.5 lb/A at Clayton; 2 lb/A at Rocky Mount) + 1.5 lb/A fluometuron (PREE) and sequential applications of 2 lb/A MSMA + 2 lb/A fluometuron + .5% surfactant applied early postemergence directed and a late postemergence application of 1 lb/A cyanazine + 2 lb/A MSMA + .5% surfactant (POST). POST treatments included .188 lb/A sethoxydim + 1 qt/A surfactant applied at both postemergence application timings.

CONSERVATION PRODUCTION SYSTEMS FOR SILTY UPLANDS

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INTRODUCTION

In 1987, the USDA-ARS National Sedimentation Laboratory, in cooperation with MAFES and Mississippi SCS, initiated an interdisciplinary research project directed at developing economically profitable and environmentally sustainable conservation production systems for silty upland soil resource areas of the mid-South. The project is located on the A. E. Nelson Farm in Tate County, south of Senatobia, MS. Primary studies include measurement of yields and economic returns from several cropping and tillage systems on replicated plots and determination of runoff and erosion amounts from plots and small watersheds. A number of supplementary studies have been added to clarify details of covercrop management, benefits of planting soybean and sorghum in narrow rows, responses of determinant and indeterminant soyhean cultivars to early-April plantings, feasibility of double-cropping tropical corn after wheat or reseeding cover crops, influences of earthworms on water infiltration rates and patterns, management of narrow grass barriers (hedges) to slow runoff and trap eroded sediment, and concentrations of nutrients and pesticides in ground and surface waters. This report presents an up-to-date overview of some results obtained from the primary studies.

METHODS

Fourteen production treatments were evaluated on 40- by 18-ft plots established in the fall of 1987, arranged in a randomized block design, and replicated 10 times. Plots were primarily located on Grenada silt loam (fine silty, mixed, thermic Glossic Fragiudalf), with some areas of Memphis and Loring soils. Three summer crops (cotton, sorghum, and soybean) have been grown under conventional chisel/disk tillage, ridge tillage, reduced (one-pass) tillage, and no-tillage. The no-till soybean treatment was doublecropped with winter wheat, the no-till cotton was planted into a killed wheat cover crop, and no-till grain sorghum was planted into a killed hairy vetch cover crop. An additional no-till treatment, a 2-year rotation of monocrop grain sorghum and wheat doubleeropped with soybean, provided a harvest of three crops in 2 years. All crops were planted in 36-inch rows except wheat and doublecrop soybean, which were drilled in 7" rows. The only no-till plots that were row-cultivated were cotton and sorghum in 1988 due to heavy populations of nutsedges and perennial vines. In the cotton treatments, soil moisture was monitored weekly each year, and soil temperature at 2 inches was recorded hourly for a few weeks before and after planting in 1992. The possibility that compaction of ridge-till beds was limiting yields was tested by paratilling five of the replicates on 5 May 1992 prior to planting crops.

Runoff and erosion from natural rainfall were measured from duplicate sets of eight runoff plots (12 ft wide by 72.6 ft long on a 4% slope) starting in 1990 and from three watersheds (5 to 7 acres in size with slopes ranging from 1 to 8%) starting In 1989. Treatments evaluated on the erosion plots Included conventional till, ridge till, no-till monocrop, and no-till doublecrop soybean; no-till grain sorghum with and without a vetch cover crop; and no-till cotton with and without a wheat cover crop.

All watersheds were farmed identically during 1988 and 1989 with a reduced-tillage soybean production system in which a single pass of a mulch-tinisher was made prior to planting, and rows were cultivated twice. Beginning in 1990, one watershed (#2) was farmed with conventional (chisel, disk twice, cultivate) tillage and the other two with no-till soybean. One no-till watershed (#3) had a grassed waterway established in 1991, and the conventional-till watershed had two 18-ft wide fescue buffer strips established 150 ft apart in 1992.

RESULTS AND DISCUSSION

Weather

Rainfall amounts and timing (Table 1) have varied greatly among the years of this study and this has affected the yields, profitability, runoff, and erosion

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[2] Mississippi Agri. and Forestry ExpStn., Mississippi State, MS.

Table 1. Rainfall at the Nelson Farm during the past 5 years.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Tot.
	(in)												
1988	1.95	2.91	4.71	4.52	0.69	0.04	1431	029	521	1.19	6.90	638	49.1
1989	6.07	7.09	5.52	127	3.68	13.42	8.62	2.94	5.12	123	4.19	2.93	61.9
1990	4.80	12.66	738	5.81	8.14	2.08	2.44	0.22	1.68	5.53	3.89	13.50	68.1
1991	2.12	932	539	15.82	6.48	335	234	3.18	1.45	4.70	8.05	6.68	682
1992	234	2.88	8.70	2.00	0.90	6.62	4.75	5.13	2.03	2.59	3.79	436	46.1
Norm	4.84	4.76	5.55	5.47	5.51	3.58	3.54	2.99	3.70	228	4.80	520	522

from all cropping systems. In 1988, very dry weather during May and June was followed by heavy rains in July and then another period of drought in August. Wet weather during June 1989 promoted soybean disease (stem canker) development, which subsequently was aggravated by dry weather. Unusually dry weather from June through September 1990 limited yields of all crops. Exceptionally wet weather during April 1991 delayed conventional tillage land preparation, hut timely rains in August salvaged yields of most crops. Well-distributed rainfall during June through August 1992 resulted in good yields.

Crop Yields

Productivity of no-till fields has sometimes increased with length of time that no-till practices were followed. This has been the case with cotton at the Nelson Farm. No-till cotton yields were lower relative to those from conventional tillage in the first year (1988) but were greater after the second year (1990 through 1992) (Table 2). In the second year (1989), all cotton was damaged by contamination in the first insecticide application, and no significant differences in yield resulted. Since the third year, no-till-planted cotton has grown faster and plants have been larger and fruited earlier than those of other tillage systems. Increased water use by these larger plants has resulted in drier soil conditions under no-till as monitored by a neutron gage.

In the spring of 1988, organic matter content in the top inch of soil was 1.8 to 1.9% in all plots. By the spring of 1992, it had increased to 2.8% in the no-till cotton treatment and decreased to 1.6% in the conventional cotton treatment. In 1992, soil in no-till plots was usually cooler than that in conventionally bedded plots in the afternoon hut was warmer at 8:00 AM. Higher minimum temperatures, less herbicide injury (because of higher soil organic matter), less crusting and sealing following hard rainfall, greater water holding capacity, and better fertility status in the top inch may all have contributed to the enhanced early seedling growth of no-till-planted cotton. This growth enhancement was observed during the wet springs of 1990 and 1991 and the dry spring of 1992. Serious erosion was visually evident on many of the conventionally tilled cotton plots. This may have contributed to decreased yields and a reduced soil organic matter fraction relative to no-till plots.

Table 2. Yield of DES 119 cotton[1] on Nelson Farm plots, 1988 through 1992.

system	Seed Cotton Yield 1988	1989[2]	1990	1991	1992
	(lb/A)				
Conventional tillage	1830	1230	1125	1540	2480
Ridge tillage	1560	960	825	1460	2275
One-pass tillage	1430	1080	1130	1740	2425
No-till (wheat cover crop)	1560	890	1335	2200	3000
	(days after planting)				
Growing season length	190	210	147	162	182

[1] Fertilized with 90 lb N/A as NH,NO, 1988 to 1991,115 lb N/A in 1992.

[2] All 1989 cotton treatments were damaged by a contamination in tbe first insecticide application during July 1989.

A similar trend of improved no-till yields relative to conventional tillage developed in the grain sorghum plots (Table 3). This trend started in the second year of the study and continued up to 1992. A cover crop or a crop rotation was utilized in both no-till sorghum systems, and these practices may have contributed to the increased yield of the no-till systems.

Table 3. Yields of DPL G-1602 sorghum from Nelson Farm plots, 1988 through 1992.

system	1988	1989	1990	1991	1992
	(lb/A)				
Conventional tillage1	3990	4240	2640	4370	4610
Ridge tillage'	3710	3920	2280	3890	3450
Onepass tillage2	3930	4250	2050	3960	3910
No-till (vetch cover)'	3580	4780	2930	5250	4660
No-till (soybean rotation)'	3160	5290	3160	5210	4720

[1] Fertilized with 120 lb N/A as NH_4NO_3
[2] Fertilized with 45 lb N/A as NH_4NO_3 1988 to 1990 and 70 lb N/A in 1991 and 1992.

In contrast to cotton and sorghum, soybean yields have not been significantly influenced hy tillage (Table 4); however, all no-till soybean treatments were planted later (after wheat harvest) than those of other tillage systems. Full-season soybean yields have been disappointing, largely due to the influence of drought in July and August that limited reproductive development of large soybean plants. Double-crop yields have been similar to yields of full-season beans. The timeliness of planting wheat in the continuous double-crop system was improved when the soybean cultivar was switched from 'Centennial' (Group VI) to 'DPL-415'(Group V) in 1990. Weed control has required less herbicide in wheat and soybeans grown in rotation with sorghum than in the continuous double-crop system.

Paratilling in 1992 loosened and dried out the soil, slowed seedling establishment, and resulted in reduced yields of cotton and sorghum where no rain fell between paratilling and no-till planting (Table 5). In contrast, paratilling resulted in increased yields of soybean planted after beds were settled and moistened by 0.75 inches of rainfall. The benefit of occasional paratilling in no-till systems on silt loam soils deserves further research.

Table 4. Yields of soybean' and wheat (Florida 302) on Nelson Farm plots, 1988 through 1992.

system	1988	1989	1990	1991	1992
	(bu/A)				
			Soybean		
Conventional tillage	20.5	20.2	14.8	31.8	35.7
Ridge tillage	20.4	21.9	173	31.6	43.6
One-pass tillage	23.5	19.6	14.4	28.1	41.8
Continuous double crop	24.7	26.7	133	31.6'	42.1
Sorghum/double croprotation	–	24.0	14.1	34.6	43.0
			Wheat		
Continuous double crop	81.0	29.7	44.1	0‡	49.1
Sorghum/double crop rotation	77.4	40.2	44.7	24.6	45.0

[1] Soybean cultivars were Bedford (monocrop, 1988-89); Centennial (double crop, 1988-89); or DPL415 (1990 to 1992).
[2] Wheat was killed with herbicides due to severe weed infestation, and soybean was drill-planted at time of monocrop plantingin 1991.

Table 5. Influence of Paratill on yield of ridge-tilled crops, 1992

Crop	Planting Date	Rainfall'	Yield Paratill	Yield No-Paratill
		(in)	(@/A)	
Cotton	5/12	0	2050	2550
Sorghum	5/14	0	3010	3800
Soybean	5/20	0.75	2950	2410

† Rainfall between paratilling (4 May 1992) and planting.

Economic Returns

Economic analyses have been completed only for the first 4 years of the study (Table 6). Tbey have indicated that cropping systems involving wheat have been the most profitable. Continuous doublesrop soybean and wheat has been the single most profitable system despite a complete failure in one wheat crop due to inadequate weed control. Interrupting the buildup of grass weeds (ryegrass, little barley, cheat) in wheat by occasionally killing the wheat as a cover crop and

Table **6.** Net returns to land and management from production treatments for **1988** through **1991.**

Treatment	1988[1]	1989[2]	1990[3]	1991[4]	Average[5]
	------------------------------	------------------------------	dollars/A	------------------------------	------------------------------
			Cotton		
Conventional tillage	61.06	no	-112.08	54.17	1.05
Ridge tillage	11.98	meaningful	-145.46	56.78	-2556
Minimum tillage	- 23.92	data	- 99.70	11639	- 2.41
No-till with wheat cover crop	2.54	obtained	- 88.40	151.80	21.98
			Grain Sorghum		
Conventional tillage	- 16.95	- 1433	- 5926	21.85	-17.17
Ridge tillage	- 3138	- 32.90	- 66.82	16.08	-28.76
Minimum tillage	- 34.68	- 238	- 6835	16.88	-2230
No-till with vetch cover crop	- 5227	- 3.55	- 64.41	31.01	-2230
No-till (SB/W rotation)	- 88.75	20.78	- 44.84	4827	-16.14[6]
			Soybean		
Conventional tillage	13.05	- 25.12	- 4627	68.88	2.64
Ridge tillage	- 536	8.82	- 3125	86.62	14.70
Minimum tillage	12.74	1730	- 40.18	60.80	12.66
No-till with wheat double crop	229.93	64.01	5259	28.26[7]	93.70
No-till with wheat (GS rotation)	21737	61.23	59.96	131.33	117.47[6]

[1] Ricer paid based on 1988 prices and prices received are based on a 5-year average (1984-88): cotton Lint ($0.59/lb); cotton seed ($0.03/lb); grain sorghum ($4.11/cwt); wheat ($3.21/bu); and soybeans ($5.95/bu).

[2] Prices based on 1989 prices and prices received are based on 5-year average (1985-89): cotton lint ($0.56A/lb); cotton seed ($0.03/lb); grain sorghum ($3.62/cwt); wheat ($3.24/bu); and soybean ($5.91/bu).

[3] Input prices based on 1989 prices and prices received are based on 5-year average (1986-90): cottou Lint ($0.57/lb); cotton seed ($0.04/lb); grain sorghum ($3.95/cwt); wheat ($3.26/bu); and soybeans ($5.86/bu);

[4] Input prices based on 1991 prices paid and prices received are based on 5-year average (1987-91): cotton Lint ($0.59/lb); cotton seed ($0.04/lb); grain sorghum ($4.03/cwt); wheat ($3.25/bu); and soybeam ($6.03/bu).

[5] Three years for cotton, 4 years for other crop combinations.

[6] Average return per acre per year from all three crops is $50.67.

[7] Wheat crop terminated due to severe weed pressure following planting without burndown herbicide application.

planting a rotation crop, such as no-till cotton (see below), into the killed residue may be a sound management practice.

The 2-year rotation of monocrop sorghum with doublesrop soybean following wheat was the second most profitable system. While the soybean and wheat crops were more profitable in rotation than in the continuous double-crop system, the grain sorghum crop generated a net loss in some of the alternate years. In a related study, a 4-year average yield from continuous corn was 119 bu/A (datanot presented). Such a yield, if sustainable, would make corn a more profitable rotational crop than grain sorghum on this soil.

No-till cotton planted flat into a killed wheat cover crop has been, on average, a profitable system. It has been the most profitable of all cotton systems, but all have shown great variability in profit or loss among years. Future research will address the possibility of using dense cover-crop residues to reduce herbicide costs in no-till cotton production.

Runoff, Erosion, and Sediment Yield

As expected, the average monthly runoff for all plots was significantly related to monthly rainfall with r = 0.80 **($p \geq 0.99$).** To a large degree, this significance reflects general coherence between rainfall amounts and intensities, with minimal variance attributable to antecedent soil water conditions. Only two monthly values exhibited large deviations. These two outliers occurred in April 1991 (runoff of 20% for 15.8 in. of rainfall) and June of the same year (runoff of 20% for only 3.4 in. of rain). This latter outlier resulted primarily from one large event on June 12 and 13, whereas the relatively low runoff in April resulted from prolonged low-intensity rainfall (26 different storms occurred) with a paucity of high-intensity rains. Excepting these two outliers, the correlation would have been r = 0.90.

Although only 2 years of results are available, several tendencies are apparent based on the annual runoff from the eight management systems (Table 7). Grain sorghum with a vetch winter cover produced the least runoff, about 82% of rainfall for these 2 years. This lesser runoff is attributed to the increased water consumption by vetch in late winter and early spring, increased soil mesofauna activity, and the dense ground cover, which limited surface crusting or sealing. In contrast, runoff from conventionally tilled soybean plots was about three times larger, averaging 23% of rainfall for these 2 years. Runoff percentages for both grain sorghum systems, the conventionally tilled soybean system, and the double-cropped soybean-wheat system did not vary between years. The two no-till cotton and the no-till soybean treatments, however, had about an 8% runoff reduction the second year. This reduction coincided with better cover crop growth (wheat or volunteer) following the 1990 cotton harvest.

Watershed runoff (Table 8) was generally greater than from runoff plots. The maximum monthly runoff percentage varied from 0 to 80% (data not shown). The 1989 average yearly runoff percentages were 52, 44, and 38% for Watersheds 3, 2, and 1, respectively, when reduced conventional tillage was used for all watersheds. The yearly runoff percentages for 1990 and 1991 presented no clear trends. No-till planting was employed in Watersheds 1 and 3, and annual runoff percentages declined marginally from the 1989 values. Watershed 2 was tilled conventionally in 1990 and 1991, and although the 1990 runoff percentage was slightly reduced relative to the 1989 value, the 1991 percentage was actually 7% larger than the 1989 value. The 3-year average runoff percentages for Watersheds 1, 2, and 3, respectively, were 35, 45, and 47%, again reflecting primarily topographic and soil controls.

Runoff and erosion differences between the plot and watershed studies are sizeable (Tables 7 and 8). Runoff relations for the plots are materially influenced by management-system effects on the plot surface and near-surface conditions. Conditions at greater soil depths are not of great importance due to free drainage of infiltrated waters out of the plot areas. A fragipan is close to the soil surface in the toe- or foot-slope landscape positions in the Nelson watersheds. Waters infiltrated upslope within the watershed are returned to the surface at these locations of minimum depth to the pan, contributing to surface flow and/or prolonged saturation of the soils in the swale position (immediately downstream of the toe slope). Both of these influences directly contribute to the higher runoff rates from the watersheds relative to the plots.

Annual soil losses for the erosion plots were greatest for the conventionally tilled soybean system with volunteer winter cover (4.6 to 5.0 t/A) and least for the no-till treatments with vetch following grain sorghum or wheat following soybean (0.3 to 0.6 t/A). Soil loss from cotton plots was greater, in 1990, where a wheat cover crop was planted than from the volunteer cover treatment. Poor wheat growth resulted following the late 1989 planting, and this did not compensate for the increased erosion caused by disturbance of the cotton residue by the no-till grain drill. In 1991, a better wheat cover crop reduced soil loss compared with the volunteer-cover treatment.

Annual sediment yields for the two no-till watersheds averaged 0.5 t/A. In contrast, the 2-year average sediment yield from the conventionally tilled watershed was 9.6 t/A, well above the T-value of 3 t/A. Three-year (1990 to 1992) soybean grain yields averaged 29.0 and 27.1 bu/A for the no-till and conventionally tilled watersheds, respectively.

CONCLUSIONS

Ongoing research has identified several conservation production systems that appear to limit soil erosion to tolerable levels while allowing profitable production of agronomic crops on silty upland soils in the mid-South. Systems involving winter wheat as a crop or cover crop were the most profitable during the first 5 years of this study. No-till planting techniques and winter cover cropping improved growth and yield of cotton, reduced runoff and erosion rates, and increased economic net returns.

Table 7. Annual runoff and erosion from Nelson Farm erosion plots'.

Crop	Treatment	1990 Runoff	1990 Soil Loss	1991 Runoff	1991 Soil Loss
		--(in)--	---(t/A)---	--(in)--	--(t/A)---
Cotton	No-till with wheat cover	18.9	3.0	11.8	1.2
Cotton	No-till with volunteer cover	11.8	1.6	8.0	1.6
Sorghum	No-till with vetch cover	5.6	0.4	5.5	0.6
Sorghum	No-till with volunteer cover	11.1	0.8	12.6	1.0
Soybean	Ridge-till w. volunteer cover	12.1	1.2	9.5	1.8
Soybean	Double cropped w. wheat	10.6	0.3	11.0	0.3
Soybean	No-till w. volunteer cover	14.5	0.6	8.8	0.8
Soybean	Conventional w. volunteer cover	15.0	4.6	16.8	5.0

† 1992 results are not complete at this time.

Table 8. Annual runoff and sediment yield from Nelson Farm watersheds'.

Watershed number	1989 IRainfall=61.9 in) Treatment	Runoff	Sed. Yield	1990 (Raint'all=68.1 in) Treatment	Runoff	Sed. Yield	1991 (Rainfall=682 in) Treatment	Runoff	Sed. Yield
		--(in)--	-(t/A)-		--(in)--	-(t/A)-		--(in)--	-(t/A)-
1	Reduced/ Conventional	23.4	8.3	No-till	212	0.5	No-till	24.8	02
2	Reduced/ Conventional	272	19.6	Conventional	272	4.5	Conventional	34.7	14.6
3	Reduced/ Conventional	32.4	13.3	No-till	30.6	1.0	No-till with grassed waterway	31.7	0 3

† 1992 results are not complete at this time.

NO-TILL VS CONVENTIONAL TILLAGE FOR PEANUT vs ROW SPACING AND IRRIGATION

D.L. Wright and I.D. Teare[1]

ABSTRACT

Optimal plant population and irrigation are two methods of increasing yields of row crops. This study was to evaluate the peanut (Arachis hypogaea L.) yield advantage of no-till and conventional tillage methods at differing row spacings and under irrigated and nonirrigated conditions. Research was conducted at the North Fla. Res. and Educ. Ctr. at Quincy, FL on a Norfolk sandy loam soil. Row spacings studied were 15 and 30 inches, and irrigation regimes were no-irrigation and irrigation at three tensiometer levels (20, 60, and 100 cb) during 1981,1982, and 1983. The 15-inch row spacing significantly outyielded the 30-inch row spacing in 1981. In general, no advantage was found between no-till and conventional tillage. The best signal for scheduling irrigation on peanut seems to be 60 and 100 cb, depending on the weather.

INTRODUCTION

One method of increasing yield of row crops is to use optimal plant population that can he achieved by modification of farming equipment. Optimal in-row spacing in peanut has been reported as 4.6 plant/ft by Chin Choy et al. (1982) for maximum yield and quality.

Knauft et al. (1981) found 16 inches the best row spacing over 8- or 32-inch row spacings that were in his experiment, Chin Choy et al. (1982) found that the 10-inch row spacing gave the highest yield, which was the narrowest row spacing in his study. Hauser and Buchanan (1981) found that the narrower row spacings (8- and 16-inch) yielded 14% higher than the 32-inch row spacing. They showed that the 8- and 16-inch row spacings reduced sicklepod DM yields 53 and 28%, respectively.

A second method for increasing peanut yields is by irrigation. Yield enhancement is most evident in arid and semi-arid regions, but irrigation may or may not be valuable in the more humid areas of the Southeast. Coffelt et al. (1985) found irrigation increased peanut in Virginia. Wilson and Stansell (1983) found that water stress during the last 40 to 75 days of the peanut season contributed to atlatoxin contamination of peanut kernels.

The objective of this study was to evaluate the yield advantage of no-till and conventional tillage methods at differing row spacings and under irrigated and nonirrigated conditions.

MATERIAIS AND METHODS

All peanut studies reported herein were conducted at the North Fla. Res. and Educ. Ctr. on a Norfolk sandy loam soil (fine-loamy, siliceous, thermic, Typic Kandiudult).

Cultural practices used on Florunner peanut for 1981, 1982, and 1983 are shown in Table 1. Peanut irrigation dates and amounts of irrigation water applied are shown in Table 2. Rainfall distribution in relation to irrigations for the growing seasons are shown in Figures 1, 2, and 3.

The experimental design of the row spacing experiment was randomized complete block with four replications and the three irrigation experiments were split-plot arrangements with four replications per treatment. The main plots were tillage methods and the subplots were irrigation treatments assigned at random.

RESULTS AND DISCUSSION

The peanut results cannot be discussed without first describing the weather for the years of 1981,1982, and 1983 (Fig. 1, 2, and 3). The 1981 peanut growing season was very dry. Only 10 inches of rainfall occurred. Thirteen irrigations were scheduled on the 20-cb irrigation treatment or 12.8 inches of irrigation for the season. The 1982 peanut growing season was wet, but contained two dry periods from day 145 to 176 and day 238 to 259. Ten irrigations were applied (4.5 inches of irrigation) for the season to the wettest treatment (20 cb) during the two dry periods. Nine irrigations were scheduled on the 20-cb irrigation treatment (52 inches of irrigation) for the 1983 growing

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Table 1. Cultural practices used on Florunner peanut in 1981, 1982, and 1983 at Quincy, FL.

Date			
1981	1982	1983	
5 June	19 May	3 June	Planted inoculated Florunner seed at 45,000 seed/A with Temik at 15 Ib/A, Paraquat at 1 1/2 pt/A, and Prowl at 1 lb ai/A
9 June	26 May	9 June	Cracking
			30 days after planting, Bravo was sprayed on a 2-week schedule until 2 weeks before harvest.
			Fertilizer was applied according to soil test results.
			Herbicides (i.e., Poast, Butoxone, Lasso, and Basagran) were applied as needed during the season.
12 Oct	1 Oct	19 Oct	Peanuts inverted.
14 Oct	4 Oct	26 Oct	Peanuts harvested.

season. A dry period did occur from day 260 to 275 where irrigation was needed.

In 1981, an experiment was conducted to measure the yield advantage of narrow rows on peanuts. Population densities were maintained at approximately 45,000 plants/A in the narrow- and wide-row treatments. The 15-inch row spacing yielded significantly more peanuts than the 30-inch row spacing (Table 3). Peanut yields between conventional and no-till planting methods were not significantly different.

An irrigation study with four water regimes was conducted in 1981, 1982, and 1983 with a row spacing of 30 inches and a population density of approximately 45,000 plants/A The dry 1981 season resulted in two significant groupings (Table 4). The 0 irrigation and 20-cb regime were not significantly different, indicating that the 20-cb irrigation signal ovenvatered the peanuts. The 60- and 100-cb regimes were not significantly different, but both yielded significantly more peanuts than the 0 irrigation and 20-cb regimes.

The 1982 peanut growing season was wet (29 inches rainfall), except for the two short periods mentioned previously. Peanut yield was greatest with 0 irrigation, indicating ovenvatering for all irrigation treatments (Table 5). The 100-, 60-, and 20-cb regimes were not significantly different.

The 1983 peanut growing season received 22 inches of rainfall, which occurred primarily during the first part of the growing season followed by a dry period from day 255 to harvest. The greatest peanut yields were at the 100-cb water regime and 0 irrigation and were not significantly different, but both were significantly different from the 20- and 60-cb water regimes (Table 6), indicating that 20- and 60-cb irrigation signals ovenvatered the peanut crop.

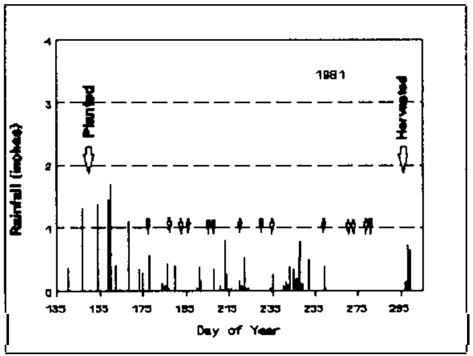
The peanut yield between no-till and conventional tillage methods were not significantly different in 1981 or 1983. The peanut yields for no-tillage was significantly greater than conventional tillage during the wet year of 1982, which may indicate no-tillage allowed more runoff.

Table 2. Peanut irrigation dates and amounts of irrigation water applied during 1981, 1982, and 1983 at Quincy, FL.

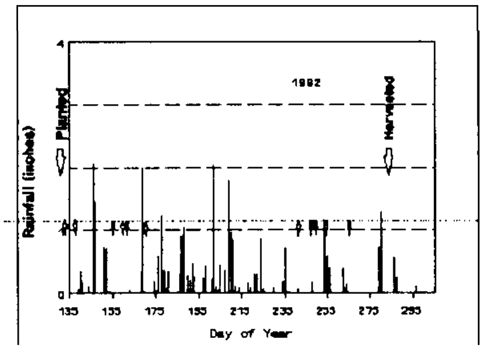
1981	Water Regimes		
Date	20-cb (acre-inch)	60-cb (acre-inch)	100-cb (acre-inch)
30 June	1.00	--	--
8 July	1.00	--	--
14 July	1.00	--	--
17 July	1.00	--	1.00
25 July	0.75	0.75	--
28 July	1.00	--	--
7 Aug	1.00	--	--
17 Aug	1.00	1.00	--
21 Aug	1.00	1.00	1.00
11 Sept	1.00	--	--
22 Sept	1.00	1.00	1.00
25 Sept	1.00	--	--
26 Sept	--	1.00	--
1 Oct	1.00	--	1.00
ΣSeason	12.75	4.75	4.00

1982	Water Regimes		
Date	20-cb (acre-inch)	60-cb (acre-inch)	100-cb (acre-inch)
21 May	0.25	0.25	0.25
25 May	0.25	0.25	0.25
10 June	0.50	--	--
14 June	0.33	--	--
16 June	0.33	--	--
24 June	0.33	--	--
27 Aug	0.50	--	--
1 Sept	0.75	0.75	--
3 Sept	--	--	0.75
7 Sept	0.75	--	--
17 Sept	0.50	--	--
ΣSeason	4.49	1.25	1.25

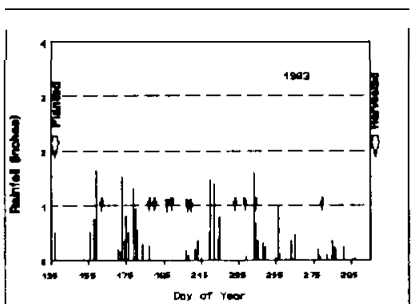
1983	Water Regimes		
Date	20-cb (acre-inch)	60-cb (acre-inch)	100-cb (acre-inch)
16 June	0.50	--	--
8 July	0.50	--	--
12 July	0.50	0.50	--
18 July	0.50	--	0.50
20 July	0.50	0.50	--
25 July	0.50	--	--
28 July	--	0.50	0.50
19 Aug	0.50	--	--
24 Aug	0.75	0.75	--
29 Aug	--	--	0.50
30 Sept	1.00	0.50	1.00
ΣSeason	5.25	2.75	2.50



Fqure **1.** Rainfall during the **1981** peanut growing **season** in relation to rainfall and irrigation amounts and dates of events. **Arrows** identify irrigations.



Fqure **2.** Rainfall during the **1982** peanut growing **season** in relation to rainfall and irrigation amounts and dates of events. **Arrows** identify irrigations.



Fqure 3. Rainfall during the **1983 peanut** growing **season** in relation to rainfall and irrigation amounts and dates of events. Arrows identify irrigations.

Table 3. Influence of row spacing with near constant population densities of 45,000 plants/A on peanut yields under no-till and conventional conditions (Quincy, FL), 1981.

Row	Yield (lb/A)		
Spacing	No-till	Conventional	Average
15"	**3462**	**3940**	**3701** a
30"	**3049**	**3348**	**3199** b
Avg. lb/A	**3256**	**3644 NS**	NS

Table 4. Influence of four water regimes on peanut yields at 30-inch row spacing and a population density of 45,000 plants/A under no-till and conventional conditions (Quincy, FL), 1981.

Water[1]	Yield (lb/A)		
Regime	No-till	Conventional	Average
0 irrig	**2882**	**3257**	**3070** b
100 cb	**3624**	**3960**	**3792** a
60 cb	**3648**	**3832**	**3824** a
20 cb	**2868**	**3359**	**3114** b
Avg. lb/A	**3256** ns	**3602** ns	

[1] Rainfall during growing season = **10.0** inches.

Table 5. Influence of four water regimes on peanut yields under no-till and conventional conditions (Quincy, FL), 1982.

Water[1] Regime	Yield (lb/A) No-till	Conventional	Average
0 irrig	**4233**	**4123**	**4178** a
100 cb	**3675**	**3284**	**3470** b
60 cb	**3633**	**3201**	**3417** b
20 cb	**3738**	**3361**	**3350** b
Avg. lb/A	**3820** a	**3492 b**	

[1] Rainfall during growing season **= 29** inches.

Table 6. Influence of four water regimes on peanut yields under no-till and conventional conditions, (Quincy, FL), 1983.

Water[1] Regime	Yield (lb/A) No-till	Conventional	Average
0 irrig	**3340**	**3289**	**3314** a
100 cb	**3384**	**3356**	**3370** a
60 cb	**3105**	**2563**	**2834** b
20 cb	**2468**	**2893**	**2680** b
Avg. Ib/A	**3074** ns	**3025** ns	

[1] Rainfall during growing season 22 inches.

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CONSERVATION TILLAGE APPLICATIONS FOR A DOUBLE-CROPPING SYSTEM

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INTRODUCTION

Conservation tillage is a generic term that includes many different soil management practices. It is generally defined as being any tillage system that reduces soil or water loss in comparison with conventional tillage methods (Lal, 1989). Conservation tillage systems are receiving increasing acceptance as effective methods for reducing erosion (Berg et al., 1988). The effectiveness of any tillage system for controlling erosion is dependent upon the amount of crop residue left on the soil surface. Previous research has shown that for each 10% increase in ground cover from crop residue, erosion may he reduced by as much as 40%. In a study by Moldenhauser et al. (1983), the greatest reduction in erosion occurred between 0 and 20% soil surface coverage. A 65% reduction in soil loss was achieved at a 20% soil surface coverage level.

Some success in controlling nonpoint-source pollution from agricultural practices have also been attributed to conservation tillage management methods (Baker and Laflen, 1983; Dao and Nguyen, 1989).

Double-cropping and other multiple-cropping practices have had a resurgence in the United States over the last two decades. Unstable crop market prices have influenced many producers to look for additional ways to reduce production costs. Double-cropping is one of those practices. Sanford (1982) suggested some advantages of double cropping are: (1) increased profits resulting from more fully utilized climate, land, and other resources; (2) reduced soil and water losses from having the soil covered during most of the year with a plant canopy; and (3) the opportunity to enhance utilization of soil, water, and energy conserving tillage methods. Other researchers' findings coincide with those of Sanford (Lewis and Phillips, 1976; Howard and Lessman, 1991; Coale and Grove, 1991).

Double-cropping systems provide excellent opportunities to apply conservation tillage methods. Time is a critically important factor in the success of a douhle-cropping system. An adequate number of growing-season days must be available to produce two crops a year on the same field. Reduced- or no-till methods can decrease tbe time between harvesting the first crop and planting the second crop of a double-cropping system.

The objective of this study was to evaluate the effects of several tillage regimes on a soybean-winter wheat double-cropping system.

MATERIAIS AND METHODS

This study was conducted at the Langston University Research Station in central Oklahoma on a tine sandy loam soil.

Tillage Treatment Levels

No-tillage	------	Direct drilling of seeds
Reduced-tillage	......	Disking only
Conventional tillage	......	Moldboard plowing + disking

Two conservation tillage systems were compared with each other and with conventional tillage in a soybean-winter wheat douhle-cropping system. Three nitrogen levels were applied to the winter wheat crop. Nitrogen was topdressed in the spring as ammonium nitrate (34-0-0) at 0, 100, and 200 lb/A. The experimental design was a split-plot with main plots consisting of tillage systems. Individual plots were 5 x 12 ft. Soybeans were planted in 20-inch rows. Winter wheat was subsequently planted in the same rows formerly occupied by soybeans to take advantage of available residual nitrogen left by soybeans. Soybeans were harvested for grain. Winter wheat was harvested once for above-ground biomass.

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RESULTS AND DISCUSSION

The summer drought of 1988 reduced dryland soybean yields (Table 1). Soybean yields were low, regardless of the tillage regime. However, during the 1988 drought, conventionally tilled soybeans out-yielded no-tilled soybeans by 71% and reduced-tilled soybeans by 65%. In the winter wheat component for 1988-1989, both reduced-tilled and conventionally tilled winter wheat produced significantly higher biomass levels than no-tilled winter wheat (Table 2).

Dryland soybean yields for 1989 were noticeably higher than in 1988 (Table 1). Yields for conventionally tilled soybeans were 12% better than no-tilled and 44% better than reduced-tilled soybeans. Yields for 1989-1990 winter wheat showed conventionally tilled wheat yielding slightly better than the two conservation tillage systems.

Conventionally tilled soybeans and winter wheat produced slightly higher yields than reduced- or no-tilled under a double-cropping system. Nitrogen applications did not have a significant effect on winter wheat yields. Based upon field observations, conventionally tilled soybeans and winter wheat were more weed-free than reduced- or no-tilled plots. Less weed competition may have contributed to yield advantages by conventional tillage. However, since time is such a crucial factor in double cropping, especially in temperate climates, the time saved by using reduced- or no-till methods may outweigh possible yield advantages gained by using conventional tillage.

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Table 1. Effect of tillage regime and residual nitrogen (N) fertilizer on double-cropped soybeans.

Tillage Regime	Residual Nitrogen Fertilizer Level/A*	1988 Yield (bu/A)	1989 Yield (bu/A)
No-Tillage	0	9.0	22.0
	100	9.8	25.0
	200	10.0	23.0
Mean		9.6	23.3
Reduced Tillage	0	11.1	18.0
	100	8.0	20.0
	200	10.9	16.0
Mean		10.0	18.0
Conventional Tillage	0	13.3	23.0
	100	15.4	27.0
	200	20.9	28.0
Mean		16.5	26.0

* Refers to nitrogen applied to winter wheat but with possible residual levels remaining for soybeans.

Table 2. Effect of tillage regime and nitrogen fertilizer on double-cropped winter wheat.

Tillage Regime	Nitrogen Fertilizer Level/A	1988-1989 Yield (ton/A)	1989-1990 Yield (ton/A)
No-Tillage	0	0.81	0.52
	100	0.48	0.74
	200	0.59	1.01
Mean		0.63a*	0.76
Reduced Tillage	0	1.89	0.60
	100	2.45	0.70
	200	2.13	0.95
Mean		2.16b	0.75
Conventional Tillage			
	0	2.28	0.86
	100	1.56	0.92
	200	1.66	0.66
Mean		1.83b	0.81

* Means in a column followed by the same letter are not significantly different by LSD at $\alpha = 0.05$.

INFLUENCE OF CONSERVATION TILLAGE SYSTEMS ON RYEGRASS PASTURE AND STEER PERFORMANCE

David M. Ingram, W.K. Addison, and Rick Hardin[1]

INTRODUCTION

The practice of sod-seeding winter annuals has been researched extensively in Mississippi over the past four decades (Dudley and Wise, 1953; Coats, 1957; Lang et al., 1992). Interest in conservation tillage plantings of winter annuals into perennial and volunteer summer annual sod has increased since passage of the 1985 and 1990 Farm Bills, which prohibit establishment of winter forages on highly erodible land by traditional prepared seedbed (conventionally tilled) methods. Although sod-seeding winter annuals into perennial sod is a proven effective method of establishing winter annual forages, usually only late-winter and early-spring grazing are obtained from such establishment methods. The need for fall and early-winter annual forage production is essential to ensure adequate grazing for dairy farmers and cattle stocker operators in the southeastern United States. Ryegrass or ryegrass/small grain mixtures are the winter annuals most commonly utilized in winter grazing programs. Success in establishing winter annual forages into volunteer summer annual sod (primarily crabgrass and broadleaf signalgrass) has been obtained at two locations in central Mississippi (Brock et al., 1992; Ingram et al., 1992) where sufficient forage growth for fall and early-winter grazing has been achieved. However, economic analysis comparing these systems with overseeded perennial sod and prepared seedbed ryegrass pastures has not been previously reported.

Management of volunteer summer annual sod prior to seeding ryegrass in the fall is an integral component to the success of conservation tillage winter grazing programs. Excess forage must be removed by clipping, grazing, or hay harvest prior to planting ryegrass. Summer annual forage production has been monitored (Brock et al., 1992) and generally has been grazed or harvested for hay prior to no-till seedings. Fertilization of summer forages might increase high quality forage production, resulting in a longer grazing season for cattlemen in the southeastern United States.

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The objectives of this study were to: (1) compare ryegrass planted into summer annual and Coastal bermuda sod with ryegrass planted into prepared seedbed pastures for stocker steer performance and economic comparison and (2) determine herbage mass accumulation of summer annual grasses at varying rates of nitrogen (N) fertilization.

MATERIALS *AND* METHODS

Six treatment combinations were compared for backgrounding stocker steer calves from 1988 to 1992 and were as follows: (1) prepared seedbed; (2) annual sod, paraquat burndown, plant no-till; (3) annual sod, plant no-till; (4) bermuda sod, disk lightly, drill; (5) bermuda sod, paraquat burndown, plant no-till; and (6) bermuda sod, plant no-till. Prior to planting ryegrass, excess summer forage on all sod treatments was cut for hay. 'Marshall' ryegrass was seeded at 35 lb/A in the fall of 1988, 1989, and 1991. 'Elbon' rye and 'Marshall' ryegrass were seeded at 120 and 20 lb/A, respectively, in the fall of 1990. Each system of management was applied to 6-acre paddocks, and each system was replicated twice. Paddocks remained in the same tillage treatment throughout the duration of the study. In the 1988 and 1989 grazing seasons, the bermuda sod, no-till treatment was seeded in mid-October, and in the 1990 and 1991 grazing seasons, it was seeded at the same time as the prepared seedbed paddock. Lime, phosphorus, and potassium were applied according to the soil test recommendation each year. Nitrogen was applied as ammonium nitrate to supply 51 lb N/A at planting, 34 lb N/A about mid-February, and 34 lb N/A on April 1 for a total of 119 lb N/A. When ryegrass reached a height of 6 inches, each paddock was stocked with 1.5 English-European cross steer calves/A (approximately 625 lb/A). All calves were wormed and implanted with a growth stimulant when purchased and again in mid-February. Calves for all plots were purchased at the same time and maintained in drylot until placed on ryegrass. In 1990-91, calves for prepared seedbed and annual sod plots were purchased in October and calves for bermuda sod plots were purchased in December. Continuous grazing was practiced; however, grazing pressure was adjusted at periodic intervals as determined by visual assessment of forage availability. Steers were weighed every 28 days and animal grazing days/A, average daily gain, gain/steer, and gain/A were calculated. Economic data were collected from the time of calf purchase to the time of sale. Dollar returns/A were calculated for each planting system.

In a separate study, volunteer summer annual grasses (primarily broadleaf signalgrass) were fertilized at 0, 30, 60, and 90 lb N/A in mid-June and herbage mass accumulation determined in mid-July. Four strips 30 ft wide and spanning the length of a paddock (approximately 150 to 200 ft) were marked for N application. Ammonium nitrate was applied with a spin spreader to the four strips in each of three replicate 6-acre paddocks on June 17, 1992 at the specified rates. On July 10, 1992, total accumulated forage from three 1.0 ft^2 quadrats per strip was harvested. Samples were dried at 140 F (60 C) for 36 hr and weighed for dry matter determination.

RESULTS AND DISCUSSION

Results from grazing studies are presented in Tables 1-5. In the 1988-89 winter grazing season (Table l), the greatest returns/A ($9632) were obtained with the annual sod planted no-till. Data were identical in the prepared seedbed and annual sod, no-till systems; however, pasture costs/A were 16.9% less in the annual sod, no-till plot, resulting in greater dollar returns/A Initial grazing dates occurred on December 7,1988 for these two treatments. All bermuda sod treatments resulted in negative returns/A in 1988-89. Mid-January to mid-February initial grazing dates for the other treatments resulted in low animal grazing days/A, ranging from 147 to 191. Although average daily gains were greater for steers grazing ryegrass planted no-till into bermuda sod, gain/steer and gain/A were lower than the annual sod, no-till and prepared seedbed systems. The lack of sufficient animal grazing days resulted in reduced returns/A. The late planting date for the bermuda sod, no-till system resulted in later initial grazing dates for this treatment.

In 1989-90 (Table 2), annual sod treatments were planted but the emerging ryegrass was destroyed by insects. These two systems were not replanted. All bermuda sod systems performed well in this year with positive returns/A. Sods treated with paraquat or lightly disked outperformed prepared seedbed ryegrass. Calves grazing the prepared seedbed ryegrass paddock were removed for 22 days due to limited available forage, resulting in greater feed cost/steer resulting in lower return/A. Again, the no-till bermuda sod system was planted about 1 month later than other treatments, resulting in fewer grazing days and the lowest return/A ($2656).

In the 1990-91 grazing season (Table 3), the no-till bermuda sod treatment was planted at the same time as prepared seedbed ryegrass. Typical initial grazing dates were obtained in the prepared seedbed and annual sod systems. All treatments resulted in positive dollar returns/& Prepared seedbed ryegrass netted the most ($124.53), followed by annual sod, paraquat, no-till ($117.02), and annual sod planted no-till ($107.74). Bermuda sod treatments netted returns, ranging from $61 to $67/A. Initial grazing date was the same for all bermuda sod treatments January 11,1991. In the 1990-91 grazing season, different purchase dates for calves grazing prepared seedbed and annual sod plots, and calves for bermuda sod plots, resulted in a greater negative margin for bermuda sod plots at sale time causing lower returns/A. A mixture of rye and ryegrass was utilized in 1990-91 in attempt to increase animal grazing days/A. Growth of rye late in the grazing season made forage availability determinations difficult. Coupled with increased time, labor, and pasture costs, rye was utilized only in 1990-91.

No-till planted ryegrass did not perform as well in 1991-92 as in previous years (Table 4). The bermuda sod no-till systems resulted in negative returns, in contrast with the disked bermuda sod, which yielded the second best return/A ($52.02). In general, earlier grazing dates were obtained in this year, which resulted in higher animal grazing days, gain/steer, and gain/A for all treatments. However, forage became limiting in the bermuda sod no-till systems and steers were removed from paddocks for 22 to 33 days. Animal grazing days/A for these two treatments fell below 200 to about 185. The lack of sufficient days on grass resulted in higher feed costs and negative dollar returns. Prepared seedbed ryegrass produced the greatest return/A ($116.45).

The 4-year average from 1988-92 is presented in Table 5. All systems of planting resulted in positive returns/A; however, three systems produced less than $50/A returns to land and management. Bermuda sod, no-till; bermuda sod, paraquat, no-till; and annual sod, paraquat no-till produced $4.74, $38.83, and $48.09 return/A, respectively. Prepared seedbed ryegrass yielded the greatest net return/A ($9932). Annual sod planted no-till resulted in $80.94/A while the bermuda sod, disk, drill system produced $58.17/A Annual sod utilizing paraquat burndown before planting resulted in about 40% less return/A when compared with annual sod planted no-till. The cost of paraquat alone was not

Table 1. Conservation tillage systems for winter grazing stocker steer calves, Raymond, MS, 1988-89.

Sod-Seeding Treatment'	Animal Grazing Days/Acre	Initial Grazing Date[y]	ADG	Gain/ Steer	Gain/ Acre	Returns/ Acre'
			--lb--	--lb--	--lb--	--$--
Prepared Seedbed	250	12/07/88	2.52	421	632	72.88
Annual Sod Paraquat, No-till	191	01/16/89	2.72	345	518	8.01
Annual Sod No-Till	250	12/07/80	2.53	422	633	96.32
Bermuda Sod Paraquat, No-Till	191	01/16/89	2.65	337	506	-6.42
Bermuda Sod Disk, Drill	191	01/16/89	2.75	349	524	-15.04
Bermuda Sod No-Till	147	02/14/89	2.85	279	418	-47.24

x- Prepared seedbed disked two times, field cultivated and planted with a JD 8300 series grain drill. All sod plots were planted with a Marliss no-till drill. Paraquat applied at 0.3125 lb ai/A approximately 5-7 days prior to planting. Excess forage on all sod paddocks was removed as hay. All paddocks were seeded with 'Marshall' ryegrass at 35 lb/A. Average planting date 9/15/80 except for bermuda sod, no-till which was seeded on 10/17/88.

y- Paddocks were initially stocked with nine steer calves/6 acres (approximately 625 lb beef/A).

z- Dollar values are calculated from the time of purchase to the time of sale and reflect all feed costs, vet medicine, interest, pasture costs, death loss, shrinkage, and marketing.

Table 2. Conservation tillage systems for winter grazing stocker steer calves, Raymond, MS, 1989-90.

Sod-Seeding Treatment'	Animal Grazing Days/Acre	Initial Grazing Date[y]	ADG	Gain/ Steer	Gain/ Acre	Returns/ Acre.
			--lb--	--lb--	--lb--	--$--
Prepared Seedbed	252	11/20/89	2.03	341	512	83.43
Annual Sod Paraquat, No-till	---	--/--/--	----	---	---	-----
Annual Sod No-Till	---	--/--/--	----	---	---	-----
Bermuda Sod Paraquat, No-Till	207	01/11/90	2.18	301	452	168.48
Bermuda Sod Disk, Drill	207	01/11/90	1.96	270	405	134.14
Bermuda Sod No-Till	147	02/20/90	2.27	222	333	26.56

x- Prepared seedbed disked two times, field cultivated and planted with a JD 8300 series grain drill. All sod plots were planted with a Marliss no-till drill. Paraquat applied at 0.3125 lb ai/A approximately 5-7 days prior to planting. Excess forage on all sod paddocks was removed as hay. All paddocks were seeded with 'Marshall' ryegrass at 35 lb/A. Annual sod paddocks were planted but were destroyed by insects. Average planting date 9/15/90 except for bermuda sod, no-till which was seeded on 10/19/90.

y- Paddocks were initially stocked with nine steer calves/6 acres (approximately 625 lb beef/A).

z- Dollar values are calculated from the time of purchase to the time of sale and reflect all feed costs, vet medicine, interest, pasture costs, death loss, shrinkage, and marketing.

Table 3. Conservation tillage systems for winter grazing stocker steer calves, Raymond, MS, 1990-91.

Sod-Seeding Treatment[x]	Animal Grazing Days/Acre	Initial Grazing Date[y]	ADG	Gain/ Steer	Gain/ Acre	Returns/ Acre[z]
			--lb--	--lb--	--lb--	--$--
Prepared Seedbed	259	11/23/90	2.30	418	594	124.53
Annual Sod Paraquat, No-till	240	11/26/90	2.32	416	591	117.02
Annual Sod No-Till	240	11/26/90	2.25	402	570	107.74
Bermuda Sod Paraquat, No-Till	210	01/11/91	2.47	338	517	64.29
Bermuda Sod Disk, Drill	218	01/11/91	2.46	336	534	61.56
Bermuda Sod No-Till	206	01/11/91	2.55	349	524	66.92

x- Prepared seedbed disked two times, field cultivated and planted with a JD 8300 series grain drill. All sod plots were planted with a Marliss no-till drill. Paraquat applied at 0.3125 lb ai/A approximately 5-7 days prior to planting. Excess forage on all sod paddocks was removed as hay. All paddocks were seeded with 'Marshall' ryegrass at 20 lb/A and 'Elbon' rye at 120 lb/A. Annual sod paddocks were planted but were destroyed by insects. Average planting date for all plots was 9/22/91.

y- Paddocks were initially stocked with nine steer calves/6 acres (approximately 625 lb beef/A).

z- Dollar values are calculated from the time of purchase to the time of sale and reflect all feed costs, vet medicine, interest, pasture costs, death loss, shrinkage, and marketing.

Table 4. Conservation tillage systems for winter grazing stocker steer calves, Raymond, MS, 1991-92.

Sod-Seeding Treatment[x]	Animal Grazing Days/Acre	Initial Grazing Date[y]	ADG	Gain/ Steer	Gain/ Acre	Returns/ Acre[z]
			--lb--	--lb--	--lb--	--$--
Prepared Seedbed	272	11/13/91	3.07	467	700	116.45
Annual Sod Paraquat, No-till	232	12/09/91	2.85	441	661	19.23
Annual Sod No-Till	202	12/09/91	3.00	465	698	38.76
Bermuda Sod Paraquat, No-Till	181	12/11/91	2.92	387	581	71.04
Bermuda Sod Disk, Drill	242	12/04/91	2.97	477	716	52.02
Bermuda Sod No-Till	185	12/19/91	3.28	439	658	27.29

x- Prepared seedbed disked two times, field cultivated and planted with a JD 8300 series grain drill.
Paraquat applied at 0.3125 lb ai/A approximately 5-7 days prior to planting.
Excess forage on all sod paddocks was removed as hay. All paddocks were seeded with 'Marshall' ryegrass at 35 lb/A. Average planting date for all plots was 9/20/91.

y- Paddocks were initially stocked with nine steer calves/6 acres (approximately 625 lb beef/A).

z- Dollar values are calculated from the time of purchase to the time of sale and reflect all feed costs, vet medicine, interest, pasture costs, death loss, shrinkage, and marketing.

Table 5. Conservation tillage systems for winter grazing stocker steer calves, 4-year average, Raymond, MS, *1988-92.*

Sod-Seeding Treatment"	Animal Grazing Days/Acre	Initial Grazing Date[x]	ADG	Gain/ Steer	Gain/ Acre	Returns/ Acre[y]
			--Ib--	--lb--	--lb--	--$--
Prepared Seedbed	*258*	*11/23*	*2.48*	*412*	610	*99.32*
Annual Sod Paraquat, No-till'	*221*	*12/17*	*2.63*	*401*	*590*	*48.09*
Annual Sod No-Ti1l'	*231*	*12/04*	*2.59*	*430*	*634*	*80.94*
Bermuda Sod Paraquat, No-Till	*197*	*01/05*	*2.76*	*341*	*514*	*38.83*
Bermuda Sod Disk, Drill	*215*	*01/03*	*2.72*	*358*	*545*	*58.17*
Bermuda Sod No-Ti11	171	*01/24*	*2.74*	*322*	*483*	*4.74*

w- Prepared seedbed disked two times, field cultivated and all plots planted with a JD *8300* series grain drill. Paraquat applied at *0.3125* lb ai/A approximately *5-7* days prior to planting. Excess forage on all sod paddocks was removed as hay. Average planting date 9/17 (except bermuda sod, no-till).

x- Paddocks were initially stocked with nine steer calves/6 acres (approximately *625* lb beef/A).

y- Dollar values are calculated from the time of purchase to the time of sale and reflect all feed costs, vet medicine, interest, pasture costs, death loss, shrinkage, and marketing.

z- Three-year average.

sufficient to result in differences in returns/A of this magnitude. Lang (1990) reported that significant concentrations of ethylene were present in soil of both perennial and annual sods harvested for hay or chemically killed just prior to planting. It appears the concentration of ethylene may he high enough to retard ryegrass growth, and this may explain forage growth and animal performance differences among the annual sod systems. A similar condition may exist in bermuda sod plots; however, later planting dates in 2 of 4 years for bermuda sod planted no-till were responsible for lower returns/A for this treatment.

Data from this study indicate no-till seeding ryegrass into summer annual sod is a viable alternative to prepared seedbed (conventionally tilled) ryegrass pastures. In addition, the traditional method of overseeding perennial sods by lightly disking before planting still remains the best management system of planting ryegrass into permanent pastures. Data for the 4-year period suggest that average initial grazing dates of about December 1 and average animal grazing days/A in the range of 215 to 230 will result in steer gains suitable for profit, providing the negative margins from buying to selling are not too great.

Nitrogen fertilization influence on herbage mass accumulation of summer grasses is presented in Table 6. No significant differences were observed in total forage accumulation, regardless of N rate. On the average, forage dry matter ranged from 3,889 to 4,825 lb/A. With 60 lb N/A, only a 3.6% increase in dry matter occurred over the no N treatment. Brock et al. (1992) reported broadleaf signalgrass yields were in the range of 3,400 to 3,800 lb dry matter/A with no added N. The lack of forage growth response to Nmay be explained by the fact that plots used in the study were previously in ryegrass production and received 119 lb N/A annually. Residual soil N levels may have been sufficient to maximize signalgrass growth, thus, masking influence of additional N applications.

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Table 6. Influence of Nrate on dry matter accumulation of volunteer summer annual grasses, Raymond, MS, 1992.

Nitrogen Rate (lb/A)[y]	Dry Matter Forage (lb/A)[z] Plot 1	Plot 2	Plot 3	Mean
0	3790	3758	4119	3889
30	4324	3636	4912	4291
60	4062	3703	4318	4028
90	4676	4423	5376	4825
LSD (0.05)	NS	NS	NS	NS
CV %	17.4	16.7	17.4	11.9

y- Nitrogen applied as ammonium nitrate on 6/17/92.

z- Three 1.0 ft^2 quadrat samples were taken per plot/N rate. Samples were cut with hand trimmer to a uniform height of 2 inches on 7/10/92.

AGRONOMIC CONSIDERATIONS FOR SUCCESSFULLY RELAY INTERCROPPING SOYBEANS INTO STANDING WHEAT IN THE SOUTHERN UNITED STATES

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INTRODUCTION

Double-cropping wheat and soybeans is a popular cropping system across the southern U.S. Producers, however, are challenged by high costs, price volatility, and weather extremes, which reduce profit potential, especially for soybeans. For improved production efficiencies and for meeting conservation compliance requirements on highly erodible fields, new environmentally sound and cost-effective reduced-tillage ideas should be examined.

Relay intercropping or inter-seeding soybeans into standing wheat is a concept that has been explored in the Midwest as a means of extending the growing season to facilitate double-cropping (Chan et al., 1980; Duncan et al., 1990; Jeffers, 1984; McBroom et al., 1981a, b; Moomaw and Powell, 1990; Reinbott et al., 1987; and Wendt and Nave, 1979). In the South, intercropping has been examined recently in Mississippi (Buehring et al., 1990) and South Carolina (Khalilian et al., 1990; Hood et al., 1991; Hood et al., 1992; Khalilian et al., 1991; Khalilian et al., 1988; Whitwell, 1991; and Wallace et al., 1992) because of its reduced input features (e.g. for energy, labor, equipment, and herbicides). In addition, the emphasis on conservation-tillage technology has driven researcher and producer interests in this concept.

Since 1988, Clemson University researchers have investigated many of the equipment, energy, and crop and soil management factors associated with intercropping soybeans and wheat. This paper outlines some of the advantages of intercropping, recent research findings, and guidelines for successful on-farm adoption of the system.

ADVANTAGES

Conventional double-cropping, a sequential planting of soybeans after wheat harvest, is often fraught with poor stands, weed infestations, and delayed soybean planting due to adverse weather. With relay planting, soybeans are inter-seeded into wheat 1 to 3 weeks before wheat harvest. This concept has the following potential advantages over conventional double-cropping systems:

a) better utilization of soil moisture for soybean stands;
b) optimum planting time for soybeans;
c) lower energy requirements;
d) less soil erosion and runoff, and better water quality;
e) reduced soil compaction;
f) less herbicide use; and
g) more timely field operations for soybeans, including planting, spraying, and harvesting.

RECENT RESEARCH FINDINGS

When inter-seeding, both crops are planted with a special inter-seeder drill developed by Clemson agricultural engineers and currently commercially available from Valkenburg Equipment Co., Greenwood, SC. The drill plants 11 rows of wheat (13-inch spacing) in the fall, leaving two traftic lanes (24 inches) for wheel traflic (76-inch spacing). This pattern allows for the inter-seeding of eight rows of soybeans in mid- to late-May (soil moisture permitting) when wheat is in the hard dough stage, about 2 to 3 weeks before harvest. There is also an inter-seeder drill configuration available for wheel traftic with a 96-inch spacing. However, since most tractors are setup with the 76-inch wheel spacing, the former scheme is the most popular so far in on-farm producer trials. (Note: see paper by Hood, et al. in this conference proceedings for illustrations of the inter-seeding schemes and planter setups).

The following is a list of findings from the Clemson intercropping research effort, which will impact producer acceptance of this planting concept.

1. Crop yields

Yields of wheat in the wide-row pattern for inter-seeding have been no different from wheat planted in conventional drill spacings in Coastal Plain soils (Khalilian et al., 1990). In soils typical of the Piedmont

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region, however, yields of wheat were 15 to 20% lower due to reduced tillering in the wide-row scheme (Wallace et al., 1991).

For soybeans, yields were significantly higher for inter-seeding vs. conventional no-till subsoil planting in 38-inch rows after wheat harvest in the Coastal Plains (Khalilian et al., 1991). For Piedmont conditions, yields of inter-seeded soybeans have been at least as high as drilled mono-crop soybeans or conventional wide-row no-till soybeans planted after wheat harvest (Wallace, et al., 1992 and Hayes, et al., 1991).

2. Deep tillage

Research at Blackville, SC in Coastal Plain soils indicates that the need for deep tillage before planting soybeans is eliminated if a good job of deep tillage is done before wheat planting in the fall. Then, if the controlled-traffic pattern is utilized with inter-seeding, a savings of $8 to $10/A is possible (Khalilian, et al., 1991).

3. Weed management

Field observations have shown that, with inter-seeding, herbicide inputs are less in most cases vs. conventional wide-row double-cropping systems (Whitwell, 1991).

4. Crop growth

Even though inter-seeded soybeans often show an etiolated or spindly appearance due to shading from the wheat crop before and for some time after wheat harvest, research has shown no difference in yield between an inter-seeded crop and mono-crop soybeans planted the same day (Wallace et al., 1992).

5. Equipment technology

New drill technology (e.g. Airseeder, Yetter seeder-coulter, etc.) has enhanced field success and producer acceptance of inter-seeding as an alternative to conventional double-cropping systems (Hood, et al., 1992).

GUIDELINES FOR SUCCESS

To optimize yields and returns from intercropping soybeans and wheat, the following guidelines are suggested.

1. Field selection

Choose fields for intercropping that are relatively free of perennial weeds and grasses, hard-to-control broadleaf weeds, or nematodes parasitic to soybeans. Soils present should have productive potential for high crop yields, eg. at least 50 bushels for wheat and 30 bushels for soybeans.

2. Deep tillage and controlled traffic (wheat)

If soil hardpans or traffc pans exist, practice deep tillage before planting the wheat. In the light-textured Coastal Plain soils, deep tillage with a chiselplow or Paratill 1 to 2 inches into the B horizon (clay) will provide optimum crop yield response. It is important that trips across the field be minimized for application of topdress nitrogen and/or pesticides for wheat. If possible, all wheel traffc should be confined to the wheel tracks set up when planting wheat in the fall.

3. Wheat variety

Select an early- or mid-season high-yielding wheat variety with good disease resistance and strong straw strength. Successful interseeding is difficult if the wheat is badly lodged.

4. Wheat seeding rate

The seeding rate for wheat should be the same as for conventional drilled plantings.

5. Weed control (wheat)

Since there may be more winter weed pressure due to the wide-row spacing (and due to spacing for wheel tracks), weed scouting should be done during the wheat tillering stage. Herbicide(s) should be selected based on target weeds present.

6 Nitrogen topdress/herbicide application for wheat

All nitrogen topdress and herbicide (or other pesticides) application trips should be accomplished with equipment set up in the same wheel spacing (76- or 96-inch) as the interseeder drill.

7. Soybean variety

A fast-growing high-yielding Group VII or Group VIlI soybean variety should be chosen. If nematodes are known to exist in the field, select a variety with resistance, if available.

8. Interseeding soybeans

Plan to interseed soybeans at approximately 3 to 4 seed/row ft from May 10 to May 31, when wheat is in the hard dough stage of growth, and about 2 to 3 weeks from harvest maturity. Since wheat is also using soil moisture at high rates during this period, it is very important to plant in moisture adequate for germination and emergence. Shortly after soybean emergence, the seedlings will become etiolated (spindly) while growing in the shade of the wheat, Once the wheat is harvested in early June, the soybean plants quickly outgrow the effects of early shading by wheat.

9. Wheat harvest

The wheat should be harvested as soon as possible after harvest maturity and ideal seed moisture are reached. If combine wheels do not match the wheel traffic pattern, harvest at an angle or perpendicular across the crop rows. Combine wheel traffic will not significantly damage soybean stands during the first 3 to 5 weeks after planting. During harvest, the wheat straw should be chopped and spread evenly across the combine swath. Or, if feasible, curtains can be attached to the rear of the combine to force all straw into the wheel tracks.

10. Weed control (soybeans)

After wheat harvest (ASAP), scouting should be done to assess the weed situation, i.e. species, size or stage of growth, intensity, etc. Postemergence herbicide(s) should be selected based on scouting results for each field, and applied according to label directions. Use application equipment set up in same wheel spacing (76- or 96-inches) as the interseeder drill.

11. Costs and returns

Table 1 is a production costs and return comparison of intercropping vs. conventional and no-till drilling of soybeans after wheat harvest. These are based on 1992-93 enterprise budgets from the Clemson University Applied Economics Department.

As mentioned earlier in this paper, it is likely that producers can obtain higher interseeded soybean yields than for conventional double-crop systems. In such cases, more income (profit) would be possible.

Table 1. Wheat (50 bu/A) and soybean (30 bu/A).

	Conventional tillage	No-till	Interseed
Revenue*	**$365**	**$365**	**$365**
Variable costs	**215**	**213**	**216**
Income above variable costs	**150**	**152**	**149**
Fixed costs	**54**	***46***	**46**
Land charge	**30**	**30**	**30**
Overhead (**8%** V.C.)	**17**	**17**	**17**
Total costs	**316**	**306**	**309**
Income above total costs	**49**	**59**	**56**

* Wheat price = $3.00 + $1.00 def. payment and soybean price= $5.50/bu.

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RESPONSE OF TROPICAL CORN TO NITROGEN AND STARTER FERTILIZER IN CONVENTIONAL AND STRIP TILLAGE SYSTEMS

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INTRODUCTION

Tropical corn *(Zea mays* L.) has become an important alternative crop in the southeastern United States in the past few years. It has been estimated that over 50,000 acres was grown in 1991, mostly for silage (Wright et al., 1991). Due to its late optimum planting date, tropical corn serves as an alternative crop to soybeans *(Glycine max* L.), grain sorghum (Sorghum bicolor L.), and temperate corn (Wright et al., 1990a and b; Teare, et al., 1991). Obtaining a late-season grain or silage crop, in addition to high silage yields, makes tropical corn an attractive alternative crop for the South.

Double-cropping tropical corn with wheat *(Triticum aestivum* L.) using reduced tillage would be a desirable system. However, very little data have been reported regarding the nitrogen (N) requirements of tropical corn when grown as a double-crop, under no-till, or conventional-tillage systems (Reeves et al., 1991). There is also a need to assess starter fertilizer needs for tropical corn when grown as a double-crop, under no-till, and conventional-tillage systems.

MATERIAL AND METHODS

To determine optimum management practices for tropical corn in south Alabama, a 3-year field study was initiated in 1990 at the Wiregrass Substation in Headland, Alabama, on a Dothan sandy loam soil (Plinthic Paleudult). Tropical corn hybrid Pioneer 304C was planted on 1 June 1990, and tropical corn hybrid Pioneer 3072 was planted on 4 June and 13 June in 1991 and 1992, respectively. Tillage treatments consisted of strip and conventional tillage. The five starter fertilizer treatments were: (1) no starter, (2) 20 lb N/A, (3) 20 lb P/A, (4) 20 lb N and 20 lb P/A, and (5) 20 lb N, 20 lb P, and 10 lb S/A. Nitrogen treatments consisted of 0, 50, 100, and 150 lb/A. The experiment was a split-split plot design with the two tillage systems as whole plots, starter fertilizer treatments as split plots, and N rate as split-split plots.

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Wheat was planted each fall. After the wheat matured in late spring, the test area was prepared according to the tillage system. Conventional tillage consisted of chisel plowing and disking followed by in-row subsoiling at planting. Strip tillage consisted of in-row subsoiling and planting into wheat stubble. The starter treatments were applied at planting as a solution in an approximate 2 x 2-inch placement. Nitrogen as ammonium nitrate was applied as a sidedress approximately 4 weeks after planting. Each plot was 30 ft in length and consisted of 8 rows with a 36-inch spacing. Plant population for all 3 years of the study was approximately 20,000 plants/A.

Grain yields were not determined in 1990 due to severe insect pressure, but grain yields were determined in 1991 and 1992. Grain was harvested from the two middle rows of all plots on 10 October and 14 October 1991 and 1992, respectively. Grain moisture was determined on a minimum of 20 plots and averaged over the test.

Silage yields were determined by cutting a total of 10 ft of row per plot. Silage was harvested on 28 August, 5 September, and 9 September in 1990, 1991, and 1992, respectively. The whole plants were weighed and subsamples collected to determine dry matter content. Subsamples were dried at 60°C and weighed.

In 1991 and 1992, subsamples of silage were analyzed for forage quality. The silage was analyzed for crude protein, acid detergent fiber, and neutral detergent fiber.

Using SAS procedures (SAS Institute, 1985), yield and forage quality were statistically analyzed. Means were separated with Fisher's Protected LSD.

RESULTS AND DISCUSSION

In 1990, there were no interactions between tillage, starter fertilizer, or N. Excellent silage yields were obtained with the conventional and strip tillage systems, averaging 17.1 and 20.3 t/A, respectively. The addition of N increased yields, but a significant response was only obtained up to the 50 lb N/A rate (data not shown). This response was most likely due to the variety grown in 1990 (Pioneer 304C), as well as drought conditions and severe infestation of fall armyworm *(Spodoptera frugiperda).* Starter fertilizer also increased yields (Table l), with the NP treatment increasing silage yields by 3.1 t/A.

In 1991, silage and grain yields increased with N rate (Table 2), with consistently higher yields occurring under strip tillage. The best starter treatment for silage was the NP treatment under the strip-tillage system (Table 1) For grain, N alone as a starter was adequate, averaging 63 bu/A over tillage systems (data not shown).

In 1992, grain and silage yields were much lower, and the two tillage systems produced similar yields (Table 2). Grain yields in 1992 ranged from 23 to 45 bu/A and increased with increasing rates of N (Table 2). The best starter for grain was the NP treatment (data not shown). Low grain yields were the result of low rainfall distribution. This is in contrast to results obtained at two other locations in Alabama in 1992. Grain yields at these locations averaged above 100 bu/A when using the same variety and similar planting dates.

Forage quality of the harvested silage was affected primarily by the rate of N (Table 3). As expected, crude protein increased with increasing N rate. Both ADF and NDF decreased with increasing N rate.

CONCLUSIONS

Strip tillage gave higher silage yields in 2 out of 3 years and higher grain yields in **1** year when compared with conventional tillage. Higher silage yields were obtained with the NP starter when averaged over both tillage systems in 2 out of 3 years. For grain, N alone as a starter fertilizer gave the best results under strip tillage, whereas NP was the best starter under conventional tillage. In 1990, due to variety (Pioneer 304C), drought, and insect pressures, silage yields did not increase above 50 lb N/A. In 1991 and 1992, Pioneer 3072 was grown and rainfall was adequate. An increase in silage yields was obtained up to the 150 lb/A N rate.

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Table 1. Tropical corn silage yields in 1990 and 1991 averaged over N rates as affected by starter fertilizer treatments.

Starter Fertilizer[&]	1990[#]	1991 Conv.	1991 Strip
	tons/A		
None	16.9	9.5	9.7
N	18.7	8.9	11.0
P	17.3	9.8	10.0
NP	20.0	10.6	11.3
NPS	20.6	9.2	10.7
$LSD_{0.10}$	2.1	1.0[t]	

[&] 20 lb N/A, 20 lb P/A, 10 lb S/A; [#] Averaged over tillage treatments; [t] Tillage by starter interaction LSD.

Table 2. Tropical corn silage yields in 1990, silage and grain yields in 1991, and grain yields in 1992 (averaged) over starter treatments) as affected by the rate of N fertilizer.

N rate	1990 Silage	1991 Silage Conv.	1991 Silage Strip	1991 Grain Conv.	1991 Grain Strip	1992 Grain Conv.	1992 Grain Strip
lb/A	tons/A			bu/A			
0	16.3	6.9	6.3	26	29	29	23
50	17.8	9.0	10.7	46	62	36	34
100	18.3	10.9	12.0	56	74	42	45
150	17.9	11.6	13.3	60	81	45	39
$LSD_{0.05}$	2.0	NS[&]		5		4.8	
$LSD_{0.10}$	---	1.2		---		---	

[&] Tillage by N rate interaction LSD.

Table 3. Tropical corn forage quality in 1991 and 1992 as affected by the rate of N fertilizer.

Nitrogen rate	Crude Protein 1991	Crude Protein 1992	NDF 1991	NDF 1992	ADF 1991	ADF 1992
	%					
0	4.6	4.8	59	62	33	36
50	4.9	5.3	56	59	30	33
100	5.7	6.0	54	57	28	32
150	6.3	6.5	53	57	27	31
$LSD_{0.05}$	0.8	1.0	1.2	1.0	0.97	1.4

TILLAGE AND COVER CROP EFFECTS ON COTTON GROWTH AND DEVELOPMENT ON A LOESSIAL SOIL

C. W. Kennedy and R. L. Hutchinson[1]

ABSTRACT

Inconsistency in cotton production under conservation tillage systems has been attributed in part to reductions in plant population. This study was conducted to determine what effects conservation tillage systems (no-till and ridge-till) had on growth and development of cotton and what relationship these growth patterns had with economic yield and plant population. Crop growth rate (CGR), leaf area index (LAI), and yield components were analyzed over two years for cv "Stoneville 453" grown on a Gigger silt loam (fine-silty, mixed, thermic Typic Fragiudalf). Across four cover crops, the no-till system (NT) produced greater pre-bloom CGR and LAI than conventional- (CT) or ridge-tillage (RT) in 1991, but not in 1992. Across years and cover crops, NT produced a numerically greater, but not consistently significant, boll weight during the fruiting period compared with CT and RT. The greater boll weight was influenced by a greater weight per boll in the NT system. Correlation of pre-bloom CGR and LAI values with lint yield across all treatments and years was significant (r = .73 to .66). Pre-bloom CGR and LAI was also significantly correlated with plant population, hut r values were lower (.47 to 27). Across cover crops, the NT system used on this soil had the greatest potential as a successful conservation tillage system. It also appeared to be the system most varied in plant population. The RT system generally had lower pre-bloom growth. The reduced performance of this system is less likely attributable to differences in plant population as it is to some undetermined, soil-related factor that apparently begins to occur early in the growth process.

INTRODUCTION

Interest in conservation tillage systems has increased in the last decade because of the need to develop an approved conservation plan on highly erodible crop land, a need to reduce production costs, and the necessity to maintain soil productivity. A major objective of conservation tillage research has been to maintain crop productivity while providing the additional benefits attributed to conservation tillage systems (Touchton and Reeves, 1988). The use of winter cover crops is often an integral part of a conservation tillage system. The type of tillage and/or winter cover crop used may have an effect on subsequent growth and productivity of cotton. These effects, however, are inconsistent (Keeling et al., 1989; Stevens et al., 1992). Reduced plant populations in conservation tillage systems have been implicated as a major factor in reduced productivity (Grisso et al., 1984; Morrison et al., 1985). The recommended plant population in Louisiana is the range of 26,000 to 52,000 plants/A. Alternatively, lower plant populations do not always result in lower yields (Touchton and Reeves, 1988). Moreover, lower yields may not necessarily be due to lower plant populations. In order to better understand how conservation tillage/cover crop systems improve or impair cotton production on any given soil, analyses of crop growth and development should be conducted during the season. Our objectives were to 1) quantify crop growth and development throughout the season for different tillage/cover crop systems and 2) relate these growth quantities to yield and plant population.

MATERIALS AND METHODS

The cotton variety "Stoneville 453" was seeded on 5/14 and 5/4 in 1991 and 1992, respectively, into a Gigger silt loam soil (fine-silty, mixed, thermic Typic Fragiudalf). Tillage treatments consisted of CT, RT, and NT. Cover crops were native winter vegetation (NV), crimson clover (CC), hairy vetch (HV), and winter wheat (WW). Tillage and cover crops were arranged in a complete factorial randomized block experimental design with four replications. Management of cover crops, seeding method, fertilizer and herbicide applications, and harvesting are described by Hutchinson et al. (these proceedings).

Data Collection

Plant population counts were determined approximately 20 days after planting (DAP) on a

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minimum of 15 ft of row adjacent to a border row. Plant samples for growth quantification were taken from 2 ft of the same row at approximately biweekly intervals throughout the season. The number of plants within the 2 ft of row taken as a sample had to correspond to the population determined for individual plots. Leaves were excised and leaf area was determined on all leaves per sample early in the season and for leaves on one-third to one-half of the plants per sample later in the season. The total leaf area of these samples was determined by the specific leaf area method (Wells and Meredith, 1986). Total fruiting structures were counted and bolls were separated by location on the plant. Bolls were grouped according to the node position on a fruiting branch (1, 2, and 3+) and fruit branch location on the main stem (nodes 5-8, 9-12, 13-16, and 17+). All bolls produced on vegetative branches were pooled. Leaves, stems, and fruit structures were dried at 70ºC for a minimum of 48 h and weighed. Crop growth rates and LAI were determined by the use of classical formulae (Evans, 1972). Weight per boll was determined within each boll grouping and percent dry matter partitioned into bolls was determined by dividing total boll weight by total above-ground plant weight.

Data analysis

Data were combined across years in a split plot design with years as the main plot. Samples were not taken on exactly the same DAP each year, but seven sampling dates were within 7 d or less of each other and were used for the combined analysis. The following DAP were used for 1991 and 1992, respectively 29, 28; 54, 51; 63, 64;76, 78; 94, 90; 108, 101; and 132, 129. The mean of each group would be used in subsequent results and discussions. Analysis of variance and correlations were determined using the Statistical Analysis System (SAS Institute, Inc., Cary, NC).

RESULTS

Combined across years and treatments, the strongest positive relationships between lint yield and CGR or LAI was prior to blooming (Table 1). Plant population density would be expected to have influenced CGR and LAI values, especially early in the season, but correlations between these parameters were only low to moderate. The correlation between lint yield and population density was also low (r = 0.20). Significant differences in CGR and LAI did occur between treatments, primarily early in the season. Major differences occurred due to tillage, but significant tillage by year interactions indicated that growth response to a particular tillage system was not stable. The major differences occurred in the NT system, exceeding both CT and RT in 1991 but not in 1992 (Table 2). The RT system generally had the lowest rate of pre-bloom crop development in both years. Cover crop did influence the growth responses to tillage systems because the tillage by cover crop interaction was significant at the 6% level of probability. In general, cover crops had less effect under CT than under RT and NT where they tended to improve pre-bloom CGR The most consistent tillage/cover crop system in producing high pre-bloom CGR was NT/HV. The NT/WW system was equivalent to NT/HV in crop growth 28 DAP, but by 52 DAP, the former system had grown substantially slower than the latter (data not shown).

The number of squares that had developed by 52 DAP was highly correlated with lint yield (r = 0.74). Additional square production did not correlate as well. The response paralleled that found with pre-bloom CGR and LAI values. The RT system remained the most consistent in producing fewer squares, while NT was similar to or above CT responses (Table 2).

As would be expected, r values relating lint yield with yield components (boll numbers, total boll weight, percent dry matter partitioning into bolls, and weight per boll) were high to moderate and statistically significant beginning at the initiation of boll-set. Tbe average r value was 0.55 +/-26 for these yield components with lint yield (data not presented). Plant population had generally low correlations with yield components (average r = .15 ± .17), indicating that plant population did not influence the latter stages of crop development in this study. There was a cover crop-by-year interaction for boll weight. Total boll weight at the end of the season was generally greater in applied cover crops (CC, HV, and WW) in 1991 than 1992, but there was no difference between years with the NV cover (data not presented). Differences in yield components between tillage treatments were generally not significant although total boll weight was numerically greatest for NT across the season (Table 3). A major factor in the greater boll weight for NT treatments was the generally greater weight per boll for position 1 bolls located off main stem nodes 5 - 12 (Table 3). The greatest percentage of bolls was found at these positions and therefore had the greatest influence on total boll weight.

Table 1. Correlation coefficients across years, tillage, and cover crops for CGR and LAI throughout the season with lint yield and plant population.

	Days after Planting	Lint Yield	Plant Population
		r	
CGR	28	.72*	.47*
	52	.66*	.27*
	64	.06	.22*
	77	.48*	.29*
	92	.12	.10
	104	-.07	-.16
	130	-.42*	-.03
LAI	28	.73*	.45*
	52	.68*	.32*
	64	.34*	.30*
	77	.62*	.46*
	91	.53*	.48*
	104	-.22*	-.13

* Significant at $P \leq .05$.

Table 2. The effect of tillage systems on pre-bloom growth and reproductive development of Stoneville 453; 1991 and 1992.

		Days after Planting				
		28		52		
Tillage	**Year**	CGR†	LAI	CGR‡	LAI	Squares
		$gm^{-2}day^{-1}$	m^2m^{-2}	$gm^{-2}day^{-1}$	m^2m^{-2}	$no. Ac^{-1}x10^{-3}$
Conventional	91	0.20	0.09	4.28	1.39	329.8
	92	0.12	0.05	3.21	0.96	152.2
Ridge	91	0.20	0.09	4.19	1.40	331.4
	92	0.09	0.04	2.38	0.71	109.4
No	91	0.30	0.14	6.94	2.25	460.8
	92	0.09	0.04	3.21	0.94	135.9
LSD 0.05		0.04	0.02	0.98	0.28	72.5

† Determined from 0 to 28 DAP.
‡ Determined from 29 to 52 DAP.

Table 3. Tillage effects on total boll weight produced and weight per boll for Stoneville 453; average of 2 years.

Yield Component	Tillage System	Days After Planting				
		64	77	92	104	130
Boll Weight (g/m^2)	Conv.	1.6	60.1	229.9	307.6	348.2
	Ridge	2.7	61.1	234.0	342.2	356.0
	No	3.2	78.1	259.8	356.6	364.5
	LSD 0.05	NS	NS	NS	NS	NS
Position 1 Bolls, Nodes 5 - 8 (g/boll)	Conv.	0.32	1.82	4.13	5.04	5.06
	Ridge	0.46	1.72	4.10	5.11	5.13
	No	0.43	2.41	4.65	5.63	5.64
	LSD 0.05	NS	0.34	NS	NS	0.36
Position 1 Bolls, Nodes 9 - 12 (g/boll)	Conv.	----	0.78	3.06	4.25	5.27
	Ridge	----	0.83	2.84	4.16	5.08
	No	----	1.10	3.26	4.69	5.42
	LSD 0.05		0.19	NS	NS	NS

DISCUSSION

It is well established that early developmental stages of plant growth provide the future basis for a productive crop by rapidly increasing leaf area and, in the case of cotton, subsequently and concomitantly developing a branch framework for reproductive development (Muramoto et al., 1965; Potter and Jones, 1977; Watson, 1952; Mauney, 1984). The faster the early growth rate, the sooner the crop will develop greater light interception capacity that can lead to greater productivity. The correlation results of pre-bloom CGR and LAI with lint yield support this hypothesis. Depending upon the year, the NTsystem developed equivalent or greater pre-bloom CGR than any other tillage system while RT produced equivalent or lower CGR This occurred even though RT generally had a greater plant population than NT. Square production early in the season, also significantly correlated with lint yield, reflected the early CGR and LAI values in the different tillage systems.

The early, pre-bloom growth and development differences should have perpetuated a greater development of yield components. Although this was true to some extent, other factors (possibly insect damage at sub-economic thresholds, short-term moisture deficits, or other weather related factors) modulated the response. Regardless of these circumstances, NT generally had greater total boll weights, primarily due to greater weight per boll both years. Conversely, RT generally had lower values for these components compared with NT. Yield components were not influenced by plant population, which suggested that it was not a major influence on the positive or negative responses to these conservation tillage systems. Plant populations in this study were generally within the acceptable range and were not considered a limiting factor, especially for CT and RT systems. The NTsystem, however, did tend to have the best overall results when plant population was equivalent to other tillage systems (Hutchinson et al., these proceedings). These data suggest that the NTsystem could be a consistently superior conservation tillage system on this soil if plant populations were near the mid to upper part of the acceptable range. Plant populations that are slightly lower, however, but near the lower end of the acceptable range (26,000 plants/A), are adequate in NT, presumably due to better partitioning of dry matter into bolls in this system. The reason RT did not perform well on this soil was not fully understood, hut generally slower pre-bloom growth suggested that the problem began early in development and was maintained throughout the season.

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IMPROVED DRILL TECHNOLOGY FOR NO-TILL/INTERSEEDING APPLICATIONS

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INTRODUCTION

Conservation compliance has stimulated interest by southern producers in new drilling and planting systems for double-cropping soybeans and cotton with winter wheat. Researchers are investigating new methods for double-cropping peanuts (Khalilian, 1992) with wheat and soybeans following canola (Porter, 1992).

Interseeding or relay intercropping soybeans into standing wheat has been investigated extensively in Illinois by Wendte (1975), in Mississippi by Buehring et al. (1990), and in South Carolina by Khalilian et al. (1991). In general, soybean yields have been increased over conventional double-cropping methods and, in some cases, without reduction in wheat yields. Successful interseeding of cotton into standing wheat has also been reported (Garner, et al., 1992).

At Clemson University, three systems have been developed that allow interseeding of soybeans, cotton, and peanuts into standing wheat using a controlled-traffic production pattern (See Figures 1, 2, and 3). Scheme #1 uses a 76-inch tractor wheel spacing with 11 rows of wheat that permits interseeding of 8 rows of soybeans or 4 rows of cotton or peanuts. Schemes #2 and #3 use a 96-inch tractor wheel spacing. With Scheme #3, eight rows of soybeans are interseeded into 11 rows of wheat, while in Scheme #2, five rows of soybeans or cotton are interseeded into 14 rows of wheat. For the cotton application, this configuration fits the new narrow-row cotton pickers that accommodate 5-row harvesting. A summary of the crop performance and production guidelines for these interseeding systems is being presented in two additional papers presented at this conference.

Additional machinery development studies have been undertaken at Clemson University beginning in 1991 to design, assemble, and test a versatile no-till drill that would satisfy both the requirements of conventional no-till and interseeding applications. Other objectives included 1) the seed metering unit should desirably accommodate small grains, soybeans, cotton, and small seeds like canola; 2) the seed delivery/furrow openers should be toolbar-mounted to allow adjustable row spacings; 3) the drill should function both for no-till and conventional-till applications; 4) the components selected should maximize the use of commercially available parts; and 5) the drill should be readily convertible between a three-point hitch and tow version.

The purpose of this paper is to describe the Clemson no-till/interseeding drill and the field performance of the system, both in research plot studies and on-farm evaluations.

NO-DRILL COMPONENT SELECTION

An excellent coverage of most commercially available drills with their respective components is presented in Conservation Tillage Management (1992). This publication describes the various no-till coulters, seed furrow openers, and press-wheel configurations being utilized. Air seeders are also discussed in their traditional application for dry land small grain seeding in conjunction with soil-opening devices, such as disks, hoes, spikes, and seeps. Growers, mainly in the Midwest, are developing their own air systems for drilling soybeans using sweep, chisel, or double-disk furrow openers (Soybean Digest, 1993).

Based on an evaluation of available components in 1991, it was determined that an air applicator offered the most versatility for metering and transport of seed to adjustable seed furrow openers mounted at any selected distance along a toolbar. Another advantage of the air applicator is that it could be used for granular fertilizer and herbicide handing applications. A Model No. 6216C Gandy Orbit-Air application system equipped with an 18-bushel hopper with 16 metering wheels and air venturies was selected for dispensing seed. Different metering wheels that accommodate a wide range of seed sizes and types are color coded. In this study, the wheels selected were: red -wheat, white - soybeans, and yellow - cotton. Individual metering wheels can be inactivated by closing gates. Seed are delivered by air supplied by a hydraulically powered fan

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from individual venturies through hoses to seed furrow openers. Seeding rate is regulated by powering the metering wheels with a ground-wheel drive through an infinitely variable transmission.

Yetter, model no. 2977, no-till seeder coulters were selected for seed furrow openers. These units have a narrow 6.5-inch wide profile that assists with interseeding applications in standing small grain. A harrow 17-inch diameter ripple coulter is used to cut crop residue and slice a soil opening ahead of a seed slot opener that contains an internal seed tube. Seed exit through a hole at the rear of the seed slot opener at 90 degrees to the direction of travel. Soil generally flows behind the opener back into the furrow ahead of a narrow (1-inch wide, 12-inch diameter) press wheel that firms the soil and seed in the furrow. Depth and seed placement are controlled by a plastic gage wheel (two sizes available) that mounts on the side of the coulter. Press wheels have individual depth control and spring tension adjustments.

DESCRIPTION OF CLEMSON NO-TILL/INTERSEEDING DRILL

Figures 4, 5, and 6 illustrate the drill features. A three-point hitch fork assembly with mounted Gandy Orbit-Air unit couples to dual (4-inch square) toolbars to which the Yetter seeder coulters are mounted. This design feature allows the Gandy Orbit-Air unit to be retained on the tractor's three-point hitch to permit shining to another toolbar arrangement for other applications such as herbicide banding in combination with cultivation or incorporation. Several features of the Orbit-Air unit were modified slightly for this drill application. The location of the loading platform was moved to the fan side of the unit and to the rear of the machine. The hopper lid mounting was reversed to provide rear loading of the seed. These changes provided several advantages: 1) the operator could observe the seed metered into the venturi tubes and, thus, detect if a seed opener was plugged and 2) the operator was exposed to less fan noise.

The toolbars are equipped with two adjustable gage wheels that serve to regulate the overall height of the toolbars. As a three-point hitch drill, mechanical screw elements are used for wheel adjustment. For the tow version, hydraulic cylinders with stroke limiting devices are used to raise and lower the drill. One of the gage wheels drives the Gandy Orbit-Air unit through a spring compressed wheel-on-wheel drive. The drive gage wheel has a floating feature that insures continuous rotation and power to the seed hopper should the toolbars be elevated due to coulters engaging hard soil or uneven terrain.

The tongue attachment is shown in Figure 4. This attachment couples to the drill three-point hitch, and in conjunction with wheel lift cylinders, permits conversion to the towing configuration.

In Figure 6, the plastic depth gage wheel that mounts on the disk coulter is shown. An additional attachment was fabricated and added to provide scraping of the press wheel plus allow attachment of conventional drag chains that assist with seed covering for certain field conditions.

DRILL PERFORMANCE

It was determined that drill calibration was easily accomplished and provided very good repeatable accuracy based either on the number of seed/ft for the particular row spacing or lb/A In a stationary mode with the fan running and through rotation of the toolbar wheel (12 times equal 100 ft) that powers the drill, calibration was accomplished by collecting seeds in a 1-gal size plastic bag left unsealed to allow air escape. The stationary calibration correlated well when compared with plot and field size evaluations.

The drill has been evaluated for planting directly into prepared seedbeds, minimum-till, and no-till, for conventional, as well as interseeding, applications on research plots and grower fields. Crop-yield response for the interseeding applications is presented in other papers at this Conference. Coastal Plain, as well as Lower Piedmont, soil conditions in South Carolina were evaluated in the study.

Prepared seedbed Applications

Successful stands of wheat, oats, and canola were established with the drill in prepared seedbeds. One grower in Dillon County, South Carolina, obtained a very good stand on 150 acres of wheat and 40 acres of oats planted with the drill using the interseeding scheme #1 in the fall of 1992. Satisfactory stands of wheat planted in plots and small fields for later interseeding were established in Newberry, Florence, and Barnwell Counties. An acceptable stand of canola was established in Barnwell County in October 1992 in plots where soybeans will be no-till drilled with the unit following canola harvest.

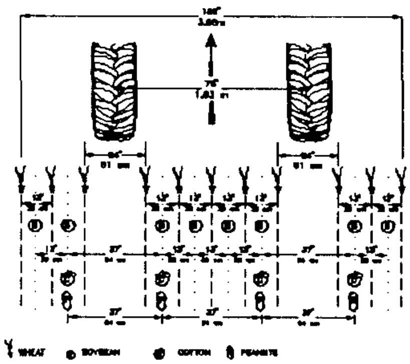


Figure 1. Interseeding scheme with 76" tractor wheel spacing - 8 rows soybeans, 4 rows cotton or peanuts (Scheme#1).

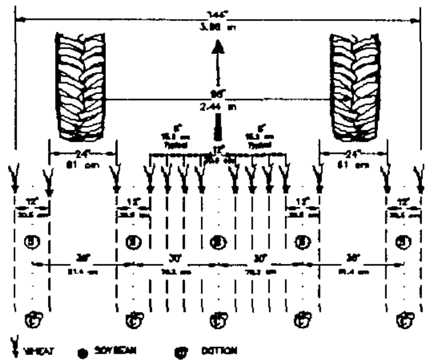
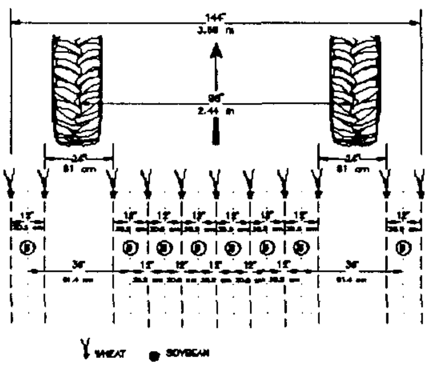


Figure 2. Interseeding scheme with 96" tractor wheel spacing - 5 rows soybeans or cotton (Scheme #2).



Fqure 3. Interseeding scheme with 96" tractor wheel spacing - 8 rows soybeans (Scheme #3).

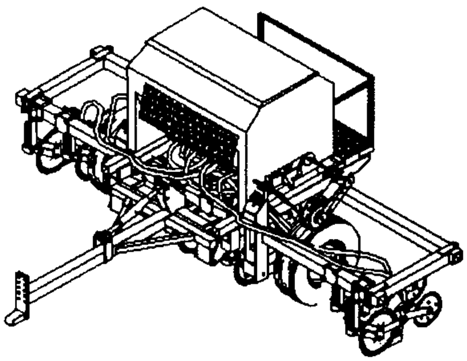


Figure 4. Overallview of Clemson no-till/interseeding drill with tongue attachment.

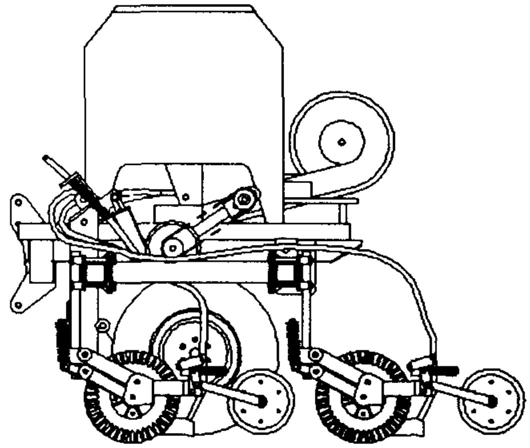


Figure 5. Side view of drill showing attachment of seeder coulters to either toolbar.

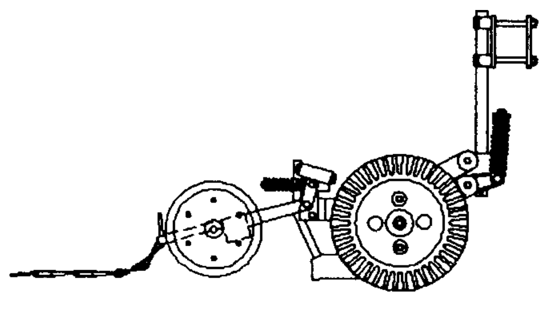


Figure 6. Yetter seeder coulter showing plastic depth gage wheel and drag chain attachment.

Minimum-Till Applications

A grower in Newberry County obtained an excellent stand of soybeans using the drill to seed soybeans following wheat using a single disking behind the combine. By towing the drill behind a deep-tillage tool that provided minimum soil disturbance in corn stubble, satisfactory wheat stands were established in plots in Barnwell County in the fall of 1992.

No-Till Applications

In late May and early June 1992, soybeans and cotton were interseeded into standing wheat in Barnwell County, and soybeans were interseeded in Florence and Newberry counties. Soybean stands were excellent. The cotton stand, both in uniformity along the row and emergence of seedlings, compared favorably with that obtained with a John Deere #71 planter.

In June 1992, the grower cited above in Newberry County used the drill to no-till plant soybeans after burning a wheat field with very good results. In October 1992, 20 acres of no-till wheat were planted directly behind the combine in soybean stubble (soybeans had been sod-planted into fescue sod) at the same farm in Newberry County. In a smaller field of about 1 acre in size, wheat was no-till planted into corn stubble (stalks mowed with rotary mower). In both cases, an excellent stand of wheat was established. On another farm in Newberry County in December 1992, 15 acres of no-till wheat were planted with the dill directly behind the combine in soybean stubble. The grower was very pleased with the wheat stand.

CONCLUSIONS

The Clemson no-till/interseeding drill shows considerable promise for both no-till and interseeding applications. Studies are continuing to evaluate the drill performance under different soil and crop residue conditions. A manufacturing agreement has been signedwith Valkenburg Equipment Corporation located at Greenwood, South Carolina to manufacture and market the drill. The first unit was delivered to a grower in the fall of 1992 to be used primarily for interseeding applications.

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COVER CROPS AND NITROGEN MANAGEMENT FOR NO-TILLAGE CORN

R.N.Gallaher[1]

ABSTRACT

Growth and yield of corn (Zea mays L.) are influenced hy N nutrition and crop management schemes. The objective of this study was to determine the N fertilizer requirements for corn following four different winter crops in four different experiments with conventional and no-tillage management. Five management regimes (conventional tillage after winter crop for forage, conventional tillage using winter crop for green manure, no-tillage using winter crop for a mulch, no-tillage after winter crop for forage, and conventional tillage fallow) were employed as main treatments in a randomized complete block design with five levels of inorganic N (0, 67, 134, 201, and 268 kg N ha^{-1} as split plots. Each experiment was replicated four times on an Arredondo fine sand (sandy, siliceous, thermic Grossarenic Paleudult) near Gainesville, Florida. No-tillage corn from the no-tillage mulch treatment reached the Nsufficiency level of 2.70% or higher with only 67 kg N ha-1 when using crimson clover (Trifolium incarnatum L.) or lupine (Lupinus angustifolius L.) as cover crops. Reduction of fertilizer recommendations by 67 to 134 kg N ha^{-1} may be possible for irrigated corn, depending upon the tillage system and cover crop. Implications for reductions in pollution of water with N fertilizer are obvious if these findings continue to prove accurate.

INTRODUCTION

Nitrogen is the single most important fertilizer input and is required in the largest quantities for crop production (Olson and Sander, 1988). A corn crop has a sufficient level of N if the concentration in the ear leaf at early silking and tasseling is between 2.70% and 4.00% (Jones et al., 1991). Legumes are one source of organic N that can be sacrificed for succeeding crops as a cover crop in double-cropping systems (Gallaher and Eylands, 1985; Huntington et al., 1985; Reeves, 1992). Cover crops, especially rye (Secale cereale L.), not only provide cover to protect the soil against erosion, hut also provide a good mulch to compete against weeds, moderate soil temperature, and conserve water for succeeding crops, such as no-tillage corn (Gallaher, 1977). Cover crops can be killed before or after planting the succeeding crop using no-tillage management (Gallaher, 1980; Gallaher, 1986). The objective of this study was to determine the N fertilizer requirements for corn following four different winter crops in four different experiments with conventional and no-tillage management.

MATERIALS AND METHODS

The studies were conducted at the University of Florida Green Acres Agronomy Farm near Gainesville on an Arredondo fine sand (94% sand, 2% silt, 4% clay). Winter crops that preceded the corn in each of the four experiments were Wrens Aburzzi' rye, hairy vetch (Vicia villosa L. Roth.), 'Tift Blue' lupine and 'Dixie' crimson clover. Five management regimes (conventional tillage after winter crop for forage, conventional tillage using winter crop for green manure, no-tillage using winter crop for a mulch, no-tillage after winter crop for forage, and conventional tillage fallow) were employed as main treatments in a randomized complete block design with five levels of inorganic N (0, 67, 134, 201, and 268 kg N ha^{-1}) as split plots. Each experiment was replicated four times.

Pioneer Brand 3320 temperate corn was planted with an in-row subsoil no-tillage planter in early March 1992 to achieve a final population of 76,500 plants ha^{-1}. Carbofuran, atrazine, metolachlor, and gramoxone plus X77 surfactant were applied at planting at labeled rates for control of insects and weeds. Water was applied by overhead sprinkler. From tasseling through rapid grain fill, 3 cm of water was applied every 4 days, depending upon rainfall. Additional fertilizer was broadcast at planting according to soil test recommendations.

Sampling for ear leaf N and yield was taken from the center two rows of the four-row plots. Ear leaf samples were collected at early tasseling and silking. Leaf samples were dried at 70 C in a forced air oven, ground to pass a 2-mm stainless steel screen in a Wiley mill, and stored in air-tight plastic bags. Micro-Kjeldahl techniques were used to determine leaf N levels (Gallaher et al., 1975; Gallaher et al., 1976). Grain yields were determined at black layer.

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Data was subjected to routine analysis of variance (ANOVA) for a split-plot experimental design. Duncan's new multiple range and LSD tests were used to separate tillage and N treatment means, respectively. Main treatment, sub-treatment, or interaction means were separated appropriately when significance occurred at the 0.05 level of probability.

RESULTS AND DISCUSSION

The Florida Extension Service recommends 268 kg N ha^{-1} for irrigated corn seeded for 74,000 plants ha^{-1}, which were the conditions for these experiments. It was observed that for most tillage systems, corn after rye reached the 2.70% N or higher sufficiency level (Jones et al., 1991) with only 201 kg N ha^{-1} (Table 1). Heavy infestation of root-knot nematodes (Meloidogyne incognita, [Kofoid and White] Chitwood) reduced the growth of vetch and is likely the reason for corn response to inorganic N fertilizer to be no better than that after the rye cover crop. The no-tillage mulch treatment resulted in the 2.70% N or higher level with only 67 kg N ha^{-1} in the corn after crimson clover and corn after lupine experiments. The benefits of cover crops in obtaining the lowest level of the N sufficiency range (2.70%) ranked in order of greatest to least benefit would be lupine > crimson clover > rye = vetch under the conditions of these experiments.

Grain yield responded to inorganic N in a quadratic manner in all experiments and tended to level off at about 201 kg N ha^{-1} (Table 2). All tillage systems gave similar responses for corn after rye and crimson clover, but fallow treatments had lower corn yields than the four cover crop treatments after vetch and lupine. Irrigation likely eliminated some of the mulching benefits from the cover crops, but also, likely provided an environment for better N use efficiency. These experiments show that the use of cover crops could reduce the N recommendation for irrigated corn by 67 to 134 kg ha^{-1} depending upon the tillage system and cover crop.

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Table 1. Corn ear leaf N (%) affected by cover crop-tillage management and N fertilizer in 1992.

Tillage†	Nitrogen level ($kg\ ha^{-1}$) 0	67	134	201	268	Avg
	percent					
	Corn after Rye					
CT-F	2.38	2.05	2.64	2.86‡	3.16	2.62a
CT-GM	2.19	2.01	2.56	3.01	3.07	2.56a
NT-M	2.47	2.39	2.37	2.91	3.18	2.66a
NT-F	2.25	1.86	2.22	2.42	2.96	2.34a
Fallow	1.77	1.87	2.14	2.14	3.01	2.31a
Avg	2.21y	2.032	2.38x	2.79w	3.07v	
	CV=10.42%	LSD=0.16	Interaction was not significant			
	Corn after Vetch					
CT-F	1.70	2.45	2.56	2.89	3.00	2.52a
CT-GM	1.96	2.11	2.43	*2.10*	2.93	2.43a
NT-M	2.01	2.51	2.57	2.59	3.15	2.57a
NT-F	1.19	2.06	2.37	2.84	3.02	2.44a
Fallow	1.33	1.83	2.31	2.66	2.97	2.22 b
Avg	1.782	2.19y	2.45x	2.74w	3.01v	
	CV=10.12%	LSD=0.15	Interaction was not significant			
	Corn after Crimson Clover					
CT-F	1.86	2.53	2.62	2.95	3.10	2.61 b
CT-GM	2.53	2.62	2.11	2.98	3.23	2.83a
NT-M	1.87	2.82	2.74	2.91	2.99	2.66ab
NT-F	1.64	2.52	2.52	2.73	3.22	2.53 b
Fallow	1.71	2.39	2.75	3.10	3.16	2.62 b
Avg	1.92y	2.57x	2.68x		2.93w	3.14v
	CV=11.88%	LSD=0.20	Interaction was not significant			
	corn after Lupine					
CT-F	2.40x a	2.72w ab	2.80vw a	3.04w a	3.06v a	2.80
CT-GM	2.21x a	2.64w ab	2.83vw a	3.11v a	3.10v a	2.78
NT-M	2.24x a	2.79vw a	2.76w a	3.03vw a	3.07v a	2.78
NT-F	1.85x b	2.44w b	2.69w a	3.12v a	3.21v a	2.66
Fallow	1.64y b	1.97x c	2.64w a	2.96v a	3.10v a	2.46
Avg	2.07	2.51	2.75	3.05	3.11	
	CV=7.89%	LSD=0.30	Interaction was significant			

†CT-F=Conventional tillage using winter crops for forage; CT-GM=Conventional tillage using winter crops for green manure; NT-M=No-tillage using winter crops for mulch; NT-F=No-tillage using winter crops for forage; Fallow=Conventional tillage with no winter crop. Values in columns among tillage treatments not followed by the same letter (a,b,c,d,e) are significantly different at the 0.05 level of probability according to Duncan's multiple range test. Values in rows among N levels not followed by the same letter (v,w,x,y,z) are significantly different at the 0.05 level of probability according to LSD. Nitrogen sufficiency range should be between 2.70% to 4.00% (Jones et al., 1991).

*Bold values show lowest N fertilizer required to obtain at least 2.70% N.

Table 2. Corn grain yield (15.5% moisture) affected by cover crop-tillage management and N fertilizer in 1992.

	Nitrogen level (kg ha^{-1})					
Tillage†	0	67	134	201	268	Avg
	g m^{-2}					
	Corn after Rye					
CT-F	241	597	879	1136	1112	795a
CT-GM	180	649	838	999	1118	757a
NT-M	236	721	834	1146	1170	801a
NT-F	238	595	782	1111	983	742a
Fallow	134	525	751	837	1063	662a
Avg	207y	617x	817w	1046v	1069v	
	cV=15.52% LSD=73 Intaraction was not significant					
	Corn after Vetch					
CT-F	371	679	878	1022	1071	804a
CT-GM	364	637	783	921	1090	759a
NT-M	356	672	824	968	1082	780a
NT-F	335	621	836	948	1013	750a
Fallow	165	564	780	993	1129	726 b
Avg	318z	635y	820x	971w	1077v	
	CV=12.30% LSD=59 Interaction was not significant					
	Corn after Crimson Clover					
CT-F	454	771	1098	1331	1317	994a
CT-GM	511	840	988	1325	1302	993a
NT-M	447	787	1052	1325	1292	981a
NT-F	366	719	978	1263	1225	910a
Fallow	286	731	961	1194	1415	917a
Avg	413y	769x	1015w	1287v	1310v	
	CV=15.03% LSD=91 Interaction was not significant					
	Corn after Lupine					
CT-F	938y a	1093xy a	1189wx ab	1357vw ab	1402v a	1196
CT-GM	734y bc	993x a	1164wx b	1323vw ab	1439v a	1131
NT-M	819x ab	1038w a	1363v a	1475v a	1451v a	1229
NT-F	620x c	997w a	1250v ab	1375v ab	1411v a	1131
Fallow	440z d	661y b	986x c	1218w b	1412v a	943
Avg	710	956	1190	1350	1423	
	CV=10.75% LSD=171 Interaction was significant					

†CT-F=Conventional tillage using winter crops for forage; CT-GM=Conventional tillage using winter crops for green manure; NT-M=No-tillage using winter crops for mulch; NT-F=No-tillage using winter crops for forage; Fallow=Conventional tillage with no winter crop. Values in columns among tillage treatments not followed by the same letter (a,b,c,d,e) are significantly different at the *0.05* level of probability according to Duncan's multiple range test. Values in rows among N levels not followed by the same letter (v,w,x,Y,z) are significantly different at the 0.05 level of probability according to LSD.

EFFECTS OF TILLAGE SYSTEMS AND WINTER COVER CROPS ON YIELD AND MATURITY OF COTTON ON A LOESS SOIL IN NORTHEAST LOUISIANA

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INTRODUCTION

Cotton is the major cash crop grown on the loess soils of the Macon Ridge in northeast Louisiana. Soils of this region are typically low in organic matter and have poor physical structure due to many years of continuous row crop production. The topography of the Macor Ridge is gently undulating with maximum slopes of 3 to 5% (Martin et al., 1981). In addition, these silt loam soils are classified as highly erodible, having erodibility (K) values of 0.41 or greater, and a soil loss tolerance of 3 t/A/year. Using the universal soil loss equation (USLE), Soil Conservation Service technicians estimated that soil losses with conventional tillage on Gigger silt loam soils with slopes of 0.5 or 2.0% exceeded 7 and 16 t/A/year, respectively (Hutchinson et a1., 1991). No-till planting into killed native vegetation reduced estimated erosion on both sites by 63% compared with conventional tillage, while no-till planting into wheat cover crop residue reduced erosion by over 85%.

The major soil series of the Macon Ridge have subsoils with dense fragipans, low pH, and high concentrations of exchangeable aluminum and manganese. As a result, most crop roots are limited to the top 12 to 18 inches of soil. Drought stress limits crop yields most years due to low water holding capacities of the soils and shallow plant root development. The fertility and water holding capacity of the plow layer are usually much higher than the subsoil. Therefore, erosion of topsoil is especially damaging to long-term soil productivity. In addition, movement of soil particles with adsorbed pesticides and nutrients into surface waters poses a threat to surface water quality.

Conservation tillage includes any tillage or planting system that maintains at least 30% of the soil surface covered with plant residue after planting. These systems, which include no-till (NT), ridge-till (RT), mulch-till (MT) and various modifications, offer an effective means of reducing soil erosion by maintaining large amounts of plant residue on the soil surface. Several studies across the cotton belt have shown that cotton yields in conservation tillage systems are usually equal to or higher than conventional tillage (Bradley, 1992; Brown et al., 1985; Harman et al., 1989; Hutchinson et al., 1991; Keeling et al., 1989; Stevens et al., 1992). Furthermore, several researchers have shown that winter cover crops improved cotton performance in conservation tillage systems (Brown et al., 1985; Keeling et al., 1989), while others showed little or no benefit (Stevens et al., 1992). A combination of factors, including soil type, rainfall distribution, cover crop species, cover crop management, and cotton production practices, are probably responsible for the inconsistent cotton yield response to winter cover crops. Although winter cover crops have several beneficial effects on soils, moisture conservation resulting from increased surface residue is probably the most important (Unger, 1978; Unger and Wiese, 1979; Van Doren and Triplett, 1973).

Proper management of winter weeds and winter cover crops is essential to the success of conservation tillage systems with cotton. Poor cotton stands following winter cover crops, especially legumes like hairy vetch and crimson clover, are often a result of cutworm damage (Gaylor et al., 1984; Hutchinson et al., 1991; Leonard et al., 1992), increased incidence of seedling diseases (Rickerl et al., 1986), or dry soil conditions at planting depth (Hutchinson et al., 1991). In addition, organic allelochemicals released from legume cover crop residues may result in poor germination and cotton growth (Bradow, 1991; Bradow and Connick, 1988). Most of these problems are minimized or eliminated if cover crops and other winter vegetation are killed at least 3 weeks prior to planting. However, in most studies where stands and/or yields were adversely affected by winter cover crops, the cover crops were killed with herbicides less than 2 weeks prior to planting.

A long-term study was initiated at the LSU Agricultural Center, Macon Ridge Research Station in

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the fall of 1986 to evaluate the agronomic and economic feasibility of alternative tillage systems and winter cover crops for cotton on a highly erodible loess soil. Other goals of this study were to identify soil, environmental, and biotic factors that influence cotton response to alternative tillage systems and winter cover crops.

MATERIALS AND METHODS

A field study was conducted from 1986 through 1992 to evaluate the effects of alternative tillage systems and winter cover crops on cotton stands, maturity, and yield on a Gigger silt loam (fine-silty, mixed, thermic Typic Fragiudalf) with a 2% slope. The experimental design was a randomized complete block with a factorial arrangement of three tillage regimes and four winter cover crop treatments and four replications. Plots were eight rows (40-inch spacing) wide and 50 ft in length. Tillage regimes were conventional-till (CT), ridge-till (RT), and no-till (NT). Cover crop treatments were native vegetation, Dixie crimson clover, hairy vetch, and Florida 302 winter wheat. Treatments were maintained in the same plots each year of the study.

Cover crop seeds were broadcast into standing cotton stalks in mid-October after harvest each year. The stalks were then cut with a rotary mower. Seeding rates for the crimson clover, hairy vetch, and winter wheat cover crops were 15, 25, and 90 lb/A, respectively.

The CT plots were disked twice in early-April and again in mid-April each year. After the final disking, the CT plots were bedded with disk hippers. A reel-and-harrow bed conditioner was used for seedbed preparation immediately ahead of the planter.

The RT plots received two preplant herbicide applications each spring to kill winter annual Vegetation and/or winter cover crops. The first application was applied in early-April and the second 7 to 10 days later. In most instances, two applications of paraquat (0.5 lb ai/A) were used on the crimson clover and hairy vetch cover crops. Glyphosate (1.0 lb ai/A) followed with paraquat (05 lb ai/A) 7 to 10 days later provided excellent control of wheat cover crops and most winter annual vegetation. At planting, a modified Buffalo RT row cleaner was used to clear the vegetation from an 18- to 20-inch wide band and remove about 1 inch of soil from the center of the bed. This "row cleaning" procedure provided a smooth residue-free surface that was suitable for planting with a conventional planter.

No-till treatments received the same preplant herbicide applications described for the RT treatments. In addition, the wheat cover crop was mowed to a stubble height of 10 inches prior to planting cotton. The NT treatments were planted directly into the previous season's beds with no seedbed preparation.

All treatments were planted with a John Deere 7100 or 7300 planter. Ripple coulters were mounted on the planter for no-till planting. Stoneville 825 cotton was planted each year from 1987 through 1990. Stoneville 453 was planted in 1991 and 1992. All plots were planted in early-May at a seeding rate of 6 seed/ft row (78,400 seed/A). Aldicarh (0.5 lb ai/A), terraclor (1.0 lb ai/A), and terrazole (0.25 lb ai/A) were applied in the seed furrow at planting.

Preemergence weed control consisted of fluometuron (0.6 lb ai/A) and metolachlor (0.75 lb ai/A) applied on a 20-inch band behind the planter. Nonionic surfactant (0.5% by volume) was added to the herbicide mixture to enhance contact activity on small emerged weeds. Postemergence weed control in all treatments consisted of mechanical cultivation (usually three trips) with a conservation tillage cultivator and postemergence directed applications of fluometuron + MSMA (0.6 + 1.0 lb ai/A), and prometryn + MSMA (0.28 + 1.0 lb ai/A) applied on a 20-inch baud. The last cultivation was used to rebuild and shape the RT beds for the following growing season.

All treatments received 70 lb/A of nitrogen as 32% UAN solution applied in a dribble surface band 10 inches from the cotton row. In addition, treatments following either a wheat cover crop or native vegetation received an additional 30 lb/A of nitrogen as foliar urea or soil-applied nitrogen solution.

All plots were defoliated in mid- to late-September each year when the latest maturing treatments reached approximately 60% open bolls. The center four rows of each plot were harvested twice with a spindle picker. The first harvest was usually performed when 80 to 90% of the harvestable bolls were opened, the second about 2 weeks later. Relative differences in maturity between treatments were determined by calculating the percentage of total yield harvested at the first picking.

RESULTS AND DISCUSSION

Cotton stand density was influenced hy tillage systems each year except 1987 and 1991 (Table 1). Stands were adequate for optimum yields in all treatments each year except for several of the NT

Table 1. Effects of tillage systems and cover crops on plant population of cotton on a Gigger silt loam soil; Macon Ridge Research Station, Winnsboro, LA, 1987-1992.

Tillage System	Cover Crop	Plant Population 1987	1988	1989	1990	1991	1992	1987-92 Mean
		plants/A x 1000						
Conventional	Native vegetation	26.0	56.2	42.6	45.6	32.6	32.0	39.2
	Crimson Clover	23.7	49.2	32.7	50.5	33.3	32.1	36.9
	Hairy Vetch	25.0	54.1	42.9	50.1	29.5	36.1	39.6
	Wheat	30.2	47.9	36.1	47.0	29.1	33.4	37.3
Ridge-Till	Native vegetation	25.2	22.1	61.5	45.4	27.8	33.5	35.9
	Crimson Clover	22.5	40.0	57.0	44.4	34.5	37.0	39.2
	Hairy Vetch	21.2	26.0	62.9	43.6	30.2	32.5	36.1
	Wheat	32.8	42.3	59.4	45.2	36.9	33.9	41.8
No-Till	Native vegetation	25.2	17.9	53.4	39.9	28.9	22.0	31.2
	Crimson Clover	26.6	9.3	62.6	34.5	27.2	23.6	30.6
	Hairy Vetch	20.6	9.5	60.3	36.9	28.0	25.4	30.1
	Wheat	31.2	31.4	55.0	44.9	34.6	20.7	36.3
Tillage means across cover crops								
Conventional		26.2	51.8	38.6	48.3	31.1	33.3	38.2
Ridge-Till		25.4	32.6	60.2	44.7	32.3	34.2	38.2
No-Till		25.9	17.0	57.8	39.0	29.7	22.9	32.1
Cover crop means across tillage systems								
	Native vegetation	25.4	32.1	52.5	43.6	29.8	29.2	35.4
	Crimson Clover	24.3	32.8	50.7	43.1	31.7	30.9	35.6
	Hairy Vetch	22.3	29.8	55.4	43.6	29.2	31.3	35.3
	Wheat	31.4	40.5	50.2	45.7	33.6	29.3	38.5
LSD (0.05) Tillage System x Cover Crops		NS	13.7	NS	NS	NS	NS	4.2
LSD (0.05) Tillage Systems		NS	6.9	8.5	3.3	NS	3.2	2.1
LSD (0.05) Cover Crops		5.4	7.9	NS	NS	NS	NS	2.4
C.V%		25.0	28.1	22.8	11.0	14.2	14.8	20.6

NS = Nonsignificant at the 0.05 probability level.

treatments in 1988. Poor stands with NT cotton following native vegetation, crimson clover, and hairy vetch in 1988 were a result of cutworm damage during the first few days after crop emergence. In addition, erosion of the NT beds during the previous winter resulted in narrow beds that were poorly suited for NT planting. Averaged over years, stands of NT cotton following native vegetation, crimson clover or hairy vetch were significantly lower than most other treatments. However, this was largely a result of poor stands with these NT treatments in 1988. In most instances from 1987 through 1992, stands of CT and RT treatments were similar to the NT treatments.

Cotton stands following native vegetation, crimson clover, and hairy vetch were usually similar. However, in 1987, 1988, and in the 1987-92 average, wheat cover crops resulted in higher cotton stand densities than other cover crop treatments. Although the tillage x cover crop interaction was statistically significant only in 1988 and in the 1987-92 average, the wheat cover crops consistently increased stands of NT and RT but had no effect on CT stands. In addition, the wheat cover crops tended to reduce the year-to-year variation in stands with the RT and NT treatments. Although the exact reasons for stand improvements with the wheat cover crop were not determined, it is likely related to beneficial mulch effects that conserved soil moisture, eliminated surface crusting, and protected the seedlings from wind and "sandblasting" injury.

Yields were significantly influenced by tillage systems each year except in 1990 (Table 2). Averaged across cover crops, yields of NT cotton were significantly higher than CT in 1989 and 1991. Conversely, CT yields were significantly higher than NT in 1988. Averaged across years, yields of NT and CT were similar. The RT treatments, with the exception of RT cotton following a wheat cover crop, generally produced lower yields than NT and CT treatments.

Although winter cover crops significantly affected cotton yield only in 1987, 1989, and 1992, yields following wheat or hairy vetch consistently averaged higher than cotton following native vegetation or crimson clover. Furthermore, cotton yield responses to cover crops, especially wheat, were larger with NT and RT compared with CT. This relationship is confirmed by the significant tillage X cover crop interactions in 1988, 1989, and in the 1987-92 average. Performance of NT and RT cotton following a wheat or vetch cover crop were usually equal to or slightly higher than CT yields, while other NT and RT treatments tended to produce lower yields than CT treatments. Although growth of crimson clover was excellent in this study, cotton yields following this cover crop were usually reduced compared with native vegetation, hairy vetch, and wheat. The poor early growth of cotton following crimson clover (data not shown) suggests that toxic allelochemicals present in the clover residue may have been responsible for the poor performance of cotton following this cover crop.

Maturity (% first harvest) of cotton was influenced significantly hy tillage each year of the study (Table 3). In 1987, 1990, and the 1987-92, average maturity of NT and CT cotton were similar. No-till cotton was significantly earlier than CT in 1989, 1991, and 1992. Conventional-till cotton was earlier than NT only in 1988. It is likely that the large delay in maturity of NT cotton in 1988 was a result of the poor stands in most NT treatments. Poor cotton stands often result in delayed maturity because a higher percentage of the crop is produced on vegetative branches that develop in response to low stand densities. In most instances, the differences in maturity between CT and NT were small; probably less than 3 to 4 days.

During the first 3 years of the study, RT cotton was usually later in maturity than NT or CT. This was due largely to the late maturity of RT cotton following crimson clover cover. Conversely, RT cotton following a wheat cover crop was usually earlier than other RT treatments. In 1990, 1991, and 1992, maturity of RT treatments were usually similar to NT and CT. These data suggest that under some conditions a wheat cover crop may enhance earliness of RT cotton, while crimson clover may delay maturity.

CONCLUSIONS

Research conducted on a Gigger silt loam soil from 1987 through 1992 indicates that yields and maturity of NT and RT cotton following winter wheat or hairy vetch cover crops were similar to CT. Winter wheat and hairy vetch were superior to native vegetation and crimson clover as cover crops with RT and NT cotton. Wheat cover crops generally improved stands of NT and RT cotton.

Adoption of alternative production systems that include conservation tillage and winter cover crops on highly erodible fields of the Macon Ridge offers a means of drastically reducing soil erosion without sacrificing yield. Reducing soil erosion on many fields is essential for preserving the productivity of these soils for future crop production and for reducing contamination of surface waters with sediments,

Table 2. Effects of tillage systems and cover crops on yield of cotton on a Gigger silt loam soil; Macon Ridge Research Station, Winnsboro. LA, 1987-1992.

Tillage System	Cover Crop	1987	1988	1989	1990	1991	1992	1987-92 Mean
		Lint Yield						
		lb/A						
Conventional	Native vegetation	641	827	494	681	958	701	717
	Crimson Clover	643	881	508	641	948	630	708
	Hairy Vetch	698	891	426	652	1051	710	738
	Wheat	634	780	578	695	1002	734	737
Ridge-Till	Native vegetation	564	566	396	618	964	607	619
	Crimson Clover	581	613	426	621	865	442	591
	Hairy Vetch	684	751	455	665	1010	638	700
	Wheat	667	801	674	643	977	664	738
No-Till	Native vegetation	587	605	517	637	1022	678	674
	Crimson Clover	657	424	546	650	1033	654	661
	Hairy Vetch	719	544	569	690	1151	752	737
	Wheat	733	650	701	716	1079	645	754
Tillage means across cover crops								
Conventional		654	844	501	667	990	694	725
Ridge-Till		624	683	488	637	954	588	662
No-Till		674	556	583	673	1071	682	706
cover crop means across tillage systems								
	Native vegetation	597	666	469	645	981	662	670
	Crimson Clover	628	639	493	637	948	575	654
	Hairy Vetch	700	729	483	669	1071	700	725
	Wheat	678	744	651	684	1019	681	743
LSD (0.05) Tillage System x Cover Crops		NS	161	77	NS	NS	NS	41
LSD (0.05) Tillage Systems		39	80	38	NS	81	61	20
LSD (0.05) Cover Crops		46	NS	44	NS	NS	70	24
C.V%		8	16	10	8	11	13	10

NS = Nonsignificant at the 0.05 probability level.

Table 3. Effects of tillage systems and cover crops on earliness of cotton on a Gigger silt loam soil; Macon Ridge Research Station, Winnsboro, LA, 1987-1992.

Tillage System	Cover Crop	First Harvest 1987	1988	1989	1990	1991	1992	1987-92 Mean
		%						
Conventional	Native vegetation	92	90	66	95	80	84	84
	Crimson Clover	92	93	71	95	a7	a7	87
	Hairy Vetch	92	92	67	95	a5	85	86
	Wheat	91	91	81	96	81	a4	a7
Ridge-Till	Native vegetation	76	80	59	94	a5	87	80
	Crimson Clover	70	78	62	94	86	aa	79
	Hairy Vetch	75	a2	68	94	a7	aa	a2
	Wheat	82	a2	80	94	81	86	a4
No-Till	Native vegetation	a4	80	78	93	a5	a7	a4
	Crimson Clover	92	77	79	94	a7	89	86
	Hairy Vetch	93	78	a2	96	90	aa	a7
	Wheat	92	76	a2	94	aa	a7	86
Tillaae means across cover crops								
Conventional		92	91	71	95	a3	a5	86
Ridge-Till		76	81	67	94	a5	a7	81
No-Till		90	78	80	94	aa	aa	86
Cover crop means across tillaae systems								
	Native vegetation	a4	a3	68	94	a3	86	a3
	Crimson Clover	85	a2	71	94	86	88	84
	Hairy Vetch	86	a4	72	95	a7	a7	a5
	Wheat	88	a3	81	95	a3	86	86
LSD (0.05) Tillage System x Cover Crops		NS	NS	8	NS	NS	NS	NS
LSD (0.05) Tillage Systems		5	3	4	0.8	3	1.8	1.4
LSD (0.05) Cover Crops		NS	NS	4	NS	3	NS	1.6
C.V%		8.1	4.5	7.4	1.2	4.8	2.8	5.9

NS = Nonsignificant at the 0.05 probability level.

fertilizer nutrients, and pesticides. It should be noted, however, that these systems are more management intensive than the production systems currently being used by most cotton producers. Furthermore, cost of production may be higher for some conservation systems compared with CT because of cover crop establishment cost and increased herbicide requirements. Current and future research aimed at developing more effective and economical weed control systems for cotton in conservation tillage systems should greatly enhance the acceptability and profitability of these systems,

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DEVELOPMENT OF TROPICAL MAIZE HYBRIDS FOR USE IN MULTIPLE CROPPING SYSTEMS

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ABSTRACT

The development of tropical maize *(Zea mays* L.) hybrids with insect and disease resistance is needed to improve maize silage and grain production in multiple cropping systems in the southeastern USA. Selection and development of inbred lines in Florida's spring and summer environments should produce materials with superior pest resistance and wide environmental adaptability. Two tropical maize inbred nurseries were initiated in 1988 using Caribbean lowland flint as base germplasm. Selection criteria were yield, earliness, husk tightness, reduced insect damage, stay green, and synchronous pollen shed-silk emergence. Hybrid yield tests of 55 inter-nursery single crosses of S_3 inbred lines were conducted in 1991. Additionally 64 crosses of S_5 inbred lines were tested in spring of 1992. Yield test plots, consisting of two rows 0.76 m apart and 3.04 m long, were arranged in a randomized complete block desgin with four replications. Two hybrid crosses (BM29 x SY60 and BY45 x SY60) produced grain yields of over 9.0 Mg ha" both years. The top 10 grain yielding crosses in 1991 and 1992 yielded comparably with commercial hybrid controls. Additional testing of elite hybrid materials will be conducted in the late spring and summer in 1993 in order to ascertain their potential for use in the multiple cropping systems of the southeastern USA.

INTRODUCTION

The long growing season in Florida allows farmers numerous multiple cropping system choices, many of which include maize as a spring- or summer-planted crop. Maize silage production has been reported to be economically advantageous compared with grain production, especially when planted in late spring or early summer (Gallaher et al., 1991). Due to the long growing season and mild winters, damage to maize can be severe by pests and diseases, i.e. fall armyworm *(Spodoptem frugiperda)* and foliar fungal pathogens *(Helminthosporium* ssp. and *Puccinia polysora).*

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Research has shown that, in general, tropical maize germplasm is photoperiod sensitive, is prone to lodging, and has poor combining ability (Goodman, 1985). It has been reported to have resistance to many foliar diseases and ear-feeding insects (Brewbaker et al., 1989). The degree of resistance to ear-feeding insects by maize has been shown to be correlated with husk number (Brewbaker and Kim, 1979). Corn ears with tight husk cover and extended husk are known to better resist damage from weevils *(Sitophilus* spp.), but selection for tight husk cover increases grain moisture at harvest. In maize silage production, whole plant dry matter and grain concentration and, generally, not grain moisture are of concern.

Temperate USA maize hybrids yield well in Florida when planted in early spring, but perform poorly when planted in late spring or early summer due to susceptibility to pests and poor adaptability to high temperatures (Gonzalez, 1989). The objectives of this research were to develop tropical maize inbred lines with acceptable agronomic characteristics and to test the hybrids created from these inbred lines for performance against adapted commercial hybrids.

MATERIALS AND METHODS

Two inbred nurseries, designated B and S, were established in 1988. Nursery B was composed of materials from five populations (Table 1) that had undergone crossing in all combinations, followed by two cycles of mass selection before selling. Nursery S was composed of materials from four populations (Table 1) derived from a recurrent selection program for yield and insect resistance by Espaillat (1990). Original materials for the recurrent selection populations were a Costa Rican flint used as the female parent and USA temperate and tropical hybrids as male parents. Selfing began for both nurseries in 1988 by selecting plants for yield, earliness, husk tightness, reduced insect damage, stay green, and synchronous pollen shed-silk emergence.

Initial yield testing of inbred lines began using S_2 lines. A replicated yield test of S, hybrid crosses was conducted in spring of 1991 using 55 single, 35 three-way, and 17 double-cross hybrids. Only the single-cross

Table 1. Genetic background of inbred nurseries B and S.

Nursery B		Nursery S	
Material	Origin	Material	Origin
White Flint	Costa Rica	FL Farmer	FL
Temp. Hybrids	USA	Droop Ear	FSRS-FL‡
Trop. Hybrids	USA	Upright Ear	FSRS-FL
Cenia-12	Dominican	Cenia-12	Dominican
Pool†	CIMMYT	Pool	CIMMYT

† Composite of seven CIMMYT open-pollinated cultivars.
‡ Fullsib recurrent selection (Espaillat, 1989).

hybrid results are presented here. Hybrid crosses were planted in two row plots of 3.04 m length; distance between rows was 0.76 m. Plant population was 64,000 plants ha^{-1}, and standard cultural practices were followed. Experimental design was a randomized complete block design with four replications. Data collected from the 1991 yield test included grain and stover yields, ear and plant heights, days to flowering and silking, percent lodging and smutty ears, grain moisture, and weevil damage to ears. Weevil damage was visually rated after manually dehusking ears in the remaining row 1 month after harvest.

Replicated yield testing of 64 single crosses of S_5 inbred lines was conducted in the spring of 1992 using the same cultural practices and experimental design of 1991. Included in the test were seven crosses that performed well in the 1991 yield test. Data collected from the 1992 yield test included grain and stover yields, days to pollen shed and mid-silk, ear and plant height, shuck length past the tip of the ear, and grain moisture.

Analyses of variance were conducted using the general linear models procedure of SAS (1984). The top 10 grain yielding crosses and their characteristics were compared with commercial hybrids using LSD means separation.

RESULTS AND DISCUSSION

In 1991, two of the top 10 yielding crosses, BM29 x SY60 and BY45 x SY60, were also top yielding crosses in 1992 (Tables 2 and 3). Both crosses yielded above 9.0 Mg ha^{-1} both years and produced plants that were tall with good husk cover. The top four yielding crosses in 1992 were all over 2 m in height, indicating the expression of tropical maize genetic effects with no evidence of inbreeding. In both 1991 and 1992, top yielding crosses were competitive with the yields of commercial hybrid checks.

Visual weevil damage ratings taken in the field 1 month after physiological maturity were not different among hybrids in 1991. High levels of smut-infested ears in 1991 were due to high incidence of insect damage and favorable weather conditions. Top yielding crosses in 1991 showed good resistance to smut. Percentage of lodged plants at harvest among hybrids was significant in 1991 and not significant in 1992 (not shown). Husk tip length of the top 10 yielding hybrid crosses in 1992 showed a wide range of tip lengths (0.16 to 2.85 cm).

Inbred lines with potential for crossing with opposite nursery inbred lines and temperate USA inbred testers include: BY45, BY20, BM29, SY60, and SY20. All inbred lines are now at the S_6 stage and kept in cold storage at the University of Florida. Additional testing of elite hybrid materials will be conducted in the late spring and summer in 1993 in order to ascertain their potential for use in the multiple cropping systems of the southeastern USA.

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Table 2. Means for yield, plant height, ear height, and percent smut infested ears of top 10 crosses and check hybrids in 1991.

Pedigree	Grain† Yield	Plant Height	Ear Height	Percent Smut
	Mg ha^{-1}	----------m-----------		----%----
BWl8x **SW08**	10.77	1.95	1.00	1.75
BY27 xSY60	9.57	1.67	**0.82**	1.75
BY07 x SY20	9.19	152	0.72	0.00
BY45 **x SY60‡**	9.16	1.92	1.00	**0.00**
BY01 x SY03	9.14	2.00	1.00	430
BW16 **x** SW50	9.11	1.90	1.00	225
BY16 **x** SYl1	9.03	1.85	0.95	3.75
BW16 x SW35	9.02	1.85	0.90	4.08
BM29 **x** SY60‡	9.02	1.95	0.85	3.00
BY16 x SY20	8.88	1.90	0.90	3.50
NK-508	**8.44**	2.10	1.00	24.75
P-3320	10.06	1.85	0.90	525
Mean	7.95	1.86	0.92	333
LSD (0.05)	0.88	021	0.12	7.11

† Grain yield at 15.5% moisture.
‡ Among top 10 yielding hybrids in both 1990 and 1991.

Table 3. Means for yield, plant height, ear height, and husk cover of top ten crosses and check hybrids in 1992.

Pedigree	Grain† Yield	Plant Height	Ear Height	Husk Cover
	Mg **ha^{-1}**	----------m-----------		--cm--
BM29 **x SY60‡**	1033	2.42	122	1.11
BY45 **x** SY16	10.13	2.45	1.40	2.85
BY20 x SY16	9.86	2.45	1.23	2.19
BY45 **x** SY60	9.47	2.50	130	2.54
BY11 **x** SY60	9.42	2.17	1.11	0.95
BY20 **x** SY30	939	226	1.00	0.16
BY45 **x SY60‡**	925	2.07	0.97	0.64
BY03 **x** SY68	9.15	2.47	1.15	238
BY20 **x** SY68	9.13	2.10	0.96	***0.47***
BM29 **x** SY20	9.12	2.17	1.03	032
P-X304C	8.01	2.10	1.00	127
P-3320	9.41	1.85	0.76	1.84
DK-XL678C	730	2.18	124	1.58
Mean	7.77	2.05	0.99	0.59
LSD **(0.05):**	2.14	0.23	0.17	028

† Grain yield at 15.5% moisture.
‡ Among the top 10 yielding hybrids in both 1990 and 1991.

CONSERVATION TILLAGE vs CONVENTIONAL TILLAGE SYSTEMS FOR COTTON: AN ECONOMIC COMPARISON

Kenneth W. Paxton, David R. Lavergne, and Robert L. Hutchinson[1]

INTRODUCTION

Increasing concern about soil erosion, water quality, and diminishing soil productivity has stimulated interest in alternative cotton production systems designed to minimize these problems. These concerns about soil and water resources have been reflected in recent legislation, including the 1990 farm bill. Current regulations apply primarily to producers on highly erodible land. Producers on soils defined as highly erodible must implement practices that reduce soil erosion rates to acceptable levels if they wish to remain eligible for certain commodity program benefits.

Approximately 40% of the cotton production in Louisiana is located in the Macon Ridge area of the state. The loess soils of this area are silt loam and are classified as highly erodible. Many of these soils have K values of 0.41 or greater. Slopes of these soils typically range from 3 to 5%, but may be 8% or higher (Martin et al., 1981). The USDA-SCS has estimated that sheet and rill erosion rates exceed the 3 tons/A tolerance (T) level on 80% of the cotton acreage in the Macon Ridge area (Hutchinson et al., 1991). Conservation of the topsoil in this area is particularly important because the layer of topsoil is very thin (approximately 4 to 6 inches). There are also naturally occurring dense subsoil layers called fragipans that inhibit root penetration (Hutchinson ef al., 1991).

Given the importance of cotton production to this area of Louisiana and the amount of cotton produced on these types of soils, it is important for producers **to** be aware of possible advantages associated with alternative tillage systems. This economical study examines alternative tillage systems for cotton in this area and evaluates them within a whole-farm context. Results of this study should be helpful to farmers faced with the decision to modify production practices.

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MATERIALS AND METHODS

Data for this analysis were obtained from research on tillage systems conducted at the Macon Ridge Branch of the Northeast Research Station for the period 1987-92. This research was conducted on a Gigger silt loam soil with a slope of about 2%. Three tillage methods (conventional tillage, ridge-till, and no-till) were studied in conjunction with four cover crops (crimson clover, hairy vetch, winter wheat, and native winter vegetation). The study was set up as a factorial arrangement of tillage systems and winter cover crops in a randomized complete block design with four replications. Each plot was maintained in the same location each year to evaluate the long-term effect of a particular tillage system. For a detailed description of the experimental design and results, see the annual reports from the Northeast Research Station (Hutchinson, 1986-92).

Additional data on erosion potential for selected tillage systems were obtained from the field demonstration/research project (Hutchinson et al. 1991). This project also evaluated the three tillage systems noted above, but with a limited number of cover crop treatments, resulting in a total of six combinations of tillage systems and cover crops. These systems were identical to systems contained in the larger on-station research above.

The agronomic data obtained from the experimental plots were combined with economic data to estimate enterprise budgets for each of the tillage systems. For purposes of this study, each combination of tillage system and cover crop was defined as a separate tillage system. The study was conducted in two phases, with the first phase involving an economic analysis to determine the preferred system from among the 12 alternatives. Individual replications were used as a unit of observation for this analysis, and a total of 24 observations for each system were obtained. The second phase of the analysis incorporated estimates of soil erosion developed for selected tillage systems. These estimates were used to evaluate the impact on profitability of the tillage system's ability to control erosion. Enterprise budgets were used to calculate returns above variable costs (gross margins) for each of the systems. These gross margins were then used to estimate returns above variable costs for each system within a whole-farm context. For this analysis, a farm was assumed to be677 acres of cotton, based on results of a recent survey of cotton farms in the area. Whole-farm returns are used because it is theoretically correct and farmers generally adopt such a system for the entire farm rather than a portion of the operation.

Stochastic dominance techniques were then used to evaluate the distributions of gross margins on a whole-farm basis. This technique allowed for the inclusion of more information in the analysis. Traditionally, mean values have been used to evaluate alternative production systems or other farm management decisions. While mean values serve as a good first approximation, analytical techniques that consider additional dimensions provide better answers and are preferred. One essential difference is that stochastic dominance techniques consider not only the mean values, but also the variability in the returns.

RESULTS AND DISCUSSION

No Soil Loss Restriction

The first phase of the analysis evaluated the 12 tillage systems without considering soil erosion associated with each system. A summary of yields and associated data from each of the 12 tillage systems (Table 1) indicated the highest average yields were obtained from the no-till system with a wheat cover crop (NT-W). This system also had less variability (as measured by the standard deviation) in yields than any of the other treatments. The wheat cover crop produced the highest yield for all tillage systems, except the conventional tillage system where there was less than a 1-lb difference between the wheat plot and the hairy vetch plot.

While yield is an important factor in evaluating the performance of a tillage system, it is more important to examine costs and returns. Table 1 also shows the per acre costs for each of the systems. These costs represent typical operations and input levels for each system and not average costs for each system. The conventional tillage system with no cover produces the lowest cost/A. The highest cost/A was for the no-till system and wheat cover crop. This system had only slightly higher costs than the no-till system with a hairy vetch cover crop. Most of the variability in costs among systems is due to differences in herbicide costs. While not shown here, there is approximately $25/A difference between the high and low herbicide costs among tillage systems. Differences in insecticide costs among systems also reflect the need to treat for cutworms on the ridge-till and no-till plots. In addition, part of the difference in costs among systems is due to differences in fuel costs. These differences reflect the varying amount of tillage and/or trips over the field required by each tillage system.

By combining the cost information with the yield information presented in Table 1, it is possible to calculate gross margins. For purposes of this analysis, constant input costs and output prices were assumed. While this assumption is somewhat restrictive, it places the focus on the performance of the tillage system and not on changes in input and/or output price changes. The conventional tillage system with a wheat cover crop yielded the highest gross margin (Table 2). Note that this system also had the highest minimum net return. This is important for producers who cannot afford a system that may produce negative returns. The standard deviation gives an indication of the Variability in net returns among the tillage systems. Note that the system with the highest net returns also has one of the lowest standard deviations. This means that this system produced a high income with low variability from one year to the next.

The distributions of gross margins were evaluated utilizing a software package developed by Cochran and Raskin (Cochran and Raskin, 1988). This program produces efficient sets for quasi first- and second-degree stochastic dominance. Results of this analysis are also presented in Table 2. As shown here, several tillage systems are in the quasi first-degree stochastic dominant set. Only those tillage systems with very low gross margins are eliminated from the efficient set. For the quasi second-degree stochastic dominant efficient set, only the conventional tillage system with a wheat cover crop is selected. This tillage system is preferred to the other systems in the test. Note that this system did not have the highest average yield nor the lowest cost on a per acre basis. However, the whole farm returns (Table 2) indicate that this system had the highest return and relatively low Variability in returns as measured hy the standard deviation.

Table 1. Average yield and standard deviation for selected cotton tillage systems, Northeast Research Station, Macon Ridge Branch, Louisiana, 1987-1992.

Tillage Systems'	Average Yield	Standard Deviation	Variable Costs	Soil Erosion'
	(lb/A)	(lb/A)	($/A)	(t/A)
CT-NC	717.04	185.21	345.45	16.17
CT-CC	708.46	163.92	351.10	N/A
CT-HV	738.25	207.59	362.06	13.88
CT-W	737.42	152.97	35959	N/A
RT-NC	61933	185.97	35835	11.91
RT-CC	591.42	154.53	361.49	N/A
RT-HV	700.71	190.57	380.96	N/A
RT-W	73758	204.25	382.87	N/A
NT-NC	674.25	190.66	366.41	6.04
NT-CC	660.67	205.97	371.14	N/A
NT-HV	737.58	229.23	387.15	3.27
NT-W	753.96	171.15	389.11	2.12

' CT = Conventional Tillage, RT = Ridge-Till, NT = No-Till, NC = No Cover, CC = Crimson Clover Cover, HV = Hairy Vetch Cover, W = wheat Cover.

³ Estimated 3-year average for the period 1988-90. For details on estimating procedure, see Hutchinson el al., 1991.

Table 2. Quasi first- and second-degree stochastic dominance rankings of cotton tillage systems, Northeast Research Station, Macon Ridge Branch, Louisiana, 1987-1992.

Tillage Systems'	First-Degree Dominant	Second-Degree Dominant	Average Returns	Standard Deviation
			($/farm)	($/farm)
CT-NC	•		166,242.90	89,937.65
CT-CC	•		157,750.10	79,264.38
CT-HV	▪		166,34030	99,666.86
CT-W	•	•	167,969.60	73,609.28
RT-NC			103,092.60	90,20020
RT-CC			85,870.35	74,930.14
RT-HV	•		132,949.40	92,150.73
RT-W	•		152,078.40	98,77530
NT-NC			128,561.10	91,723.10
NT-CC			117,961.80	99,489.94
NT-HV	▪		150,133.10	10,504.50
NT-W	•		157,863.90	83,009.95

' CT = Conventional Tillage, RT = Ridge-Till, NT = No-TI, NC = No Cover, CC = Crimson Clover Cover, HV = Hairy Vetch Cover, W=wheat Cover.

Limits on Soil Loss

The second phase of this analysis incorporated restrictions on the amount of soil loss permitted to maintain eligibility for government program participation. The analysis was restricted to six tillage systems and cover crop combinations because estimates for soil losses were available only for those six systems. These data on erosion were used in conjunction with the test plot data to estimate the possible impact of non-compliance on profitability.

It was assumed, for purposes of this analysis, that producers would maintain eligibility for program benefits if erosion could be held to less than 7 t/A/year. Program benefits, as defined here, were restricted to eligibility for deficiency payments. Producers not eligible for this payment would be limited to receiving only the market price for cotton lint. Three of the treatments met the erosion criteria assumed for this analysis (Table 1) (Hutchinson et al. 1991). All of the treatments meeting this standard were no-till treatments.

Results of the stochastic dominance analysis comparing the six tillage systems are shown in Table 3. As shown here, three of the systems were in the first-degree efficient set. This included one system (CT-HV-NG) deemed not eligible for program benefits. Inclusion of this system was somewhat surprising because the average returns were lower and the standard deviation was higher than the conventional tillage system without a cover crop. The primary reason the conventional tillage system was not in the first-degree efficient set was that it had negative returns for some observations. In addition, the stochastic dominance technique used here also considered higher moments of the distribution, such as skewness and kurtosis. Under the rationale of the analytical procedure used here, a low positive return is preferred to a negative return.

Only the no-till system with a wheat cover crop was included in the second-degree eflicient set. This system yielded the highest average net return with a relatively low standard deviation. The average net return for this system was approximately $157,864 compared with $103,173 for the CT-HV-NG system in the first-degree eflicient set. This implies that non-compliance with the assumed level of erosion tolerance cost the producer $54,691 on the average for the whole farm (or approximately $82/A). However, some years the cost would be lower and some years it would be higher.

Table 3. Quasi first- and second-degree stochastic dominance ranking of selected cotton tillage systems, with soil loss constraints, Northeast Research Station, Macon Ridge Branch, Louisiana, 1987-1992.

Tillage Systems[1]	First-Degree	Second-Degree	Average Returns ($/farm)	Standard Deviation ($/farm)	Minimum Return ($/farm)
CT-NC-NG			**105,115.60**	**73,616.69**	**-9830.58**
CT-HV-NG	*		**103,173.30**	**81,543.29**	**-49504.90**
RT-NC-NG			**50,310.94**	**73,963.00**	**-64789.80**
NT-NC-WG			**128,561.10**	**91,723.10**	**2773.87**
NT-HV-WG	*		**150,133.10**	**110,504.50**	**-51055.90**
NT-W-WG	*	*	**157,863.90**	**83,009.95**	**45525.53**

[1] CT = Conventional Tillage, RT = Ridge-Till, NT = No-Till, NC = No Cover, HV = Hairy Vetch Cover, W = Wheat Cover, NG = No Government Payments, WG = With Government Payments.

SUMMARY AND IMPLICATIONS

Twelve tillage systems were evaluated within a whole-farm context utilizing stochastic dominance techniques. The systems included a wide range of tillage operations ranging from no-till to conventional tillage. Each tillage system was evaluated with alternative cover crops, including native winter vegetation. From an agronomic point of view, it is interesting to note that some of the reduced-tillage plots had yields equal to or greater than the conventional tillage plots. Similarly, gross margins on some of the no-till plots were about the same as those on the conventional plots. One important difference was that the no-till plots yielded larger negative returns than conventional tillage plots. This difference in negative gross margins was largely responsible for the no-till systems not being included in the second-degree efficient set.

The conventional tillage plot with a wheat cover crop was the dominant tillage system if limits on soil erosion were not considered. This system produced higher gross margins and lower variability of gross margins than other tillage systems. Costs/A were higher for this system, but the higher returns from increased yields were great enough to offset the higher costs.

Many of the systems did not meet restrictions imposed on the allowable amount of soil erosion. Under these limits, the no-till system with a wheat cover crop was the preferred system. This system produced the highest net returns while keeping soil erosion within the assumed limits.

LIMITATIONS

The results obtained here are applicable to the soil and environmental resources identified above. Since the soils on which the experiments were conducted do not require subsoiling, results obtained here may not be applicable to cotton production on soils requiring deep tillage. Data for this analysis were collected over a 6-year period of time. While this is a substantial time period for most agronomic work, it is not a long time period for observing changes in weather patterns. Results of this analysis might be altered if examined over a longer time period; however, data for longer time periods were not available. While this analysis attempted to incorporate the potential benefits of the soil-conserving abilities of the systems, more work is needed in this area. The soil erosion measures used here were based on estimates of erosion rather than actual measurements. Furthermore, these estimates were not available for all 12 systems. While this analysis incorporated costs to the producer of non-compliance with assumed soil loss tolerances, no attempt was made to estimate costs on a broader scale.

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COTTON YIELD AND GROWTH RESPONSES TO TILLAGE AND COVER CROPS ON SHARKEY CLAY

D.J. Boquet and A.B. Coco[1]

INTRODUCTION

A large portion of the crop land in the humid mid-South is made up of soils with a high clay content. Because of their unique physical characteristics, low organic matter content, and slow internal and surface drainage, these clayey soils require specific management techniques to produce profitable cotton yields. The most important of these is tillage practices.

Tillage of clay soils in the mid-South can have either beneficial or detrimental effects. Tillage can be important for weed control and is necessary to build raised beds that improve surface drainage. Rapid surface drainage is needed for good growth of a winter cover crop. Raised beds also provide a better aerated and warmer seedbed that allows earlier planting and enhances early-season cotton development. If needed tillage procedures are completed in the fall, such practices have no apparent ill effects on cotton production. Tillage in the spring, however, often delays planting because, after the wet winter months, clay soils are slow to dry, and large clods are formed by normal tillage procedures of disking and bedding up. Several inches of rain and additional tillage are needed to restore soil moisture and structure before planting. Thus, the degree of effectiveness in providing beneficial results as opposed to detrimental results is largely reliant upon timing of the tillage procedures so that the need for extensive tillage in the spring is circumvented.

The continuing development of reduced tillage systems that include the use of preemergent and postemergent herbicides in lieu of preplant soil incorporated herbicides has greatly reduced the need for potentially harmful spring tillage (Crawford, 1992; Hutchinson et al., 1991; Reynolds, 1990). These effective and economical herbicides applied before and after planting has made possible new management techniques for clay soils, such as the formation of beds in the fall or late winter, which are then planted with limited or no tillage in the spring (Crawford, 1992; Boquet and Coco, 1991; Reynolds, 1990; Elmore and Heatherly, 1988). These reduced tillage systems have greatly enhanced the opportunities for producing cotton successfully on clay soils in the mid-South. Morrison et al. (1990) developed and evaluated no-till systems, such as raised permanent wide-beds and controlled-traffic patterns, that resulted in crop yields similar to, or better than, those for conventional tillage on the Vertisols of the central Texas Blackland Prairie.

One of the major problems with extensively row cropped clay soils in the mid-South is the low content of organic matter in the soil. Use of year-round cropping systems, such as hairy vetch followed by grain sorghum or wheat-soybean double-cropping, have been used to reverse the organic matter depletion that results from continuous row cropping of clay soil (Boquet and Hutchinson, 1992). There is, however, little information in the literature about the influence of a winter cover crop on the soil organic matter of clay land used for cotton production.

In addition to having positive effects on soil organic matter, winter legume cover crops can accumulate large quantities of N (Boquet and Dabney, 1991; Oyer and Touchton, 1988; Rickerl and Touchton, 1986). On silt loam soils, a legume cover crop can replace one-half to two-thirds of the total inorganic fertilizer N needs of a cotton crop (Hadden, 1953; Breitenbeck, et al., 1989, Touchton and Reeves, 1988). However, the fertilizer N requirement on clay soil is 30 to 40% greater than on silt loam (Maples et al., 1992). Further, there is no information on the potential N loss by denitrification or other mechanisms in clay soil managed with different cover crop species and seedbed preparation systems. It is, thus, unclear what influence legume-fixed N will have on cotton production on clay, and therefore, to what extent the use of fertilizer N can be reduced.

The objectives of this study were to: 1) compare two reduced tillage systems (no-till and ridge-till) with conventional spring tillage procedures for yield and growth of cotton and 2) determine the influence of a winter cover crop on cotton yield, soil organic matter content, and fertilizer N requirements of cotton.

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MATERIALS AND METHODS

These experiments were conducted on Sharkey clay at the Northeast Research Station near St. Joseph, Louisiana. The tillage plots were initially established in the fall of 1987. The tillage treatments were no-till, ridge-till, and conventional-till. The first cover crop of hairy vetch was planted in the fall of 1988. Each tillage plot consisted of 16 rows 120 ft in length. Row spacing was 40 inches. The tillage plots were divided into two 8-row cover crop subplots of: 1) hairy vetch or 2) no cover crop (native vegetation). The experiment was conducted with the two treatments of tillage and cover crop for 3 years, 1988 through 1990, under a uniform N rate of 110 lb/A. In 1991, the experiment was modified and N rate was added as a third variable. Two N rates were applied to subplots of the cover crop treatments - the normal rate for this soil type of 110 lb/A and, in addition, a reduced rate of 80 lb/A. The N was applied about 2 weeks after planting as a surface broadcast application of ammonium nitrate. The experiment was planted in a randomized complete block design with four blocks. Tillage regimes were on main plots, cover crops on sub plots, and N rates on sub-sub plots.

Spring ridge-till procedures were done with a Buffalo Ridge Runner equipped with residue clippers and sweeps. Conventional tillage consisted of two spring diskings, bedding with hipper, and smoothing with a reel and harrow row conditioner. All treatments received two cultivations with a Buffalo model 4630 All-Flex cultivator at about 4 and 6 weeks after planting in conjunction with post-directed herbicides. This equipment was also used in no-till and ridge-till treatments to rebuild beds in the fall of each year prior to stalk shredding. No fall procedures were done on the conventional-till plots except stalk shredding.

All of the no-till plots were treated with burndown applications of 0.47 lb/A Gramoxone [Paraquat dichloride (l,l'-dimethyl-4,4'-bypridinium dichloride)] in early April. Only one application was needed to kill the vegetation in the native cover plots. Hairy vetch plots were retreated 7 to 10 days later for complete kill of vegetation. All plots were planted with a John Deere 7300 planter as soon after April 15 as soil moisture and seedbed conditions were favorable for planting. No-till and ridge-till plots were planted on 21 April 1989, 24 April 1990, 15 May 1991, and 23 April 1992. The conventional-till plots were planted on 7 May 1989, l May 1990, 24 May 1991, and 23 April 1992. Thus, in 1 of 4 years, the conventional-till treatment was planted on the same date as the no-till and ridge-till treatments. In the other 3 years, seedbed preparation delayed planting of the conventional-till treatment. Deltapine 90 was planted from 1989 through 1991, and Deltapine 5415 was planted in 1992.

In addition to the burndown treatments, weeds were controlled with preemerge applications of fluometuron [l,l-dimethyl-3-(a,a,a-trifluoro-*m*-tolyl) urea] and metolachlor [2-chloro-*N*-(2-ethyl-6-methylphenyl)-N-(2-methoxy-l-methyl-ethyl) acetamide] and postemerge applications of fluometuron and MSMA (monosodium acid methanearsonate). Fluazifop-P-butyl {Butyl(R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl] oxy]phenoxy]propanoate} was applied overtop in spot treatments for grass control.

Insects were controlled with an in-furrow application of aldicarb {aldicarb[2-methyl-2-(methy1thio)propionaldehyde *0*-(methylcarbamoyl) oxime]} and season-long applications of several labeled foliar-applied insecticides on an as-needed basis. Seedling diseases were controlled with an in-furrow application of Terraclor Super X {Pentachloronitrobenzene; 5-Ethoxy-3-(trichloromethyl)-1,2,4-thiadiazole; Disulfoton: O,O-Diethyl S-[2-(ethylthio) ethyl] phosphorodithioate}.

Cotton was defoliated on an individual treatment basis when at least 60% of the bolls were open by applying Def 6 (S,S,S-Tributyl phosphorotrithioate) and ethephon (2-Chloroethyl) phosphonic acid. Two rows of each plot were mechanically harvested with a John Deere 9910 cotton picker adapted for small plot harvest to determine seedcotton yield/A.

RESULTS

Yield

In 1989, cotton in all but one of the tillage treatments produced similar yields of about 2500 lb seedcotton/A (Table 1). The conventional-till with native cover was an exception that yielded significantly less seedcotton than all other tillage-cover crop treatments. The hairy vetch cover crop, however, increased the yield of the conventional-till treatment by 600 lb seedcotton/A so that its yield was similar to the no-till and ridge-till treatments. It seems plausible that the 17-day delay in planting of the conventional-till would have had a negative influence on yield. It is not known why the cover crop, which had no effect on the yield of the no-till and ridge-till treatments, increased the yield of the conventional-till treatment by such a substantial amount.

In 1990, differences in yield among tillage treatments were not significant, and within the no-till and ridge-till treatments, cover crop did not significantly increase the yield of cotton. The conventional-till with native cover, which had yielded lowest in 1989, was again the lowest yielding treatment in 1990. Its yield was significantly lower than all treatments except ridge-till with native cover. As in 1989, the vetch cover crop significantly increased the yield of cotton in the conventional-till treatment only.

Nitrogen rate did not have a significant influence on yield in 1991 or 1992, and the tillage-by-N rate and cover crop-by-N rate yield interactions were not significant. This suggests that, to determine the contribution of legume N in reducing the N requirements for cotton, the N rates in this study should be lower than those used in this study in 1991 and 1992. In the following results and discussion, the effects of tillage and cover crop for 1991 and 1992 are reported averaged across N rates.

The average yield of cotton in the ridge-till treatment in 1991was significantly higher than both the no-till and conventional-till. This was the first year in which tillage had an effect on cotton yield. As in previous years, the vetch cover crop did not significantly influence the yield of cotton in no-till and ridge-till treatments. In contrast with previous years' results, the yield of cotton in the conventional-till treatment was not increased by the vetch cover crop.

In 1992, the tillage treatments had a significant effect on cotton yield. In treatments where no cover crop was planted, the yield of cotton in conventional-till was significantly higher than in either no-till or ridge-till. With a vetch cover crop, results were somewhat different, and both ridge-till and conventional-till produced higher yields than no-till. Under each of the three tillage regimes, a winter vetch cover crop significantly increased yields compared with the native winter vegetation.

Plant height

In each year, plant height was affected significantly by tillage and by cover crop. The differences among treatments were smallest in 1990 (only 1 inch) and largest in 1989.

In 1989, the tallest plants were produced in conventional-till even though the planting date was 16 days later than no-till and ridge-till (Table 2). The vetch cover crop had an additional stimulatory effect on growth of cotton in conventional-till. The improved growing conditions imparted by the cover crop were reflected in the large yield increase in the vetch cover crop treatment compared with native cover (Table 1).

In 1991, with native cover only, both no-till and ridge-till produced taller plants than conventional-till. The vetch cover crop increased plant height in the conventional-till treatment but did not affect plant height in the no-till and ridge-till treatments (Table 2). The taller plants in the conventional-till vetch plots did not result in higher yield production for this treatment (Table 1).

In 1992, the vetch cover crop significantly increased plant height in each tillage regime by 3 to 7 inches. The greater plant height of the vetch cover crop treatment was associated with increase in seedcotton yield. Plant height was also significantly affected by tillage, but these effects were only about one-half as large as those induced by the vetch cover crop.

Averaged across years, the effects of tillage on plant height were small (1 to 2 inches) but statistically significant. The average effect of cover crop on plant height was larger with conventional-till than with no-tiil or ridge-till.

DISCUSSION

Results among years were consistent in that tillage regimes had little influence on yields. No one tillage regime among the three consistently produced significantly higher yields than another. When differences did occur among tillage treatments, they may have been related to planting date. The yield reduction in conventional-till in 1989, for example, may have been due to the unavoidable delay in planting of that treatment, and the superior performance of cotton in conventional-till in 1992 was possible only because planting was not delayed by spring tillage in that year.

Both no-till and ridge-till had a significant advantage in earliness of planting cotton because, in three of four years, planting of the conventional-till treatment was delayed by seedbed preparation. Early planting has several advantages. First, the earlier planting date would be expected to result in earlier crop maturity and, thus, reduces the number and cost of insecticide applications at season end when insects are most numerous and difficult to control. Second, the resultant earlier harvest would often produce a

Table 1. Effect of tillage practices and winter cover crop on the yield of cotton grown on Sharkev clav.

Tillage regime	Cover crop†	Seedcotton yield				
		1989	1990	1991	1992	Average
		lb/A				
No-till	Native	**2,525**	**3,280**	**4,050**	**3,800**	**3415**
	Vetch	**2,580**	**3,420**	**3,850**	**4,330**	**3545**
Ridge-till	Native	**2,535**	**3,155**	**4,130**	**3,790**	**3400**
	Vetch	**2,560**	**3,285**	**4,220**	**4,560**	**3660**
Conventional-till	Native	**1,950**	**3,075**	**4,070**	**4,000**	**3275**
	Vetch	**2,565**	**3,460**	**4,050**	**4,680**	**3690**
LSD (0.05) =		**250**	**200**	**208**	**195**	**120**

†Native, native vegetation; Vetch, hairy vetch

Table 2. Effect of tillage practices and winter legume cover crop on plant height of cotton grown on Sharkev clav.

Tillage regime	Cover crop†	Plant height				
		1989	1990	1991	1992	Average
		inches				
No-till	Native	**37**	**55**	**42**	**33**	**43**
	Vetch	**35**	**55**	**42**	**36**	**44**
Ridge-till	Native	**38**	**54**	**43**	**34**	**44**
	Vetch	**36**	**55**	**44**	**37**	**45**
Conventional-till	Native	**41**	**54**	**40**	**32**	**42**
	Vetch	**46**	**55**	**44**	**39**	**46**
LSD (0.05) =		**4**	**1**	**2**	**1**	**1**

†Native, native vegetation; Vetch, hairy vetch.

superior grade of cotton fiber than is obtained from late harvest dates. Third, early destruction of crop residue eliminates food sources for boll weevils entering diapause, thereby reducing the need for insecticides the following spring. Finally, early harvest on Sharkey clay is important to avoid possible damage to the fields due to late harvest on wet ground that would require extensive tillage procedures to correct, further delaying spring tillage operations.

The no-till treatment reduced the tillage costs of seedbed preparation by about $15/A. Herbicide costs, however, increased because of the need to control weeds and to burn down the vetch cover crop, which required two applications of Gramoxone. The ridge-till treatment also reduced tillage costs compared with conventional-till and required less herbicide than no-till because weeds or cover crop residue were mechanically removed from the top of the seedbed rather than needing extensive burndown applications. Thus, the type of minimum tillage represented by ridge-till may be preferable to no-till because of its low cost and reduced need for herbicides.

Replacing the native winter vegetation with a planted cover crop of hairy vetch increased cotton yields an average of 330 lb/A during the 4 years of the experiment. We do not know the reasons for the response to the vetch cover crop as it does not seem to be related to N availability. However, as indicated by the increases in plant height and yield, a vetch cover crop can act synergistically with tillage to improve crop growing conditions. The increase in gross returns from the vetch cover crop would be variable, depending upon prices for cotton. At an average return of $.65/lb of lint, the increase in gross income/A from vetch would be about $75.

Planting vetch increases the cost of production by about $35/A for seeding the vetch and for additional burndown herbicides. The vetch, however, should reduce fertilizer N costs by about $7/A. (Our data on this point is thus far inconclusive since the N rate did not affect yield and the cover crop-by-N rate interaction was not significant.) Thus, a winter vetch cover crop can increase net/A returns by as much as $30 to $40.

CONCLUSIONS

A combination of limited- or no-till either with or without a winter legume cover crop can produce beneficial results for cotton grown on Sharkey clay, including earlier planting and reduced cost of production. This significantly reduces the risks associated with cotton production on Sharkey clay. A winter legume cover crop has several beneficial effects for cotton production. It substantially increases yield, improves crop growth rate, reduces the amount of fertilizer N needed for cotton, and increases soil organic matter.

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INFLUENCE OF CANOLA, WHEAT, AND CLOVER AS COVER CROPS ON SOUTHERN CORN BILLBUG INFESTATIONS IN NO-TILLAGE AND PLOW-TILLAGE CORN

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ABSTRACT

Field tests were conducted for 3 years in the GeoMa Coastal Plains to determine the influence of cover crops and tillage practices on the initiation and intensity of southern corn billbug, *Sphenophorus callosus* (Oliver) (SCB), infestations in seedling corn. Infestations were lowest in areas where canola, *Brassica napus* L, was used as the winter cover crop compared with crimson clover, *Trifolium incarnatum* L., and wheat, *Triticum aestivum* L. Increased feeding damage to young seedlings occurred in all the winter cover areas when no-tillage practices were utilized as compared with plow-tillage.

INTRODUCTION

The SCB is a well-known insect pest of corn in Coastal Plains areas of Georgia, South Carolina, and North Carolina (Wright et al., 1982). Both adult and larval stages feed on corn, *Zea mays* L., but only adults produce damage, which is usually debilitating, hut on occasion may be lethal (Metcalf, 1917; DuRant, 1975). The SCB has one generation a year and, from the standpoint of pest hazard, can be considered a "sedentary"-type pest that tends to increase in severity each year in mono-crop corn systems. The SCB adults feed on various grasses, hut larvae can survive only on corn and yellow nutsedge, *Cyperus esculentus* L.

This study was prompted when it became apparent that certain sustainable agricultural practices, such as no-tillage, may increase hazard for SCB infestations in corn (All et al., 1984). Since SCB feeding habits are restricted to a few grasses and populations tend to be sedentary, it seemed possible that nongrass cover crops, such as canola or crimson clover, might negatively influence the development of infestations in corn as compared with wheat.

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MATERIALS AND METHODS

The tests were conducted from 1990 to 1992 at the University of Georgia Southeastern Branch Experiment Station, which is located in the Coastal Plains. The soil type was Marlborough sandy loam. A randomized complete block split-split plot experimental design was used in most years with winter cover areas as main plots, either no-tillage or plow-tillage as subplots, and poultry manure and/or soil insecticides as sub-subplots. This report will encompass only results from cover crop and tillage treatments. Winter cover areas, measuring 520 m^2, and tillage blocks were maintained in the same location each year. Planting of corn seed (DK689) was done with a John Deere Flex 71 no-tillage planter.

Three winter cover crops, wheat, crimson clover, and canola, and a fallow area, which had been planted in corn the previous growing season, served as winter cover areas. The cover crops were planted in the fall of 1989-1991 using standard agricultural practices. Prior to maturation of the cover crops, the areas were mowed and the land was prepared for planting of corn.

The winter cover areas were split into blocks of either no-tillage or plow-tillage. No-tillage blocks received no plowing prior to planting; whereas, plow-tillage areas included tillage operations with a moldboard plow and disk harrow until a smooth seedbed was prepared. Paraquat at 0.70 kgai/ha was used as a burndown herbicide, and atrazine at 224 kg ai/ha provided residual weed control.

The SCB feeding damage on corn was determined when plants reached Stage 1 [four leaves fully emerged (Hanway, 1971)] because injury to young seedlings at this stage has maximum impact on yield. Damage was evaluated by making counts of damaged and undamaged plants in 7 m of two adjacent rows in each treatment replicate so that a percent damaged stand parameter could be calculated. Yield was determined by harvesting all ears of the two rows of each plot that were examined previously for damage. Grain moisture was determined, and all grain weights were standardized at 15.5% grain moisture content.

Results of SCB feeding damage and yield were analyzed with a computer-based statistical analysis program for a split-split plot design (SAS Institute, 1985). Treatment means were separated with Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Infestations by SCB, as indicated by feeding damage to Stage 1 corn seedlings, demonstrated that the different cover crops had a differential effect on the insects' population biology. In all years, corn following canola had significantlyfewer (P<0.05) damaged plants as compared with the crop planted in the fallow areas. In general, lowest percent damaged stand of corn occurred in canola plots < crimson clover = wheat < corn fallow. Data for percent damage in 1990, 1991, and 1992 [means for the different cover crops followed by the same letter for a specific year were not significantly different (P<0.05)] were: canola treatments - 5.6a, 7.la, and 1.9ab; crimson clover - 10.0bc, 11.5b, and 1.0b; wheat - 8.2ab, 12.9b, and 3.1bc; and fallow - 14.3c,15.3c, and 5.3c.

Percentage of corn plants in Stage 1 of development exhibiting damage symptoms of SCB feeding was significantly less (P<0.05) in plow-tillage compared with no-tillage systems during all 3 years of tests. Data for percent damage in no-tillage plots in 1990, 1991, and 1992 were 11.9, 13.8, and 42 as compared with plow-tillage, which were 7.1, 9.5, and 1.5.

Grain yield was significantly reduced (P<0.05) in no-tillage compared with plow-tillage in all years except 1990, which was an abnormally dry year, and higher yields in no-tillage may be attributed to increased soil moisture in these areas. Yield (bu/A) for no-tillage plots in 1990,1991, and 1992 was 30.7, 40.7, and 73.4 as compared with plow-tillage, which was 18.7, 70.0, and 1292. No significant interactions between tillage practices and winter cover areas on yield were observed, indicating that the cover crops produced similar effects on SCB populations, irrespective of tillage practices.

In summary, these tests demonstrate that winter cover crops and tillage practices influence the potential of infestation (i.e., hazard) by SCB on corn. In most years, use of winter cover crops significantly reduced SCB damage compared with a fallow area that had been planted in corn the previous season. Canola, used as a winter cover crop, had the greatest negative influence on SCB infestations. The SCB infestations in the no-tillage plots were always higher than in plow-tillage, demonstrating increased SCB hazard in reduced-tillage systems.

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CULTURAL MANAGEMENT OF CUTWORM SPP. IN CONSERVATION TILLAGE SYSTEMS FOR COTTON

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INTRODUCTION

Conservation tillage practices result in a favorable microenvironment for insect populations by increasing host plant density and mediating soil moisture and temperature extremes (Gaylor and Foster, 1987; Stinner, 1990). The primary soil-dwelling cotton insect pests most likely to be affected hy conservation tillage practices include several cutworm spp. The black cutworm, *Agrotis ipsilon* (Hufnagel), granulate cutworm, *Agrotis subterrnea* (F.), and variegated cutworm, *Peridroma saucia* (Hubner), are considered to be occasional insect pests of seedling cotton. These insects indirectly reduce cotton yield by reducing plant stand densities below that which are necessary to produce optimum yields.

As producers implement reduced tillage systems and plant winter cover crops, adult oviposition sites and alternate hosts for cutworm spp. larvae become more available, and the probability of economic infestations of these insects increases. Cutworm spp. larvae are generally already present in conservation tillage production fields at the time cotton is planted. Destruction of the field vegetation that serves as alternate hosts causes these insect pests to move to cotton as an available food source.

Cutworm spp. infestations in cotton can be managed with insecticides, but in many instances, treatments are applied after serious plant stand loss has occurred. In addition, many of the in-furrow insecticides currently recommended to control other early-season insect pests possess little or no efficacy against cutworm spp. A preferred strategy to chemical control of these insect pests in California has been to terminate vegetation in fields at least 3 weeks before planting cotton (Anonymous, 1984). This study was conducted to determine the effects of vegetation management strategies applied at selected preplant intervals on cutworm spp. damage in cotton.

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METHODS AND MATERIAIS

This study was conducted at the Macon Ridge Branch of the Northeast Research Station located near Winnsboro, Louisiana during *1991 and 1992. A winter* cover crop of hairy vetch, *Vicia sativa* L., was seeded on preformed rows in all plots (25 lb seed/A) in the fall of 1990 and 1991 to increase the prospect of economic cutworm spp. infestations during the following production season. Chembred 219 and Chembred 1135 cotton cultivars were planted in 4-row x 30 ft plots on 40-inch centers at approximately 4.6 seed/row ft. in 1991 and 1992, respectively. Planting dates were 6 May 1991 and 2 May 1992. Aldicarb (Temik 15G, 05 lb ai/A) was used as an in-furrow insecticide in all treatments to control cotton seedling insect pests because of its low efficacy against cutworm spp.

The test design was a randomized complete block with a factorial arrangement of treatment combinations in four replications. The treatments in this study included two vegetation management methods (tillage, herbicide) and four application timings (6, 4, 2, and 1 weeks preplant). Conventional tillage practices consisted of disking each plot twice with a disk harrow at each application interval. A final disking and bedding operation was performed 1 to 2 weeks before planting. The herbicide-treated plots received two applications of paraquat (Gramoxone Extra 25E, 0.47 lb ai/A) with the first being applied at the selected interval and the second treatment following 1 to 2 weeks later. The herbicide was applied with a tractor-mounted boom equipped with a compressed air delivery system calibrated to deliver 20 gallons total spray solution/A through flat fan 8004 nozzles (two/row) at 38 psi. Application timings for the vegetation management method were 19 and 13 March (6 weeks preplant), 2 and 2 April (4 weeks preplant), 17 and 15 April (2 weeks preplant), and 25 and 28 April (1 week preplant) in 1991 and 1992, respectively.

Recommended cultural practices, fertilization, and integrated pest management strategies were used to maintain all plots in a similar manner within each test. All plots receiving the tillage treatment were planted with a conventional planter. To facilitate the no-till planting operation through heavy surface vegetation in the herbicide-treated plots, the planter was modified with ripple coulters mounted in front of each seeding unit. All treatments were mechanically cultivated (1-2X) for weed control. No irrigation was used in these tests.

Treatment efficacy against cutworm infestations was evaluated by measuring plant stand density, plant stand reduction by cutworm spp., estimating intra-row skips (>40 inches) between plants, seedcotton yields, and crop maturity. Plant stand density, plant stand reduction, and intra-row skips were determined by sampling the entire two center rows of each plot. Plant stand reduction from cutworm spp. was calculated by sampling each plot once a week for 4 weeks after seedling emergence and using the cumulative total damaged plants. Plant stand density was measured at 4 weeks after seedling emergence, and the number of intra-row skips was recorded post-harvest. Seedcotton yields were determined by harvesting the center two rows of each plot with a mechanical spindle-type cotton picker on 18 September and 2 October during 1991 and 8 and 28 September during 1992. Crop maturity was determined by calculating the percentage of the total yield collected on the first date of harvest.

Results were subjected to analysis of variance (ANOVA) to determine significant treatment effects. Treatment means were separated with least significant differences (LSD, P = 0.05). These procedures were done using Statistical Analysis Systems (SAS) software modified for personal computers (SAS Institute, 1988).

RESULTS

Samples of larvae collected from the test areas consisted primarily of black cutworms, although granulate cutworms and variegated cutworms were present in 1991 and 1992. Both methods of vegetation management, tillage and herbicide, adequately controlled the hairy vetch cover crop and significantly affected cutworm spp. infestations. Vegetation management and application timing significantly affected cutworm spp. infestations and influenced plant stand densities, seedcotton yields, and crop maturity (Table 1).

Plant Stand Density

Plant stand densities in the plots treated with tillage (3.3 and 2.3 plants/ft) were significantly higher compared with that for the herbicide-treated plots (2.4 and 1.6 plants/ft) in 1991 and 1992, respectively. The plots treated 4 and 6 weeks before planting had higher plant stand densities compared with that for the plots treated 1 week preplant during both years (Table 2). A significant interaction between vegetation management and application timing was observed only in 1991. Although plant stand densities were consistently lower in the herbicide-treated plots compared with that for those plots treated with tillage for all application intervals, plant densities in the plots treated with a herbicide 1 and 2 weeks before planting were affected more than the plots treated with tillage at the same application intervals (Fig. 1).

Table 1. Summary of the analysis of variance results testing effects of vegetation management and application timing on plant stand density, percent stand reduction, intra-row skips, seedcotton yields, and crop maturity.

	1991			1992		
Variable	Veget. Manag. Method	Appl. Timing	Method x Timing	Veget. Manag. Method	Appl. Timing	Method x Timing
Plant stand density	**[1]	**	**	**	**	NS
Stand reduction (%)	**	**	**	**	**	•
Intra-row skips	**	**	**	**	*	NS
Final yields	NS	NS	NS	*	**	•
1st harvest (%)	**	*	NS	*	**	NS

[1]NS, no significant effect; * and ** indicates significance at 0.05 and 0.01 levels, respectively.

Table 2. Effects of vegetation management timing nn cotton plant development and cutworm spp. damaged plants (±SE).

Application Timing[1]	Year 1991	1992
Plant Stand Density (No./ft)		
Six weeks	3.3±0.2a[2]	2.4±0.1a
Four weeks	3.0±0.1ab	2.0±0.1b
Two weeks	2.7±0.2b	1.7±0.2bc
One week	2.4±0.3c	1.6±0.2c
LSD	0.31	0.37
Stand Reduction (Percent)		
Six weeks	0.5±0.3b	1.2±0.4b
Four weeks	1.4±0.5b	2.0±0.5b
Two weeks	6.5±2.8a	4.4±1.4a
One week	10.8±4.6a	5.0±1.6a
LSD	4.82	2.03
Intra-Row Skips (No./Plot)		
Six weeks	0.1±0.1b	0.1±0.1b
Four weeks	0.0±0.0b	0.2±0.1b
Two weeks	0.3±0.2b	1.0±0.4ab
One week	1.4±0.6a	1.2±0.5a
LSD	0.61	0.89
Seedcotton Yield (lb/A)		
Six weeks	3776±212a	1787±74a
Four weeks	3691±240a	1776±67a
Two weeks	3814±216a	1669±124a
One week	3582±300a	1433±106b
LSD	308	185
First Harvest (Percent)		
Six weeks	86.8±2.2a	81.4±0.9a
Four weeks	86.1±2.2ab	79.8±1.8ab
Two weeks	85.8±2.3ab	75.9±1.86b
One week	83.0±2.9b	69.9±2.8c
LSD	3.26	4.52

[1]Preplant timing treatments averaged across vegetation managment methods.
[2]Treatment means for each variable followed by a common letter are significantly different (LSD, P=0.05).

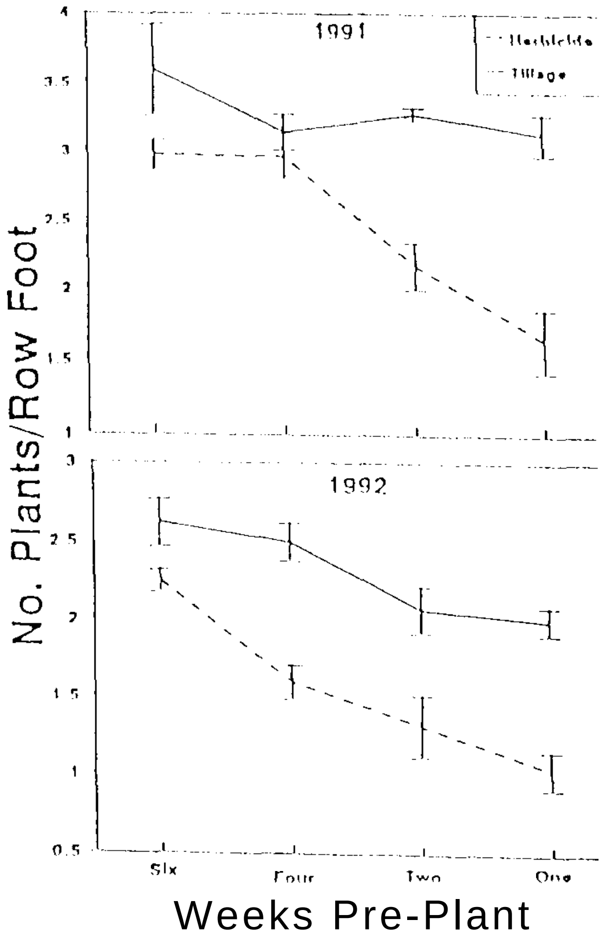

Fig. 1. Effect of vegetation management influenced by application timing on cotton plant stand density (±SE).

Cutworm Spp. Damaged Plants

The plots treated with tillage had lower plant stand reductions compared with that for the herbicide-treated plots, regardless of application timing. Percent stand reduction was significantly lower in the plots treated 4 and 6 weeks before planting compared with that for the plots treated 1 and 2 weeks preplant (Table 2). A significant interaction between factors was also observed for percent stand reduction and intra-skips during 1991 and 1992. Percent stand reductions were higher in the plots treated with the herbicide than in the plots treated with tillage at all application intervals, but plant stand losses increased dramatically in the plots treated with a herbicide 1 and 2 weeks before plant-ing compared with the tillage-treated plots (Fig. 2).

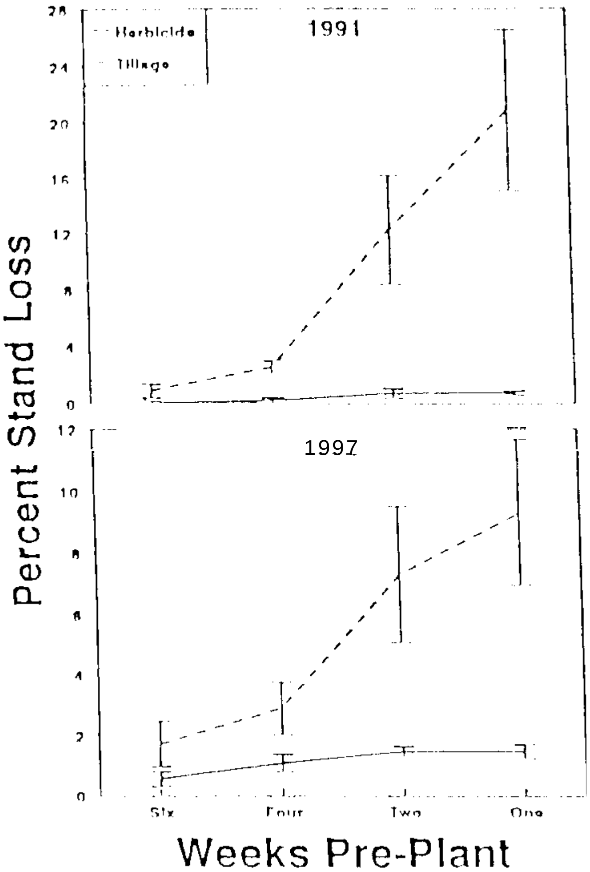

Fig. 2. Effect of vegetation management influenced by application timing on percent cotton stand reduction (±SE).

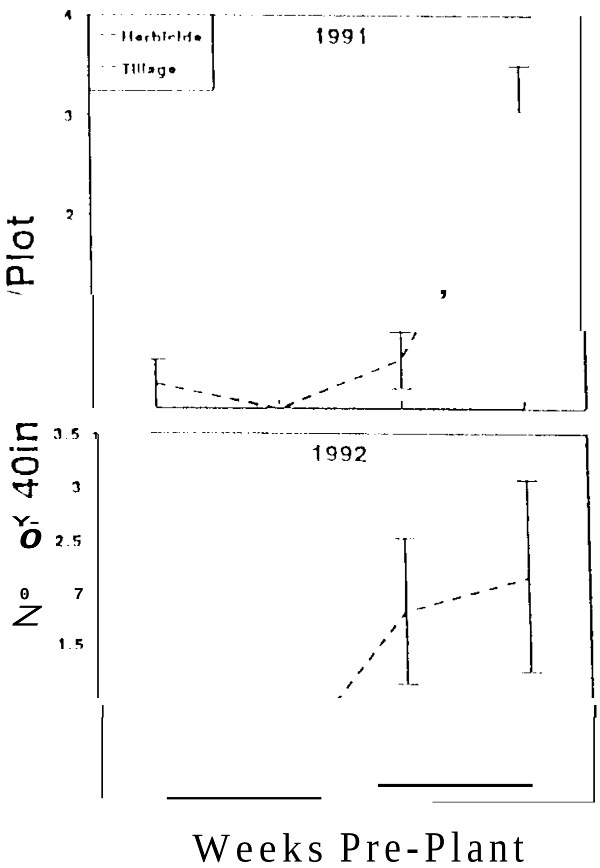

Fig. **3.** Effect of vegetation management influenced by application timing on number of intra-row 40 in. skips between cotton plants (±SE).

The plots treated with tillage also had fewer intra-row skips than that in the herbicide-treated plots, regardless of application timing during 1991 and 1992. Lower numbers of intra-row skips were observed in the plots treated 4 and 6 weeks before planting compared with that for the plots treated 1 week preplant during both years (Table 2). A significant interaction between factors was observed for intra-row skips in 1991. Intra-row skips between plants followed the same trend as that for plant stand reduction and serve to further illustrate the potential of cutworm spp. infestations, particularly in those instances where plant stand densities are only marginal for optimum yields (Fig. 3).

Seedcotton Yields and Crop Maturity

Seedcotton yields were not affected in 1991 by vegetation management or application timing. However, in 1992, seedcotton yields were significantly higher in the tillage-treated plots compared with that for the herbicide-treated plots. In 1992, the plots treated 4 and 6 weeks preplant had higher seedcotton yields compared with that for the plots that were treated only 1 week preplant (Table 2). Results for seedcotton yields are more variable than the other parameters, and a significant interaction between vegetation management and application timing was observed only in 1992. Seedcotton yields decreased In the plots treated with herbicides more consistently than in the tillage-treated plots as the application intervals approached the time of planting (Fig. 4).

During both years, the plots treated with tillage had an earlier maturing crop than that for the herbicide-treated plots. Earlier crop maturity was

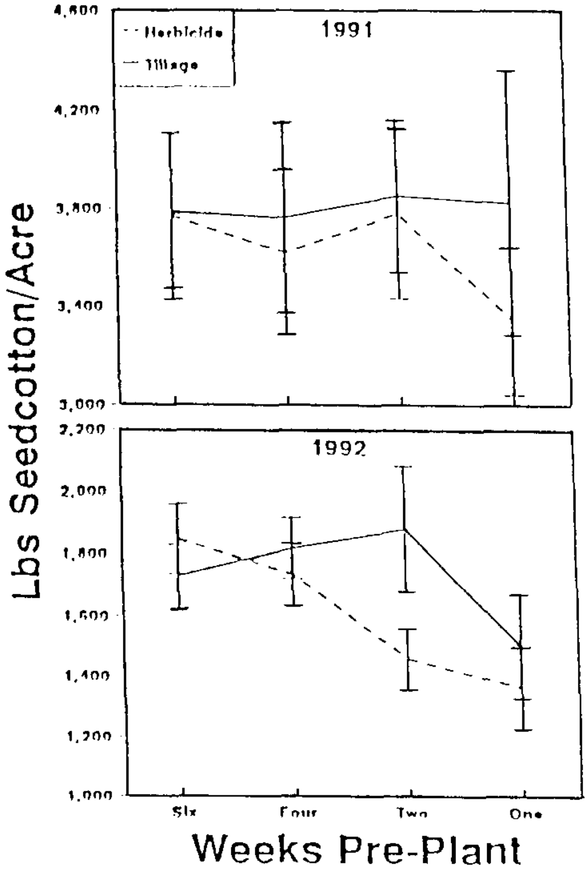

Fig. 4. Effect of vegetation management influenced by application timing on seedcotton yields (±SE).

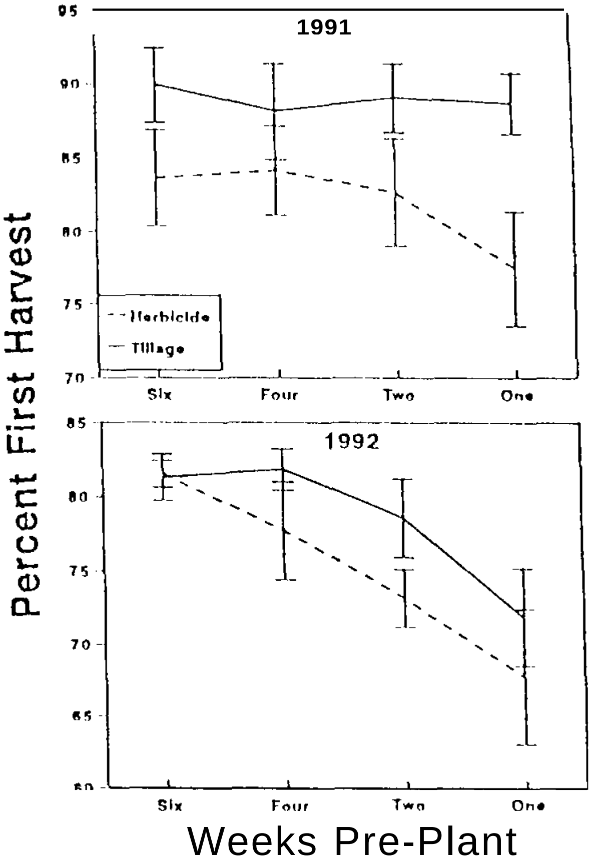

Fig. **5.** Effect of vegetation **management** influenced by application timing **on** crop maturity (±SE).

observed in the plots treated 4 and 6 weeks before planting compared with that for the plots treated 1 week preplant during both years (Table 2). A significant interaction between factors on crop maturity was not observed in either year. However, in response to the reduction in plant stand density and the increase in intra-row skips, crop maturity appeared to be delayed, especially in the herbicide-treated plots (Fig. 5).

DISCUSSION

Although cutworm spp. remain occasional pests, studies in cotton have illustrated an increase in infestation densities and plant damage associated with conservation tillage production systems (Dumas, 1983; Gaylor et al., 1984). Reduced-tillage practices promote the development of weedy plant species that can serve as oviposition sites for adults and alternate hosts for larval development. In addition, the use of hairy vetch and crimson clover, *Trifolium incarnatum* L., as cultivated winter cover crops in conservation tillage systems fosters the development of economic cutworm spp. infestations (Oliver and Chapin, 1981; Gaylor and Foster, 1987).

Tillage can be an important source of mortality for cotton insect pests, including cutworm spp. (Gaylor and Foster, 1987). The results of this study demonstrate a significant increase in cutworm spp. damage to cotton in plots treated with a herbicide and planted no-till compared with those managed with conventional tillage practices. Optimum stand in conservation tillage systems is generally more difficult to obtain compared with conventional tillage practices because of the additional plant residue that remains on the soil surface. Therefore, the impact of cutworm infestations becomes more important as tillage practices are modified.

Preplant herbicide use strategies are as effective as tillage in managing native vegetation and winter cover crops, but the effects are somewhat delayed compared with the nearly immediate destruction obtained with tillage (Crawford and Collins, 1991; Hutchinson and Shelton, 1991). Depending on the specific herbicide treatment, the target plant species, and environmental conditions, complete desiccation of vegetation may require a few days to several weeks. Any delay in completely terminating vegetation with herbicides could improve the survival of cutworm spp. larvae and increase the probability of economic infestations occurring in seedling cotton. In the present study, two applications of paraquat were required to completely kill the hairy vetch cover crop because of vegetative regrowth. Plant root material probably provided an adequate food source for several days after the final herbicide treatment was applied. At least some of the differences between tillage and herbicide treatments were probably related to incomplete kill of the hairy vetch in the herbicide-treated plots that allowed cutworm spp. larvae to survive until cotton became an available host.

The timing of vegetation management operations had a significant effect on cutworm spp. infestations by removing alternate hosts before cotton seedlings became available. A lapse of 14 days between the destruction of vegetation with tillage and the time of planting corn was sufficient to significantly reduce economic damage from black cutworm (Showers et al. 1985). Recommendations to manage cutworm spp. in California suggest that the destruction of vegetation should occur at least 3 weeks prior to planting cotton (Anonymous, 1984). In addition to decreasing the survival of larvae already present in the field, early preplant destruction of vegetation reduces oviposition by decreasing alternate host attractiveness to cutworm spp. adults.

The information obtained in the present study provide additional evidence showing that cutworm spp. damage to cotton may be increased in conservation tillage systems compared with conventional tillage practices. These results also suggest that cutworm spp. damage to cotton can be suppressed by managing vegetation with tillage or with the herbicide paraquat at least 3 to 4 weeks in advance of planting (4 to 5 weeks before plant emergence). With the proper selection of herbicides, application rates, and treatment timing, it is likely that satisfactory vegetation management in conservation tillage systems can be accomplished. Additional information is needed to develop effective and economical preplant weed control strategies for conservation tillage systems that reduce economic infestations of cutworm spp. in cotton.

ACKNOWLEDGMENTS

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A REDUCED-TILLAGE WHEAT-SOYBEAN, COTTON, AND PEANUT INTERCROPPING SYSTEM FOR SOIL AND ENERGY CONSERVATION

A. Khalilian[1], C.E. Hood[1], P.M. Porter[2], and J.H. Palmer[2]

INTRODUCTION

Current production practices for cotton, soybean, and peanuts involve high inputs and minimal soil conservation practices. Declining government subsidies and necessity for a conservation plan on highly erodible land makes it obvious that we must develop alternative production systems to maintain profitability in crop production.

The increasing availability of short-season cotton varieties with high fiber quality make double-cropped, conservation tillage cotton a potential alternative to the conventionally tilled, single crop system now in use. Also, currently, approximately 55% of the soybean acreage in South Carolina is double-cropped. A major problem with double-cropping systems is reduced yield of the summer crop due to delayed planting. In addition, current farming methods promote excessive soil compaction, resulting in hardpans that require energy-intensive deep tillage under less than optimum moisture conditions in early June.

A new double-cropping system developed at Clemson University allows interseeding or planting of one crop, such as cotton, soybean, or peanuts, into a second crop, such as winter wheat, before the harvest of the second crop (Hood et al, 1991). All field operations, including planting of wheat, fertilizer application, herbicide application, and wheat harvesting, utilize the same wheel traffic lanes to prevent compaction in the plant growth zones. The interseeding planter was modified in 1991 to improve efficiency and flexibility. The new Clemson no-till/ interseeding drill utilizes a versatile toolbar design equipped with a Gandy Orbit-Air applicator and Yetter no-till seeder coulters (Hood et al., 1992).

Intercropping of soybean into wheat has been investigated by a number of researchers (Chan et al., 1980; Reinbott et al., 1987; Buehring et al., 1990). Khalilian, et al. (1991) reported that interseeded soybean (1987-90) consistently yielded more than conventional double-cropped soybean at both irrigated and non-irrigated locations.

In an 8-year Tennessee study, Bradley (1989) indicated that no-till cotton can be produced successfully in killed small grains that have been grown for winter cover. Interseeding cotton into wheat is a relatively new practice that potentially has conservation, economic, and soil management advantages. No research on interseeding peanuts into standing wheat was found in the literature.

The objectives of this study were to evaluate production systems to conserve soil and energy, reduce effects of soil compaction, gain economic benefit of double cropping, and meet conservation compliance requirements without sacrificing profit.

PROCEDURES

To accomplish these objectives, three tests were conducted as a randomized complete block design at the Edisto Research & Education Center at Blackville, SC on a Varina loamy sand, a typical productive soil in the southeastern Coastal Plain.

Test 1 was initiated in 1990 to determine proper production strategies for interseeding cotton into stand wheat. Six replications of the treatments (Table 1) were planted and carried to cotton yield using recommended practices for seedbed preparation, seeding, fertilization, and insect and weed control. John Deere 71 Flexi-planter units with double-disk openers and depth bands were used to interseed cotton into standing wheat. The concept of interseeding cotton into standing wheat utilizes the benefits of deep tillage before wheat planting since there is no tillage prior to cotton planting. The cotton cultivar planted was Delta-Pine 50. Seeding rate was approximately 2 to 3 seeds/ft for the conventional plots and about 4 to 5 seeds/ft in the interseeded and no-till plots.

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Table 1. Treatments for cotton interseeding test (1990-92), Edisto Research and Education Center, Blackville, SC.

Treat. No.	Tillage Before Wheat[1]	Wheat Planting Method[2]	Tillage Before Cotton[3]	Cotton Planting Method	Planting Date
1	Paratill	Clem	None	Interseed	Early-May
2	Paratill	Clem	None	Interseed	Mid-May
3	Chiselplow	Drill	KMC/Sub	Gramoxone (plant)	Early-May
4	None	Fallow	Sub/Bed	Conv. full season	Early-May
5	Chiselplow	Drill	KMC/Sub	After wheat harvest	Early-June
6	Paratill	Fallow	Sub/Bed	Conv. full season	Early-May

1 Paratill = A 4-shank Tye Paratill with a 24-inch spacing, operating 12- to 13-inch deep; Chiselplow = an 11-shank chisel plow with 12-inch spacing, operating at 11-inch depth.
2 Clem = Clemson Interseeder; Drill = Conventional grain drill with 7-inch rows.
3 KMC/Sub = KMC subsoiler-planter with 38-inch rows; SUB/bed = A 4-shank 38-inch spaced subsoiler-bedder operating at 12- to 13-inch depth.

To determine the effects of deep-tillage equipment on soil compaction, a microcomputer-based, tractor-mounted recording penetrometer was used to quantify soil penetration resistance. Penetrometer data were taken about 2 and 7 months after fall tillage and immediately after cotton harvest.

Test 2 was initiated in 1992 to evaluate the new interseeding drill and interseeding schemes compared with old interseeding equipment and planting schemes. Six replications of the treatments (Table 2) were planted and carried to soybean yield using recommended practices for fertilizer and disease, insect, and weed control.

Wheat variety 'Coker 9766' was planted in late November immediately after tillage at a seeding rate of 90 lb/A. The soybean variety 'Haygood' was interseeded in Treatments 1, 2, and 5 (Table 2) at a rate of 60 lb/A between rows of standing wheat around mid-May. Fertilizer applications for all tests, including fall preplant and spring sidedressing, were based on soil analysis and recommendations of the Clemson University Cooperative Extension Service. Post-emergence herbicides were applied as needed.

Test 3 was initiated in 1992 to determine the technical feasibility of interseeding peanuts into standing wheat and comparing results with conventional full-season, full-tillage peanuts. The Clemson interseeding planter used for interseeding soybean and cotton into small grains was modified for planting four rows of peanuts. John Deere 71 Flexi-planter units equipped with peanut plates were used to interseed peanuts into standing wheat. Four replications of the following treatments were planted:

1. Conventional mono-crop peanut (no wheat, deep-tillage operation with moldboard plow planted May 15).

2. Interseeded peanut (fall-tillage moldboard plow prior to wheat planting, no spring tillage, interseeded into standing wheat May 19).

3. Interseeded peanut (fall-tillage paratill, no spring tillage, interseeded into standing wheat May 19).

Temik 15G (1.1 lb ai/A) was applied in-furrow for conventional plots. No Temik was used in the interseeded treatments.

Table 2. Tillage/planting treatments for soybean interseeding test (1992), Edisto Research and Education Center, Blackville, SC.

Trt. No.	Fall Tillage	Wheat Plant	Spring Tillage	Soybean Plant	Planting Date
1	Paratill	Old	None	Old	mid-May
2	Paratill	New	None	New	mid-May
3[1]	Fallow	None	KMC	KMC	May 10-15
4[2]	Paratill	New	None	New	June 6
5	Durou[3]	New	None	New	mid-May
6[4]	Chisel	Grain drill	KMC	KMC	June 6

Old First prototype interseeding machine with center wheel spacing of 76 inches (11 rows of wheat followed by 8 rows of soybean 13-inch row spacings).

New Airseeder with center wheel spacing of 96 inches (14 rows of wheat followed by 5 rows of soybean, 30 inches apart).

KMC Combination 4-row KMC subsoiler planter.

1 Conventional mono-crop soybean (38-inch row spacing).

2 In this treatment, soybean planted after wheat harvest.

3 Durou refers to 4-shank DUROU Cuti. Vie II deep-tillage tool manufactured in France with 38-inch shank spacing.

4 Conventional double-cropping method for wheat and soybean in coastal plain soils.

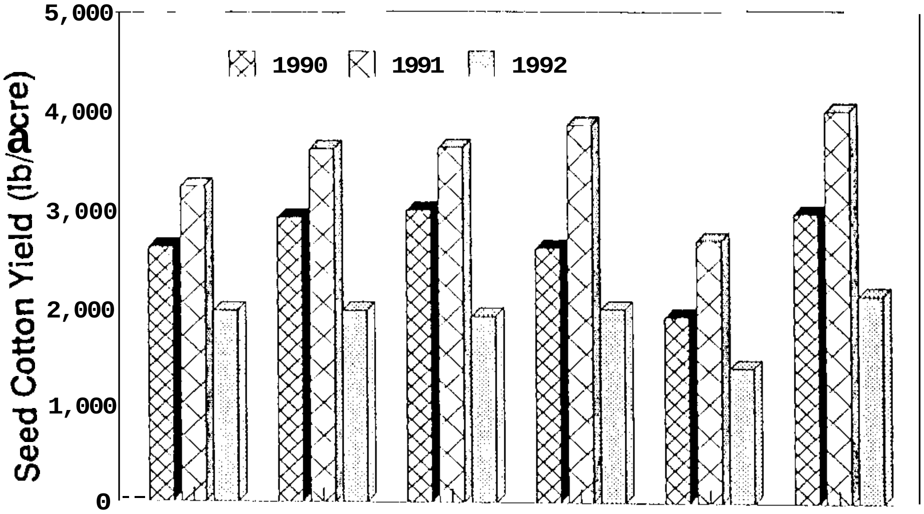
RESULTS AND DISCUSSION

Test 1. The John Deere Flexi-planter unit worked well between the rows of wheat for planting cotton, and the depth bands provided a uniform depth for seed placement. Small beds were formed by the S-tine openers during wheat planting. With the controlled-traffic procedure, these beds provided an excellent non-compacted zone for the later interseeding operation.

There were no significant differences in yields between cotton interseeded into standing wheat 2 weeks before harvest ("interseed late"), conventional mono-cropped cotton, and cotton planted in killed cover crop (Fig. 1). The conventional cotton plots, which had an extra deep-tillage operation with Paratill in the fall, produced the highest seed cotton yield. Double-cropped cotton planted after wheat harvest produced less yield compared with the rest of the treatments. In 1990 and 1991, plots interseeded 2 weeks before wheat harvest (early) produced higher yields than those interseeded 4 weeks before wheat harvest (late).

Figure 2 shows profiles of cone index versus depth for interseeded cotton plots 7 months after fall tillage and at cotton harvest. Compaction values measured in June 7 months after tillage were not high enough to restrict root growth. This indicates that one tillage operation in the fall, deep enough to remove a hardpan and using controlled traffic, could eliminate the need for an additional deep tillage in the spring for cotton in Coastal Plain soils. This could result in a savings of $8 to $10/A. Cone index values at harvest indicates that the residual effect of deep-tillage operations will extend for one additional year when interseeding is practiced. The tire track zones were highly compacted, and would make it possible to interseed cotton or soybean immediately after rainfall.

Table 3 shows the fuel requirements for three different cropping systems for cotton production. The interseeding system required about 37% less fuel compared with conventional double-cropped cotton planted after wheat harvest and about 10% less fuel than mono-crop, full-season cotton.



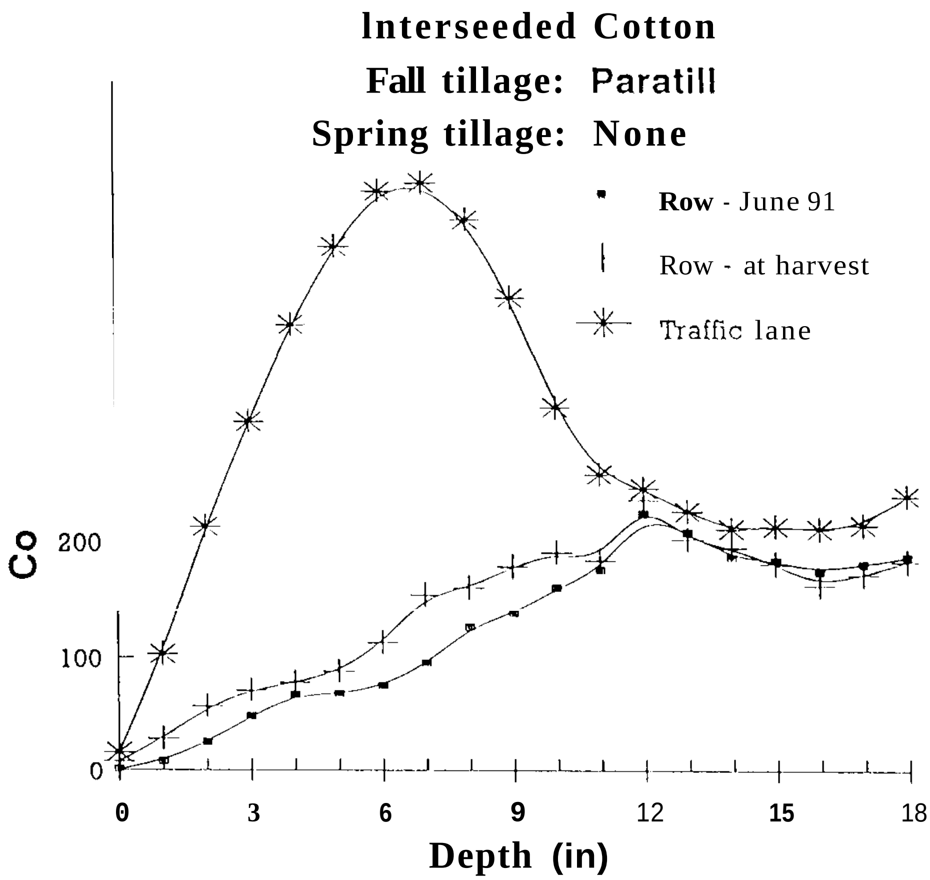


Figure 2. Effect of traffic on formation of hardpan 7 and 11 months after tillage.

Table 3. Fuel requirements (gal/A) for different cotton production systems.

Operation	Mono-crop	Interseeded	Double-cropped
Disk	1.35	0.45	0.45
Chisel plow	----	----	1.60
Subsoiler	1.38	----	1.38
Bedder	0.27	----	----
Paratill	----	**1.58**	----
Cult.(2 times)	0.90	----	0.90
Sprayer	0.20	**0.20**	0.20
Grain drill	----	**0.35**	0.35
Planting row crop	0.50	0.35	0.50
Harvest(wheat)	----	1.00	1.00
Harvest(cotton)	2.80	2.80	2.80
TOTAL	**7.40**	**6.73**	**9.18**

Source: W. Bowers and M. Paine, OSU Extension Facts No. 1704 and Khalilian et al, 1988.

Internode length for plants in each treatment was recorded 54 and 89 days after planting, and the boll location was determined prior to cotton harvest. The wheat stubble played an important role in the height of the lower nodes. By 89 days after planting, the height of the fourth node averaged 8.8 inches for the mono-cropped treatments versus 153 inches for the interseeded treatments (Fig. 3). For cotton in the

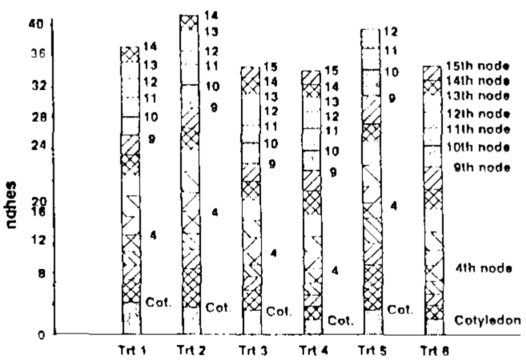


Figure 3. Node height 89 days after planting. See Table 1 and text for treatment description.

mono-cropped plots, over 15% of the bolls were formed on or below the fifth node, which averaged 10.8 Inches above the ground, whereas, for the conservation tillage plots, the number of bolls formed on or below the fifth node was under 6% and averaged 163 inches above the ground (Porter et al. 1992). Yield losses due to inability of the cotton picker to pick low bolls were greatest for the mono-cropped treatments. There was no consistent evidence of difference in quality factors for the treatments of this study, and thrips were not a problem in interseeded cotton.

Test 2. Table 4 shows wheat and soybean yields for 1992. Wheat yields were the same for plots drilled with a conventional grain drill, first prototype interseeding machine and the new Clemson Airseeder drill. Interseeded soybean (Treatment 2) yielded significantly more than double-cropped soybean planted after wheat harvest (Treatment 4). Although not statistically different, soybeans interseeded in between rows of standing wheat (Treatment 2) produced higher yields compared with conventional mono-crop soybean (Treatment 3). There was no significant difference in soybean yields between eight-row interseeded soybean plots (13-inch spacing, Treatment 1) and five-row inter-seeded soybean plots (30-inch spacing, Treatment 2).

Table 4. Wheat and soybean yields (bu/A), Edisto Research and Education Center, Blackville, SC. 1992.

Treatment No.[1]	Wheat Yield	Soybean Yield
1	**76.5** a	**57.6** ab
2	**75.3** a	**60.4** a
3	----	**56.3** ab
4	**78.3** a	**52.3** b
5	**72.8** a	**54.9** ab
6	**79.2** a	----

Values followed by the same letter are not significantly different (Duncan's multiple range test, $a = 0.05$).
[1] See Table 2 for treatment descriptions.

Also, no difference was observed in soybean yields between plots tilled with paratill compared with Durou plowed plots.

Test 3. Table 5 shows wheat and peanut yields for 1992. Statistically, there was no significant difference in peanut yields between conventional and interseeded treatments.

SUMMARY

Cotton can successfully be interseeded into standing wheat with yields comparable with those of the conventional mono-crop cotton. Interseeding should be done following a good rainfall after mid-May. Cotton interseeded into standing wheat will mature in time for a productive harvest. A planned system for control of broadleaf and grass weeds must also be developed for the interseeded treatment. The two conservation cropping systems using a wheat cover crop and interseeding can reduce soil erosion and energy requirements compared with conventional double-cropped cotton.

Deep tillage before small grain planting benefitted cotton due to controlled traffic patterns associated with the interseeding system. The residual effect of deep-tillage operations will extend for one additional year when interseeding is practiced.

Wheat yields were the same for plots drilled with a conventional grain drill, first prototype interseeding machine and the new Clemson Airseeder drill. Interseeded soybean yielded significantly more than double-cropped soybean planted after wheat harvest.

There were no significant differences in peanut yield between conventional and interseeded treatments.

ACKNOWLEDGMENTS

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DISCLAIMER

Mention of proprietary names does not necessarily imply recommendations of the product or equipment.

Table 5. Wheat and peanut yields, Edisto Research and Education Center, Blackville, SC. 1992.

Trt. No.	Tillage Before Wheat	Tillage Before Peanut	Peanut Planting Method	Wheat Yields (bu/A)	Peanut Yields (lb/A)
1	None	Moldboard plow	Conventional		**3864** a
2	Moldboard plow	None	Interseeded	**77.2** b	**3491 a**
3	Paratill	None	Interseeded	**83.2** a	**3310** a

Values followed by the same letter are not significantly different (Duncan's multiple range test, $\alpha = 0.05$).

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STARTER FERTILIZER APPLICATION RATES AND APPLICATION METHODS FOR CONVENTIONAL AND NO-TILLAGE COTTON IN TENNESSEE AND LOUISIANA

D.D. Howard and R.L. Hutchinson[1]

INTRODUCTION

Banding starter fertilizers has increased cotton (Gossypium hirsutum L.) yields in some studies, but increases were influenced by year, tillage, N-P_2O_5-K_2O combination in the starter, and placement methods (Touchton et al., 1986; Funderburg, 1988; Howard and Hoskinson, 1990). Touchton et al. (1986) reported starter applications increased no-tillage (NT) cotton yields 2 out of 3 years and conventional tillage (CT) yields in 1 out of 3 years in north Alabama. When cotton was subjected to moisture stress during flowering and fruiting, yields were increased by banding 23-23-8 lb/a of N, P_2O_5, and K_2O, respectively, but were not increased by banding either 23-0-0 or 23-23-0 lb/A. Funderburg (1988) reported a 93 lb/A average lint yield increase from 17 of 18 locations over a 3-year period from banding 150 lb/A of either 10-34-0 or 11-37-0 (N, P_2O_5, and K_2O) solutions to CT cotton in Mississippi. The band was 3 to 4 inches wide and was applied as a surface band (SB) directly over the row and behind the planter press wheel. Banding N plus P_2O_5 increased yields at two locations relative to banding N alone. Howard and Hoskinson (1990) reported that 2x2 banding of 15-15-0 lb/A of N and P_2O_5 produced higher NT cotton yields when compared with starters containing higher P_2O_5 rates. They also reported that starters did not affect yields in a year when spring weather conditions were hot and dry.

Information on cotton response to starter fertilizer, as affected by placement, nutrient composition, and tillage, is limited. This research was initiated to evaluate methods and rates of applying 11-37-0 for CT and NT cotton production on the loess soils in Tennessee and Louisiana.

[1]Professors, University of Tennessee, Agri. Exp.Stn., Dept. of Plant and Soil Sci., West Tenn. Exp. Stn., Jackson; and Louisiana State University Agricultural Center, Northeast Research Station-Macon Ridge Branch, Winnsboro, respectively.

METHODS AND MATERIALS

Field experiments evaluating rates and methods of applying 11-37-0 in CT and NT systems were initiated in 1991 at the Milan Experiment Station in Milan, TN on a Loring silt loam (Typic Fragiudalf) and at the Macon Ridge Branch Research Station in Winnsboro, LA on a Gigger silt loam (Typic Fragiudalf). Soil extractable P and K levels were both high on the Loring soil, while the P level was high and the K level was low on the Gigger soil. The Loring soil starter application methods included 1) in-furrow (IF) spraying of 1157-0 directly into the seed furrow, 2) banding 11-37-0 2 inches to the side and 2 inches below the planted seed (2x2), and 3) applying 11-37-0 in a 2- to 4-inch wide surface band over the row behind the planter (SB). Rates of 11-37-0 applied IF were 1.5, 3.0, and 4.5 gal/A diluted with water and applied at a constant pressure. The 2x2 and SB treatments were applied at 7.5 gal/A of undiluted 11-37-0. Starter fertilizer treatments were supplemented with broadcast applications of ammonium nitrate, triple super phosphate, and potassium chloride to provide the total fertilizer rates presented in Table 1. In addition, two broadcast (no starter) treatments were included for comparison. One broadcast fertilization treatment did not include phosphorus (P) in the fertilizer application while the other received a broadcast rate of 40 lb/A P_2O_5,

Separate CT and NT tests were located in adjacent areas on each soil. The experimental design was a randomized complete block for each tillage system at both locations. Treatments were replicated five times on the Loring soil and six times on the Gigger soil. Individual plots were 133 ft wide (four rows) and 30 ft long on the Loring soil and 50 ft long on the Gigger soil. The cultivar 'Deltapine 20' was planted by mid-May in 1991 and 'Deltapine 50' was planted by mid-May on the Loring soil in 1992. 'Deltapine 50' was planted both years by late-April on the Gigger soil. Recommended rates of fungicides and insecticides were applied IF at planting at both locations. A winter

Table **1.** Fertilizer rates and application methods.

Treatment	Rate of 11-37-0	Application methods Broadcast	Starter	Total
	-gal/A-	--------lb/A	$N-P_2O_5-K_2O$	--------
No Starter	**0**	**80- 0-60**	**-------**	**80-0-60**
No Starter	**0**	**8040-60**	**----**	**80-40-60**
In-furrow[1]	**1.5**	**78-33-60**	**2-7-0**	**80-40-60**
In-furrow	**3.0**	**76-27-60**	**4-13-0**	**80-40-60**
In-furrow	4.5	**74-20-60**	**6-20-0**	**80-40-60**
2x2 band[2]	**7.5**	**70- 7-60**	**10-33-0**	**80-40-60**
Surface band[3]	**7.5**	**70- 7-60**	**10-33-0**	**80-40-60**

[1] Materials applied in direct contact with seed.
[2] Fertilizer applied 2 inches to the side and 2 inches below planted seed.
[3] Fertilizers applied in a 4-inch wide surface band over the row behind the planter.

wheat cover crop was fall planted on the Gigger soil. Roundup was applied prior to planting the NT sites at both locations to kill existing vegetation. Recommended herbicides and application rates were used at both locations for weed control.

Yield measurements were obtained by harvesting the two middle rows of each plot with a mechanical spindle picker. At Milan, sub-samples from each replicated treatment were combined following harvest for ginning to determine gin turnout. At Winnsboro, a given length of row was hand harvested from each plot and ginned on a 20-saw laboratory gin to determine lint percentage. Yields and other plant measurements were statistically analyzed using standard analysis of variance procedures (SAS Institute, 1988). The least square means procedure was utilized to separate means that were determined to be significant at the **0.05** probability level.

Means for the individual treatments by soil and year were utilized to calculate relative yield, relative plant heights, and relative leaf surface area to be utilized in a regression analysis of early plant measurements with yield. An additional analysis of variance was conducted evaluating treatment effects across soils and years. Treatment means for each individual treatment of a tillage system were utilized as a replication of the treatment. The data were analyzed as a split plot; with location, the main plot and tillage, the sub-plots.

RESULTS

Starter effects on early plant growth measurements and yields were inconsistent with year and location. Therefore, the data will be presented by year and location.

Loring soil, 1991:

Starter fertilizers did not affect early CT plant stand or height, but yields were affected by the starter applications (Table 2). Applying 4.5 gal/A of 11-37-0 IF increased yields when compared with either broadcasting 80-40-60 or applying 1.5 and 3.0 gal/A IF. Broadcasting 80-40-60 resulted in lower yields when compared with yields of other treatments, except banding 1.5 and 3.0 gal/A IF.

Table 2. Effect of starter fertilizer treatments on plants/ft row, plant height, and yield of conventional-tilled cotton on a Loring silt loam at Milan during 1991.

Treatment	Rate of 11-37-0	Plants /Ft.[1]	Plant Height[2]	Lint Yield	First Harvest
	-gal/A-		--in.-	-lb/A-	---%--
No Starter[3]	**0**	**2.9**	**20.6**	**1249**	**66**
No Starter[4]	**0**	**3.1**	**20.1**	**1074**	**64**
In-furrow	**1.5**	**3.1**	**203**	**1176**	**66**
In-furrow	**3.0**	**3.1**	**21.4**	**1142**	**73**
In-furrow	**4.5**	**3 2**	**20.1**	**1388**	**63**
2x2 band	**7.5**	**3 3**	**213**	**1288**	**70**
Surface band	**7.5**	**3.0**	**21.0**	**1311**	**68**
L.S.D. (0.05)		NS	**NS**	**150**	

[1] Evaluated June **25.**
[2] Evaluated June **28.**
[3] 80-0-60 Ib/A $N-P_2O_5-K_2O$ broadcast.
[4] 80-40-60 Ib/A $N-P_2O_5-K_2O$ broadcast.

Surface banding the starter reduced NT plant stand but starters did not affect plant height or yield (Table 3). Yields were relatively high for both tillage systems, averaging approximately 2.5 bales/A.

Table 3. Effect of starter fertilizer treatments on plants/ft row, plant height, and yield of no-tilled cotton on a Loring silt loam at Milan during 1991.

Treatment	Rate of 11-37-0	Plants /ft.[1]	Plant height[2]	Lint yield	First harvest,
	-gal/A-		--in--	-lb/A-	---%---
No Starter'	0	2.7	28.3	1199	88
No Starter'	0	3.1	28.5	1239	88
In-furrow	1.5	2.1	24.8	1241	87
In-furrow	3.0	2.6	27.9	1261	88
In-furrow	4.5	2.5	26.0	1213	85
2x2 band	7.5	2.6	27.4	1174	86
Surface band	7.5	2.0	26.1	1185	88
L.S.D. (0.05)		0.7	NS	NS	

[1] Evaluated June 25.
[2] Evaluated June 28.
[3] 80-0-60 lb/A $N-P_2O_5-K_2O$ broadcast.
[4] 8040-60 lb/A $N-P_2O_5-K_2O$ broadcast.

Gigger soil, 1991:

Starter fertilizers applied as a 2x2 band generally increased the early CT plant growth measurements of stand, plant height, and plant leaf surface area compared with other treatments (Table 4). Applying starters IF reduced stands when compared with other treatments. The2x2 banded treatment significantly increased plant height compared with 4.5 gal/A applied IF and broadcasting only N and K_2O. Maturity of the IF starter treatments was delayed significantly compared with the 2x2 and SB treatments. Lint yields were unaffected by starter fertilizer applications regardless of application method.

Starters applied at 1.5 gal/A IF or as a 2x2 band increased NT plant stands when compared with broadcast fertilization (Table 5). Plant height was unaffected by treatment. Leaf surface area was greater for 2x2 banding than other treatments. No-tillage yields were higher for the SB than for other treatments, except for the 2x2banding. Maturity of NT cotton was not affected by treatments.

Loring soil, 1992:

Starters increased early CT plant measurements and yields (Table 6). Applying starters IF reduced plant stand when compared with other treatments. Banding 2x2 increased plant height more than IF and SB applications. In-furrow applications had lower leaf surface areas than with the 2x2 application method. Starters applied 2x2 resulted in higher yields than either starter applied IF or the broadcast treatments. Surface banding tended to increase yields, but the increase was significant only when compared with applying 3.0 gal/A IF.

Starter applications affected NT plant stand and height and yield (Table 7). Compared with other treatments, all IF treatments reduced stands. Stand differences due to applying other starter treatments were not observed. Plant heights were greater for 2x2 banding than applying either 3.0 or 45 gal/A IF. Leaf surface area was unaffected by treatment. Banding either 3.0 or 4.5 gal/A reduced yields more than other starter or broadcast treatments did, probably as a result of stand reduction.

Yields were relatively high for both tillage systems, averaging approximately 25 bales/A.

Gigger soil, 1992:

Plant stands of CT cotton were reduced by all starter treatments compared with broadcast treatments (Table 8). The greatest stand reduction was observed with 4.5 gal/A applied IF. No significant differences in plant height, leaf area, or maturity were noted among treatments.

Applying starters IF reduced NT stands when compared with either 2x2 or SB application methods (Table 9). The 45gal/A IF treatment caused the greatest stand reduction. Starters did not affect plant height, leaf area, yield, or maturity.

Yields were slightly lower than the previous year for both tillage systems, averaging approximately 1.5 bales/A.

Table 4. Effect of starter fertilizer treatments on plants/ft of row, plant height, leaf surface area, and yield of conventional-tilled cotton on a Gigger silt loam at Winnsboro during 1991.

Treatment	Rate of 11-37-0	Plants /ft[1]	Plant height[1]	Leaf area/ plant[1]	Lint yield	First harvest
	-gal/A-		--in--	-cm^2-	-lb/A-	---%---
No Starter[2]	0	2.4	6.5	219	1006	84
No Starter[3]	0	2.4	7.3	261	973	84
In-furrow	1.5	2.0	7.2	289	980	82
In-furrow	3.0	1.9	6.4	252	1024	83
In-furrow	4.5	1.7	6.8	300	944	82
2x2 band	7.5	2.9	8.6	403	1024	86
Surface band	7.5	2.6	7.7	304	1000	86
L.S.D. (0.05)		0.4	1.4	104	NS	2.7

[1] Evaluated June 3.
[2] 80-0-60 lb/A N-P_2O_5-K_2O broadcast.
[3] 80-40-60 lb/A N-P_2O_5-K_2O broadcast.

Table 5. Effect of starter fertilizer treatments on plants/ft of row, plant height, leaf surface area, and yield of no-tilled cotton on a Gigger silt loam at Winnsboro during 1991.

Treatment	Rate of 11-37-0	Plants /ft[1]	Plant height[1]	Leaf area/ plant[1]	Lint yield	First harvest
	-gal/A-		---in---	--cm^2--	-lb/A-	---%--
No Starter[2]	0	2.3	5.1	106	1019	88
No Starter[3]	0	2..4	5.2	105	1080	88
In-furrow	1.5	2.7	4.6	93	1064	88
In-furrow	3.0	2..4	4.5	97	1085	88
In-furrow	4.5	2.3	4.8	107	1070	86
2x2 band	7.5	2.8	5.5	150	1100	88
Surface band	7.5	2.3	5.3	111	1166	87
L.S.D. (0.05)		0.3	NS	27	74	NS

[1] Evaluated May 24.
[2] 80-0-60 lb/A N-P_2O_5-K_2O broadcast.
[3] 80-40-60 lb/A N-P_2O_5-K_2O broadcast.

Table 6. Effect of starter fertilizer treatments on plants/ft row, plant height, leaf surface area, and yield of conventional-tilled cotton on a Loring silt loam at Milan during 1992.

Treatment	Rate of 11-37-0	Plants /ft[1]	Plant height'	Leaf area/ plant[2]	Lint yield	First harvest
	-gal/A-		--in--	--cm²--	-lb/A-	---%---
No Starter'	0	3.4	4 2	107	1256	58
No Starter'	0	3.6	4.1	108	1306	65
In-furrow	1 5	2.7	3 8	91	1293	56
In-furrow	3.0	2.0	3.6	84	1182	55
In-furrow	4 5	2 2	4.0	90	1248	60
2x2 band	7 5	3.8	4 5	123	1423	61
Surface band	7.5	3.5	3.9	104	1354	59
L.S.D. (0.05)		0.5	0.5	31	110	

[1] Evaluated June 5.
[2] Evaluated June 10.
[3] 80-0-60 lb/A N-P_2O_5-K_2O broadcast.
[4] 80-40-60 Ib/A N-P_2O_5-K_2O broadcast.

Table 7. Effect of starter fertilizer treatments on plants/ft row, plant height, leaf surface area, and yield of no-tilled cotton on a Loring silt loam at Milan during 1992.

Treatment	Rate of 11-37-0	Plants /ft[1]	Plant height'	Leaf area/ plant[2]	Lint yield	First harvest
	-gal/A-		--in--	.em,--	-lb/A-	---%--
No Started	0	3.9	4.9	163	1387	73
No Starter'	0	3.8	4.6	130	1328	74
In-furrow	1.5	3.1	5.0	175	1322	70
In-furrow	3.0	2.0	4.4	145	1230	68
In-furrow	4 5	1.9	4 5	144	1215	65
2x2 band	7.5	4.0	5 2	194	1413	74
Surface band	7.5	3.8	4.9	139	1403	73
L.S.D. (0.05)		0.7	0.6	NS	135	

[1] Evaluated June 5.
[2] Evaluated June 10.
[3] 80-0-60 Ib/A N-P_2O_5-K_2O broadcast.
[4] 80-40-60 lb/A N-P_2O_5-K2O broadcast.

Table 8. Effect of starter fertilizer treatments on plants/ft row, plant height, leaf surface area, and yield of conventional-tilled cotton on a Gigger silt loam at Winnsboro during 1992.

Treatment	Rate of 11-37-0	Plants /ft[1]	Plant height'	Leaf area/ plant'	Lint yield	First harvest
	-gal/A-		--in--	--cm²--	-lb/A-	---%---
No Starter[2]	0	4.0	8.0	255	847	81
No Starter[3]	0	4.1	8.0	252	807	76
In-furrow	1 5	3 8	7.6	253	803	79
In-furrow	3.0	3.7	7.9	264	840	77
In-furrow	4 5	3.4	7.1	248	778	78
2x2 band	7 5	3.7	8.0	281	841	78
Surface band	7 5	3 8	8.1	243	806	80
L.S.D. (0.05)		0 2	NS	NS	NS	NS

[1] Evaluated June 1.
[2] 80-0-60 Ib/A $N-P_2O_5-K_2O$ broadcast.
[3] 80-40-60 Ib/A $N-P_2O_5-K_2O$ broadcast.

Table 9. Effect of starter fertilizer treatments on plants/ft row, plant height, leaf surface area, and yield of no-tilled cotton on a Gigger silt loam at Winnsboro during 1992.

Treatment	Rate of 11-37-0	Plants /ft[1]	Plant height'	Leaf area/ plant'	Lint yield	First harvest
	-gal/A-		--in--	--cm²--	-Ib/A-	---%--
No Starter[2]	0	3.1	6.9	162	823	75
No Starter'	0	3.2	6 2	190	862	77
In-furrow	1 5	2.8	6.6	200	911	76
In-furrow	3.0	2.8	6.7	229	896	75
In-furrow	4 5	2 5	6 3	213	835	76
2x2 band	7 5	3 3	7.6	259	849	76
Surface band	7 5	3 2	6.9	223	936	77
L.S.D. (0.05)		0.3	NS	NS	NS	NS

[1] Evaluated June 1.
[2] 804-60 Ib/A $N-P_2O_5-K_2O$ broadcast.
[3] 80-40-60 Ib/A $N-P_2O_5-K_2O$ broadcast.

DISCUSSION

Starter fertilizer applications were inconsistent in increasing either CT or NT early plant growth or yields at the two locations. Treatment responses in 1991 on the Loring soil may have been affected by rainfall. Within 30 minutes after planting, it began to rain, with a total of 5.67 inches recorded 2 weeks after planting. It has been speculated this rainfall may have leached the fertilizers from the application zone (measurements were not taken to evaluate movement). This speculation was supported by the CT data showing the highest yield resulted from applying 4.5 gal/A IF. Most of the other data indicated that 4.5 gal/A applied IF tended to reduced plant stands and yields. Also, the 1991 NT stands were reduced by the SB application indicating that fertilizer movement into the seed zone may have reduced germination.

Stands of both tillage systems appeared to be most affected by IF applications, especially at the two higher fertilizer rates. Applying 3.0 and 4.5 gal/A IF reduced stand counts of both tillage systems and appeared to be a questionable application method for cotton production. In 1991, the highest yield on the NT Gigger soil was the SB treatment having 2 3 plants/row ft. The cotton plant has the ability to compensate for low plant populations through increased production from the vegetative branches. Regressing stand counts (means for each treatment by year and soil) with relative yields showed a positive linear relationship for NT yields across soil and years (RY= 0.8565 + 0.0303 S, R^2 0.18), but the relationship for CT was not significant. This relationship suggested that NT plant population may have been affected more by starter fertilizers than CT stands.

Treatment effect on plant height was limited to the CT Gigger site in 1991 and both tillage systems on the Loring soil in 1992. Regressing relative plant height with relative yield showed a positive linear relationship for NT plots across soil and years (RY = 0.6648 + 03014 RPH, R^2 0.17). Alternatively, this relationship for CT was not significant, which suggested that plant height may be more affected by fertilizer starters applied to NT cotton than CT.

Leaf surface area appeared to be affected more by starters in CT cotton than in NT. Regressing relative leaf surface area of each year and tillage site with relative yield showed a positive quadratic relationship For CT plots across soil and years (RY = 1.7416 - 2.1643 RLA + 1.4252 RLA^2, R^2 036). However, the relationship for NT sites was not significant.

CONCLUSIONS

Yield responses to starter Fertilizer treatments were inconsistent. Compared with broadcast Fertilization at 80-40-60 Ib/A of N, P_2O_5, and K_2O, cotton yields were increased in only three oF eight experiments from 1991-1992. In Tennessee (Loring soil), starters increased yields in the CT system in 1991 and 1992, while in Louisiana (Gigger soil), yield increases were observed with NT in 1991. Otherwise, responses to starter fertilizers were generally similar at both locations. In most instances, 2x2 placement and surface banded treatments were superior to in-furrow application methods.

In-furrow applications of starter Fertilizer (11-37-0) at 3.0 and 4.5 gal/A usually reduced cotton stands and, in several instances, reduced yield and/or delayed maturity. Applying 1.5 gal/A IF generally had no effect on stands, growth, or yield.

Early plant growth and leaf area responses to starter fertilizers were also inconsistent. In several instances, however, plant height or leaf area increased with the 2x2 starter compared with other starter treatments and broadcast applications.

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AN EXPERIMENTAL APPROACH TO DETERMINE THE ECONOMIC INCENTIVE FOR BREEDING CORN, COTTON, AND SOYBEAN CULTIVARS ADAPTED TO REDUCED-TILLAGE SYSTEMS

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ABSTRACT

Crop cultivars now being grown in no-till production systems were developed by selecting for performance in conventionally tilled environments. In order to maximize production of corn *(Zea mays* L.), cotton *(Gossypium barbadense* L.), and soybean *[Glycine max* (L.) Merr.] in a no-till environment, it may be necessary to select for performance under the same conditions. The economic incentive for developing cultivars to produce in no-till environments cannot be determined without measuring the genotype times tillage interaction using genotypes that have not been selected for previous performance in a specific tillage regime. The experimental approach outlined here for determining the potential for improving performance in no-till systems is two-fold. The first experiment entails measuring crop and root growth rates, agronomic characteristics, and yield of commercial cultivars in conventional and no-till environments. Results from the first study should help identify cultivars with superior performance in no-till regimes and perhaps assist in establishing selection criteria for cultivar development programs. The second experiment measures the same performance parameters using randomly selected experimental strains that have not undergone selection in a specific tillage system. The second experiment should provide a reasonable measure of the genotype times tillage interaction for cultivars developed from crosses between elite parents, the source of most new commercial cultivars.

INTRODUCITION

The primary purpose of this article is to outline an approach for developing corn, cotton, and soybean cultivars that are better adapted to the relatively new cropping systems that are rapidly emerging in agriculture. Although there are many facets to consider in defining and attaining sustainable agricultural systems, there are at least two inherent requirements for any cropping system to survive in the long run which are not negotiable and must be met. The first is that the cropping system cannot be dependent upon consumption of non-renewable resources, and the second is that there cannot be a net toxic effect to the environment. Tbe urgency of developing alternative production culture for any single factor is determined by how scarce the resource is or the degree of toxicity to the environment. Francis (1991) outlined the dimensions of future cropping systems based on current trends, and characteristics of cultivars needed for those systems (Table 1).

In recent years, extensive effort has been made to conserve soil resources and reduce energy use by producing row crops with less tillage. Although significant acreage is now in reduced-tillage systems, nearly all crop cultivars now in production were selected for performance in conventionally tilled seedbeds (Triplett, 1986). Differences in performance of crop cultivars grown in tilled and untilled soil have been reported (Brakke et al., 1983; Newhouse and Crosbie, 1987; Triplett, 1986). In order to develop cultivars with improved performance in reduced-tillage systems, (1) growth factors influenced by tillage must be identified, (2) genetic variability for growth factors affected by tillage must be large enough to select for, (3) selection criteria to identify superior lines in segregating populations must be established, and (4) progeny with improved characteristics for reduced tillage must possess other agronomic traits, making for an adapted and competitive cultivar (revised from Kronstad et al, 1978). Francis (1990) emphasizes the need to carefully assess the potential for profit before establishing a long-term breeding program for new environments such as no-till regimes. This paper outlines an experimental approach for determining the genotype times tillage interaction for corn, cotton, and soybean cultivars.

PROCEDURE

Experiment 1- Determine the genotype times tillage interaction for commercial cultivars

The purpose of this experiment is to determine if commercial cultivars exist that display superior performance in no-till systems. Cultivars recommended

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Table 1. Dimensions of future systems and characteristics of cultivars for those systems.

Feature of system	Plant breeding solution
1. Reduced pesticide inputs and more regulations/environmental controls	1. Genetic tolerance/resistance to insects and pathogens, changes in crop species and modified cropping sequences
2. Higher energy costs, thus nutrient costs, and more regulations on groundwater and surface nitrate	2. Response to reduced rates of applied nutrients, greater nutrient use efficiency, more use of rotations
3. Reduced tillage and greater amount of crop residues, regulations on tillage	3. Increased seedling vigor, early stress (cold) tolerance, also tolerance to eco-fallow/zero-till planting
4. Higher pumping, equipment, and other costs of irrigation	4. Greater water-use effciency in crop species, stress (drought) tolerance, changes to more resistant/tolerant species
5. Greater recognition of benefits of specific location and system adaptation of cultivars	5. Greater number of commercially available cultivars, better data on specific adaptation to unique niches in system
6. Drastically increased use of crop rotations	6. Cultivars adapted to different rotation niches, more flexibility in maturity of available genetic materials, new crops available
7. Greater use of multiple species systems, especially crop mixtures, and relay planting	7. Greater range of maturities of cultivars available, greater potential for crop complimentation in new cultivars
8. Greater diversity in crops and potential products for a global marketplace	8. Breeding efforts to improve adaptation, productivity of a wider range of crops, and new introductions from wild species
9. Increasing concerns about crop nutritional quality	9. Breeding for nutritive value, low fat, easily prepared foods, fruits/vegetables for fresh market
10. Need for multiple purpose crops and plant types to promote feeding residues and nutrient cycling	10. Breeding crops with multiple functions, attention to grain and stover or by-products, root system morphology
11. Need for perennial cereals and legumes in compatible mixtures	11. Breeding and selection of cereals with pereuniality and ability to compete well in mixtures with legumes
12. Regulation of acceptable erosion levels	12. Systems/species maximizing soil protection while optimizing per-hectare crop productivity

(From Francis, 1991)

by the Louisiana Cooperative Extension Service will be used in field tests that will be conducted on a Norwood silt loam soil in the Red River Valley of central Louisiana. No-till and conventional tillage regimes will be used in the experiment. A split-plot design with four replications will be utilized with tillage system as main plot and variety as sub-plot. In the spring, burndown herbicides will be applied to conventional and reduced-tillage plots. The plow-pan layer of conventionally tilled plots will be fractured with a chisel plow on 19-inch centers, followed by two diskings and finishing with a do-all implement. The no-till plots will receive no tillage treatments. Crops will be seeded in 38-inch rows using a John Deere Max-Emerge planter, with fluted coulters if needed. Crop and root growth rates will be determined periodically. Weed species and populations will be recorded throughout the growing season. Yield will be determined at the end of the season, along with agronomic traits, followed by statistical and economic analyses. The test is planned for initiation in the 1993 season and to be conducted for 2 years.

Experiment 2 - Determining the genotype times tillage interaction for experimental strains with no previous selection

Experiment one will determine if commercial varieties now exist with superior performance in no-till systems. Since all the cultivars to be tested were selected (assumably) for performance in conventionally tilled systems, genetic variability for yield and other growth parameters between conventional and no-till systems may be underestimated. In order to get a more accurate measure of genetic potential for improvement, the genotype times tillage interaction should be measured using experimental strains that have not been selected for performance in a conventionally tilled system. The purpose of the second experiment is to determine the genotype times tillage interaction for strains derived from crossing elite germplasm. The strains will be obtained by randomly selecting 25 corn, cotton, and soybean lines in breeding programs where no selection for performance has yet occurred. Each experimental strain will be tested for performance in conventional and no-till environments using the same procedures outlined in experiment one.

In both experiments, crop and root growth analyses, along with additional agronomic traits, will be compared with yield performance in an effort to identify characteristics correlating with superior performance in no-till systems.

Subsequent programs for developing cultivars with improved performance in no-till systems

There are two general approaches for developing cultivars with improved performance in no-till production systems. The first is to simply select for yield in a no-till environment. The shortcoming of this approach is that the genotype times environmental interaction for yield is very large due to many factors other than tillage, and it may be difficult to make rapid progress. The second approach is to identify and select for genetic characteristics that contribute to yield in a no-till environment. Both approaches may be pursued simultaneously until the one giving more rapid advancement is identified. The experiments in this study are designed to facilitate both approaches. Once traits are identified that correlate with increased yields in a no-till system, the most efficient techniques for screening may be pursued.

Additional methods for increasing genetic variability and performance in a no-till system include utilizing exotic germplasm or gene transfer from other species. These more expensive and slower methods may become necessary if sufficient progress is not made utilizing traditional breeding techniques.

CONCLUSIONS

Crop cultivars now being grown in no-till production were developed by selecting for performance in conventionally tilled environments. The economic incentive for initiating breeding programs to improve performance in no-till systems cannot be determined without accurately measuring the genotype times tillage interaction. Research is needed to determine the genotype times tillage interaction using populations where performance has not been biased due to prior selection in a specific tillage regime. The approach outlined here is to randomly select experimental strains and compare their performance in no-till and conventional tillage systems. Correlating crop and root growth parameters to yield in a no-till environment may help identify selection criteria for cultivar improvement programs.

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PREPLANT AND POST-PLANT TILLAGE FOR FULL SEASON SOYBEANS ON CLAYEY AND SILT LOAM SOILS

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INTRODUCTION

Many experiments have been performed where no-till production systems are contrasted to tilled production systems. These production systems are compared in-total to decide which are the most conducive to profitable production systems.

On soils that have poor internal drainage or impermeable layers close to the surface (less than 22 inches), preplant tillage that produces a surface mulch may conserve soil moisture by preventing evaporation in the spring prior to planting. This would be especially true in regions of ample late-winter and early-spring rainfall. Soils, such as those described above, will have a profile that is full of water. It is conceivable that a surface mulch of dead plant debris could have the same moisture conserving effect. A similar moisture conservation scenario could also be operational after planting.

The infiltration rate of swelling clay or crusting silt loam soils may be increased dramatically by physical plowing or cultivation. This could also be a contributing factor for surface mulches of plant debris that would trap and hold water in the field longer for increased infiltration.

Aeration may also be a factor that limits plant root growth and moisture uptake. Poor root growth could also be the result of soil density or compaction that can be ameliorated by tillage operations.

The basic question of the value of preplant and post-plant tillage has not been addressed in Arkansas. The objective of studies reported herein was to assess the effect of convention flat seedbed preparation and post-plant tillage on soybean production on a Sharkey and Loring soil.

MATERIALS AND METHODS

Experiments were initiated in 1992 at the Northeast Research and Extension Center (NEREC) at Keiser, AR and at the Cotton Branch Experiment Station (CBES) at Marianna, AR. The experimental design was a stripped split plot. The main plots were preplant tillage with the subplots being post-plant cultivation. The treatment design was a 2 x 2 factorial of preplant (yes or no) and post-plant (yes or no) tillage. Selected cultural practices and site characteristics are described in Table 1. Grain yields were adjusted to 13% moisture. Estimated costs and profits were made utilizing modifications of published crop production budgets (Windham, et al, 1991a; Windbam, et al, 1991b).

RESULTS AND DISCUSSION

The yield results obtained for 1992 are presented in Table 2. It should be noted that 1992 was an extremely wet growing season with ample, well-distributed rainfall. The yield differences, though small, at NEREC were statistically significant for preplant tillage but not for post-plant tillage. Those obtained for both pre- and post-plant tillage were not statistically significant at CBES.

The economic returns for each treatment combination are presented in Table 3. Production costs generally increase as tillage inputs increase. However, profits are decreasing with the increasing tillage at NEREC. A component analysis is presented in Table 4. It is quite informative to note the loss in profit associated with pre- and post-plant tillage at NEREC. At a time when profits and losses are critical, this one year's data strongly suggests that tillage is just an added expense on clay soils and is only marginally profitable, at best, on a silt loam.

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Table 1. Selected site characteristics, cultural practices, and temporal log for tillage experiments at NEXEC and CBES.

	Location	
	NEXEC	CBES
Soil *Type*	Sharkey silty clay	Loring soil
Planting Date	**6-24-92**	**6-18-92**
Seedbed Prep.		
Disking	**6-24-92**	**6-15-92**
Chem. Burndown'	**6-24-92**	**6-15-92**
Variety	**AS5403**	**AS5403**
Seeds/Row-R	**3-5**	**3-5**
Row Spacing	**19** inches	**19** inches
Harvest Date	**10-29-92**	**10-19-92**
No. Reps		
Preplant Tillage	**4**	**9**
Post-plant Tillage	**4**	**3**

[1] Burndown was with Roundup at 15pt/A of 4.7 Ib ai/gal formulation.

Table 2. Pre- and post-plant tillage effects on soybean grain yield.

Location	Tillage					
	Preplant			Post-plant		
	Yes	No	Diff.	Yes	No	Diff.
	bu/A-					
NEXEC	**48.8b'**	**51.6a**	**2.8**	50.3a	50.0a	**0 3**
CBES	**30.0a**	**28.la**	**1.9**	**302a**	**27.8a**	**2.4**

* Numbers at same location and compared for either preplant or post-plant tillage followed by the same letter are not different at the **10%** level according to Fisher's F test. **The** differences at Marianna had a probability of a greater value of F of **0.11** and **0.18** **for** pre- and post-plant tillage, respectively.

Table 3. Economic returns estimated for various tillage regimes for soybeans.

Tillage				
Preplant	Yes		No	
Post-olant	Yes	No	Yes	**No**
	NEXEC			
Operating Cost'	**$63.42**	**$60.15**	**$52.86**	**$56.86**
Total Cost[2]	**$95.08**	**$88.74**	**$79.14**	**$80.07**
Profit'	**$180.44**	**$18230**	**$208.70**	**$190.97**
	CBES			
Operating cost	**$56.19**	**$52.75**	**$5227**	**$52.74**
Total Cost	**$8655**	**$79.77**	**$7725**	**$7438**
Profit	**$8425**	**$84.87**	**$89.63**	**$7458**

[1] Operating costs are taken from published crop production budgets with modifications to reflect changed production practices.

[2] Total costs are taken from published crop production budgets with modifications to reflect changed production practices.

[3] Profit computed as soybean yield times $5.60/bu minus total costs.

Table 4. Component analysis for pre- and post-plant tillage operations.

	Yield (bu)	Operating Cost[1]	Total Cost[2]	Profit[3]
		$/A		
	NEREC			
Base (No-Till)	**51.8**	**$50.86**	**$80.07**	**$211.13**
Adding Preplant Tillage	**-2.8**	**$9.93**	**$12.31**	**-$29.11**
Adding Post-Plant Tillage	**0.3**	**$2.64**	**$2.71**	**-82.70**
Total	**49.3**	**$63.43**	**$95.09**	**$179.32**
	CBES			
Base (No-Till)	**26.5**	**$52.74**	**$74.38**	**$74.02**
Adding Preplant Tillage	**1.9**	**$1.97**	**$7.35**	**$2.74**
Adding Post-Plant Tillage	**2.4**	**$1.49**	**$4.83**	**$7.50**
Total	**30.8**	**$56.20**	**$86.56**	**$84.26**

[1] Operating costs are taken from published crop production budgets with modifications to reflect changed production practices.
[2] Total costs are taken from published crop production budgets with modifications to reflect changed production practices.
[3] Profit computed as soybean yield times **$5.60/bu** minus total costs.

WATER QUALITY IN NO-TILLAGE SYSTEMS WITH NO PRIOR MANURE APPLICATIONS

M.D. Mullen[1], K.E. Simmons[2], D.D. Tyler[1], B.N. Duck[1], M.B. Daniels[2], G.V. Wilson[1], and J.K. Bernard[3].

INTRODUCTION

Handling and disposal of animal wastes are significant concerns in the management of concentrated livestock operations such as dairy farms. Large amounts of waste are collected in dairy feedlot/milking parlor areas, resulting in storage and disposal problems. Nutrients in these wastes must be properly managed to minimize off-site water quality deterioration. Manure from these operations is usually applied to agricultural lands and farmers often also apply commercial fertilizers to supply crop nutrient requirements (White and Safley, 1984). This practice often results in the application of excessive amounts of nutrients, which can lead to off-site water quality problems.

Soil erosion is also a major problem in the mid-South region. In order to conserve soil and comply with federal regulations, many livestock producers in this area are using no-tillage methods in their animal feed production systems. They also routinely apply animal wastes, as well as inorganic fertilizers, to these fields. Effective conservation practices to minimize soil losses may conflict with the utilization of animal wastes in crop production. Incorporation of manures generally maximizes the efficiency of manure nutrient use, but will likely also result in an increase in soil erosion. The use of no-tillage methods may also result in enhanced preferential flow through the soil profile (Tyler and Thomas, 1977), therefore increasing the potential for subsurface water quality deterioration from leaching manure nutrients. Surface-applied manure in no-tillage or conservation-tillage systems may result in, increased losses of nitrogen (N) through NH, volatilization. However, little has been reported concerning runoff losses from manured land. Two reports indicate that runoff volume may be reduced by surface applications of manure (Mitchell and Gunther, 1976; Walter et al., 1987). If so, then leaching of nutrients may become a larger problem in no-tillage systems utilizing manures.

It is important to determine environmentally sound levels of manure application within conservation-tillage systems. High rates of manure, often applied with supplemental inorganic fertilizer, may represent a potential water quality problem. This research project is an effort to provide information for the prudent utilization of these wastes in conservation-based agricultural production systems. This paper reports on the impacts of manure applications in no-tillage silage production on yields, leachate water quality, and soil profile nutrient concentrations.

MATERIALS AND METHODS

Eighteen plots were established at the University of Tennessee's Martin Agricultural Experiment Station at Martin, TN in May of 1991. The Experiment Station is located in northwest Tennessee in the Loessal Uplands region. The plots are on a Loring silt loam (fine, silty, mixed, thermic Typic Fragiudalf) with average slopes of 4 to 6%. Prior to establishment of this experiment, the site had received no prior applications of animal manures.

Tension-free pan lysimeters (60 x 75 cm) were installed at the lower end of each plot at a depth of 90 cm as previously described (Tyler and Thomas, 1977; Tyler et al., 1992). Leachate is collected after every storm event for chemical analysis. Leachates were analyzed for NH_4-N, NO_3-N, and PO_4-P using standard methods.

Manure was applied at different rates to provide different annual N and P application rates. Total annual N treatments were four rates of liquid dairy manure (126, 252, 380, and 504 kg N ha^{-1}), a NH_4NO_3 rate (218 kg N ha^{-1}), and a control (0 kg N ha^{-1}). These rates were split into spring and fall applications. Spring N treatments were 84, 168, 252, or 336 kg N ha^{-1} as manure, 168 kg N ha^{-1} as NH_4NO_3, and the control. Fall N treatments were 42, 84, 128, and 168 kg N ha^{-1} as manure, 50 kg N $ha.^{-1}$ as NH_4NO_3 and the control. The applications ranged from deficient to excessive N rates;

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however, the high application rate is not uncommon for dairy operators in the region. Inorganic P and K were applied only to the NH_4NO_3 fertilizer plots at soil test recommendation rates. Treatments were replicated three times and arranged in a completely randomized design. All plots were 7.6 x 9.1 m (0.007 ha). The cropping sequence was no-till silage corn in the spring and an annual ryegrass/crimson clover mix in the fall for forage; this is a common rotation for this area.

Total manure N concentration was determined the day before application to permit calculation of field application rates. Slurry was transported to the field in a 1500 L agitated tank and pumped onto the plots using a submersible sewage pump. The volume applied was determined by monitoring a calibrated dipstick in the tank. Subsamples of the fresh slurry were taken during application for determination of total N, P and K, NH_4-N and dry matter. Analyses for all applications are shown in Table 1.

Corn for silage was no-till planted on May 15,1991 and April 28, 1992 in 95 cm rows. Corn silage was harvested on August 2,1991 and August 25,1992. Soil samples were also taken from these plots to monitor changes in nutrient balances and profile NH_4-N and NO_3-N. Samples were taken prior to manure applications in the spring and fall and separated into depth increments of 0-7.5, 7.5-15, 15-30, 30-45, 45-60, 60-75, and 75-90 cm. Two cores were taken per plot with a bucket auger; these were composited for each plot. Soils were analyzed for NH_4-N NO_3-N, total P, and Mehlich I extractable nutrients. Results for Meblich I orthophosphate will be discussed.

RESULTS AND DISCUSSION

Table 2 reports manure N rates, silage dry matter yields, and silage N concentrations for 1991 and 1992. In 1991, yields were quite low; this was primarily due to very dry conditions during July and August of 1991. There were no significant differences in silage yields among manure treatments, although there was certainly a trend for higher yields with increasing manure-N. The high manure rate and the inorganic N treatment were both significantly higher than the control. In 1992, rainfall was plentiful and yields were much higher. The highest manure rate resulted in the highest silage yield, although only the control and 84 kg manure-N ha^{-1} were significantly lower than the high manure-N rate and the inorganic N treatment. Based on 2 years of data, applying manure at rates above approximately 250 kg manure-N ha^{-1} does not appear warranted.

Nitrate-N concentrations in leachate collected from these plots have generally been below the **10** mg L^{-1} EPA standard (Fig. 1). In 1991, concentrations above 10 mg L^{-1} were observed in November and December, primarily from the NH_4NO_3 and the 126 and 252 kg manure-N ha^{-1} treatments. These peaks coincided wh increases in rainfall during this time period. Leaching earlier in the year was minimal due to sporadic rainfall. In 1992, concentrations above 10 mg L^{-1} were observed on June **5** from the three highest manure rates, and on July 29 from the 388 kg manure-N ha^{-1} treatment. In the late-fall flush of leachate, the nitrate concentration from the highest manure rate was highest, but still acceptable. We hypothesize that the adequate rainfall during the growing season in 1992 resulted in much higher uptake of N than in 1991, and thus, lower overall leaching losses occurred in the fall. Concentrations of nitrate have remained below four mg L^{-1} for all treatments during 1993.

Although there are few differences between treatments for leachate nitrate concentrations, differences in total N loss from the plots are apparent (Fig. 2). Differences in leachate volume resulted in relatively high losses of N from the highest manure treatment. Losses in 1991 were approximately 45 kg ha' for the NH_4NO_3 and highest manure rate. The highest loss for 1991 (approximately 50 kg ha^{-1}) occurred in the lowest manure treatment. In 1992, cumulative nitrate-N losses averaged 86 kg ha^{-1} from the highest manure rate (504 kg manure-N ha^{-1}), 53 kg ha" with NH_4NO_3 and 47 kg ha^{-1} for the 388 kg manure-N ha^{-1} treatment. All other treatments lost less than 55 kg NO3-N ha^{-1}. In 1993, lossesfrom the high manure rate (17 kg NO_3-N ha^{-1}) were more than twice as high as the other treatments through April 7.

There are two possible explanations for these differences. The lysimeter pans have a collection area of 0.46 m^2. Extrapolating this area to a hectare can obviously give rise to a magnification of differences. The placement of the pans may have resulted in the interception of a greater number of macropores under the high manure plots, resulting in higher leachate volumes. A second possibility is that the higher manure rates are in fact contributing to higher infiltration rates, resulting in increased leachate volumes. Infiltration rates should be examined in these plots to elucidate the mechanism. Soil sampling to a depth of 90 cm showed no differences among treatments in soil nitrate concentrations (data not shown). Nitrate concentrations from all plots were below 8 mg kg^{-1} at a depth of 15 cm or deeper. The low, uniform nitrate concentrations at these depths

Table 1. Manure analyses, Martin, TN, 1991 and 1992.

Application Date	Dry Matter (%)	Total N (%)	NH_4-N (%)	P (%)	K (%)
5/7/91	12.1	0.43	0.16	0.11	0.25
8/27/91	11.7	0.41	0.12	0.14	0.22
4/24/92	9.2	0.30	0.09	0.09	0.13
9/23/92	6.4	0.27	0.10	0.11	0.12

Table 2. Spring manure N rates, corn yields, and N concentrations, 1991-92. Martin, TN.

Nitrogen Source	Spring Nitrogen Rate (kg N/ha)	1991 Silage Yield (mg/ha)	1991 Silage N (%)	1992 Silage Yield (mg/ha)	1992 Silage N (%)
Control	0	5.9 c*	0.54 a	7.5 c	0.63 c
Manure	84	6.3 bc	0.61 a	11.4 b	0.73 bc
	168	6.9 abc	0.61 a	13.2 ab	0.73 bc
	252	8.2 abc	0.58 a	13.2 ab	0.78 bc
	336	9.0 ab	0.59 a	15.0 a	0.88 ab
NH_4NO_3	168	9.6 a	0.61 a	12.6 ab	1.02 a

* Means in a column followed by the same letter are not different at $\alpha = 0.05$ by LSD.

indicate that preferential flow was probably the most important mechanism for nitrate loss in these soils. This observation agrees with data from an identical experiment in central Tennessee where very high concentrations of nitrate were collected in leachates under heavily manured soils, but soil nitrate concentrations were less than 4 mg kg^{-1} at similar depths (see Simmons et al., 1993; this proceedings).

In addition to concerns about N, accumulation of phosphorus in manured soils may also be a problem. Leachate concentrations of orthophosphate were low (below 300 $\mu g\ L^{-1}$ from all treatments) in this experiment (data not shown). Runoff of excess P can result in eutrophication in surface waters. Mehlich I extractable phosphate was determined as a function of treatment and depth (Table 3). Extractable orthophosphate increased steadily in the mulch layer as manure rate increased. Mulch concentrations in the two highest treatments were significantly higher than for the inorganic fertilizer and control treatments. Available orthophosphate concentrations in the soil were not significantly different, although the concentrations did tend to increase in the 0 and 7.5 cm segment with increasing manure. The data indicate that there has been very little movement of P through the profile, as would be expected. Total P concentrations in the mulch also increased significantly as manure rate increased Table 4). Again, there were no differences among treatments in the soil fraction.

CONCLUSIONS

Data from the past 2 years showed that high rates of manure will support silage yields approaching or exceeding those from inorganic N applications. High rates of manure N may result in high leaching losses of nitrate-N. Based on 2 years' data, it appears that intermediate rates of manure-N will produce acceptable yields, while minimizing losses of N from the root zone. Losses of P from these plots via leaching has heen minimal. However, the high concentrations of available and total P in the mulch layer could present a runoff hazard on sloping land.

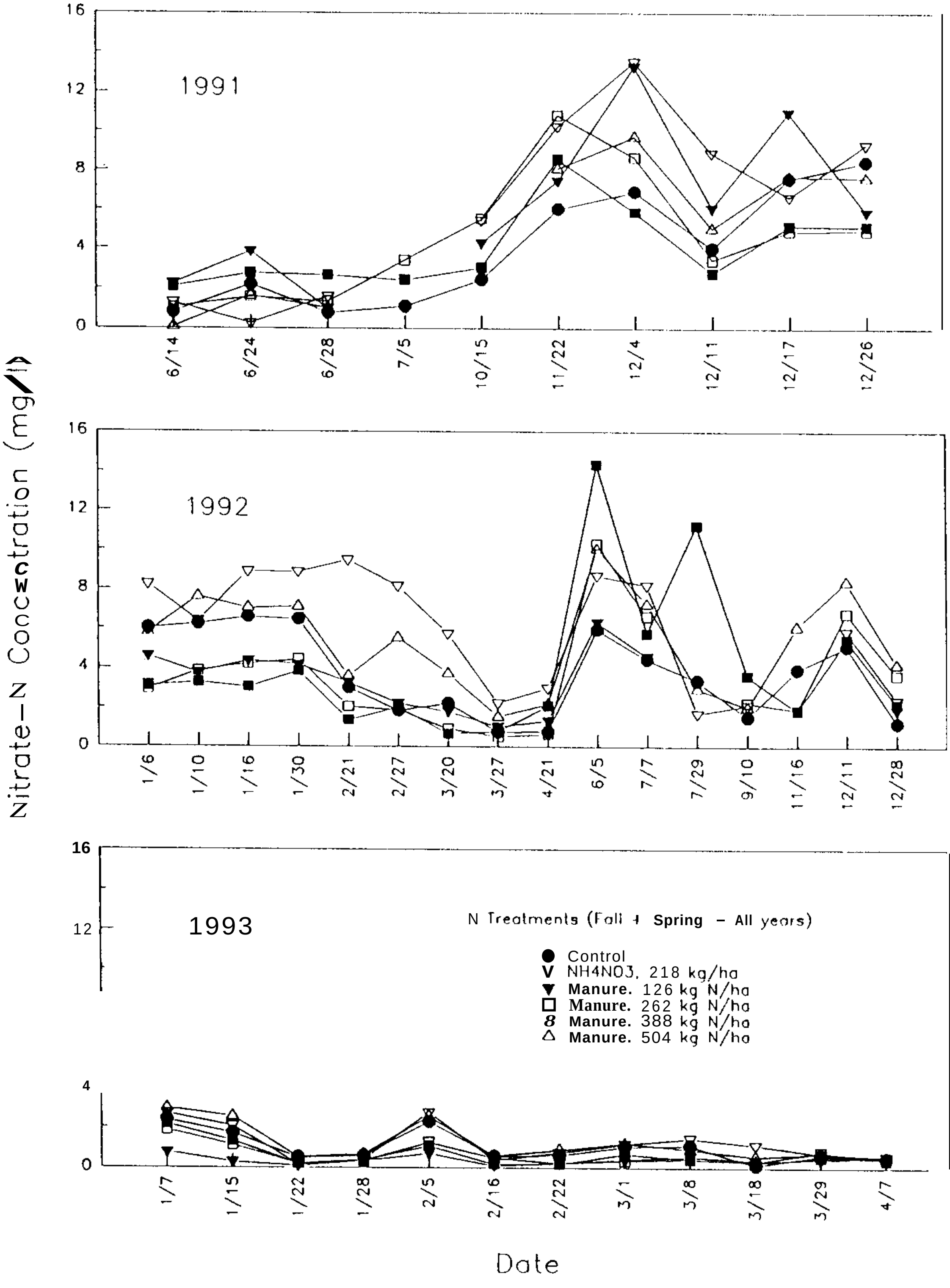

Fig. 1. **Nitrate-N concentrations in leachate collected in pan lyslmeters for June 14, 1991 through April 7, 1993. Dotted line represents the 10 mg L^{-1} concentration standard for nitrate contamination of water.**

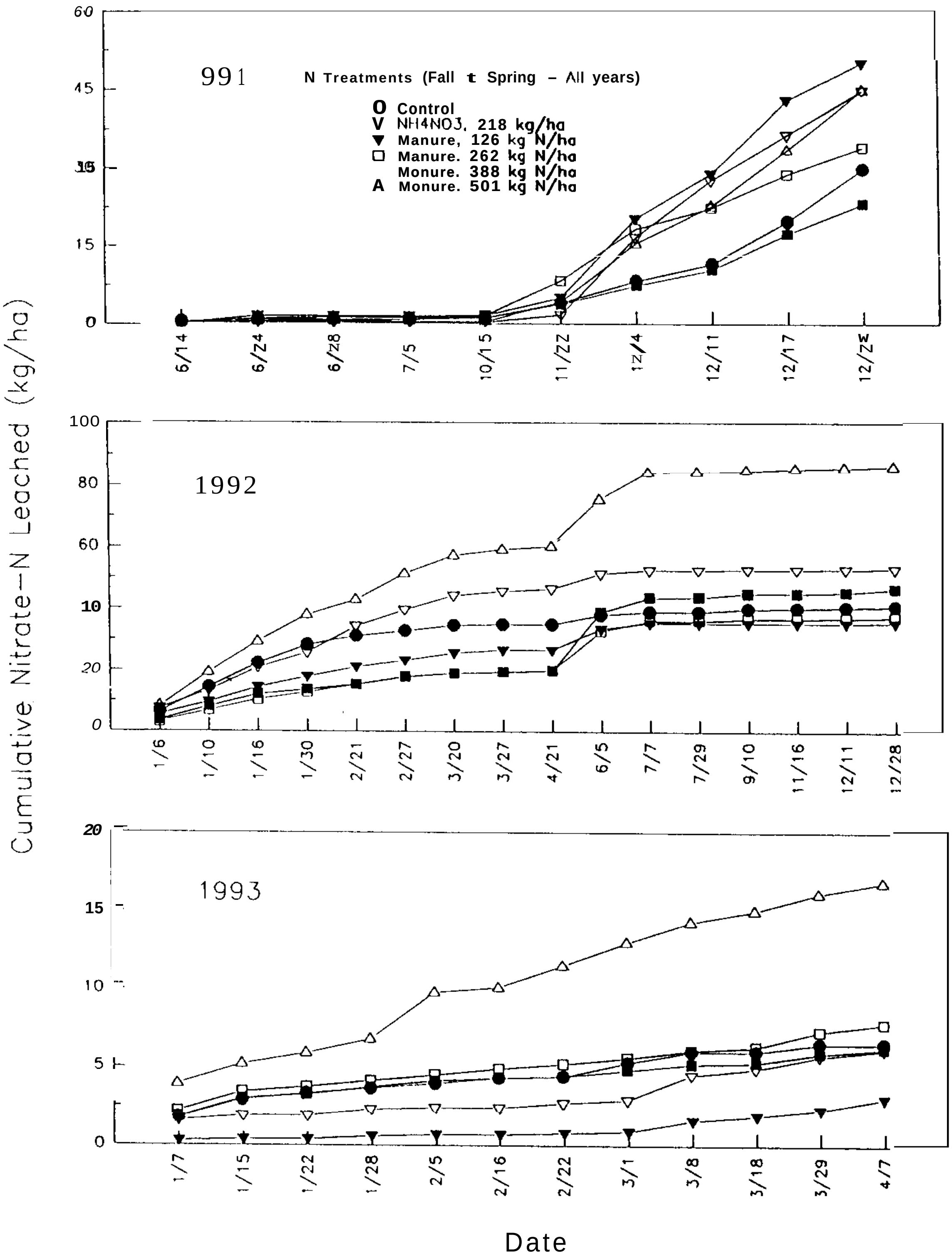

Fig. 2. Cumulative loss of nitrate-N collected in the pan lysimeters. Cumulative loss for each year is calculated from the first leaching event for that year.

Table 3. Mehlich I extractable orthophosphate as affected by manure treatment and sampling depth. August 14. 1992.

			Manure N Treatment - Spring + Fall (kg N/ha)			
Depth	Control	NH_4NO_3	126	262	388	504
cm	mg PO_4-P/kg					
Mulch*	292.0 d	810.0 cd	650.8 d	1211.4 cb	1675.7 b	2616.0 a
0 - 7.5	22.8	37.0	29.8	22.7	35.5	39.4
7.5 - 15	4.5	5.9	6.6	10.9	7.3	8.0
15 - 30	3.2	4.7	2.8	4.2	4.3	4.4
30 - 45	5.2	4.4	4.5	3.7	5.1	4.3

* Mulch means followed by the same letter are not different at α = 0.05 by LSD. There were no significant differences between means at the other depths.

Table 4. Total P as affected by manure treatment and sampling depth. August 14, 1992.

			Manure N Treatment - Spring + Fall (kg N/ha)			
Depth	Control	NH_4NO_3	126	262	388	504
cm	mg PO_4-P/kg					
Mulch*	1651 e	2364 ed	3082 cd	3883 bc	4354 b	5753 a
0 - 7.5	659	787	695	716	797	775
7.5 - 15	437	572	500	534	536	550
15 - 30	448	546	447	479	527	515
30 - 45	479	532	498	476	498	485

* Mulch means followed by the same letter are not different at α = 0.05 by LSD. There were no significant differences between means at the other depths.

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WATER QUALITY IN NO-TILLAGE SYSTEMS FOLLOWING LONG-TERM MANURE APPLICATIONS

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INTRODUCTION

Land disposal of animal waste can lead to the deterioration of ground and surface water quality if nutrients in the waste are not managed appropriately. Typically, manure applications are based on N requirements of the crop, and this N is credited towards the inorganic fertilizer N applied. This practice results in a phosphorus application exceeding the crop requirement and a subsequent build-up of soil phosphorus. This could potentially result in surface water degradation from phosphorus laden runoff waters from agricultural land. For these reasons, it is necessary to simultaneously evaluate the effect of manure applications on both nitrogen (N) and phosphorus loadings to ground and surface waters in order to make environmentally sound nutrient management recommendations.

Tennessee ranks 14th in the nation in numbers of total cattle and dairy cattle. As of January 1990, Tennessee had approximately 2 3 million head of cattle, including 195,000 head of dairy cows. Sound nutrient management of the animal waste produced is necessary for the protection of local and regional ground and surface waters. In the central portion of the state, the soils have developed on phosphatic limestone bedrock. These soils have a greater potential for macropore flow under both saturated and non-saturated conditions. Macropore flow results in the rapid flux of water through the profile and may result in increased solute transport if contaminants are dissolved in the flowing solution. Furthermore, to reduce soil erosion, no-till is becoming a more common cultivation practice. However, this reduced-tillage practice also increases the presence of macropores in the upper soil profile and, likewise, the chance of rapid solute transport through the profile (Adreini and Steenhuis, 1990; Tyler and Thomas, 1977).

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Land application of manures may also result in the accumulation of mineralizable N over a number of years. Kelsoe et al. (1991) and Simmons and Baker (1990) observed no differences in corn yield or N mineralization in soils receiving manure for 50 years after manure application had ceased for 3 years. Other researchers have also observed a reduced response to N fertilization and increased N mineralization with long-term applications of manure (Campbell et al., 1986; Xie and MacKenzie, 1986). Additionally, Addiscott (1988) demonstrated that much of the N leached during the winter was from the organic N sink and not residual fertilizer N applied the previous spring. Other researchers have demonstrated the contribution of organic N to the pool of leachable NO_3 N (Letey et al., 1977; Macdonald et al., 1990; Pratt et al., 1976).

For these reasons, it is necessary to evaluate the effects of manure applications on water quality in karst topography regions where no-till practices are common. Field work was initiated at the Lewisburg Dairy Station to meet the following objectives: 1) to evaluate the potential impacts of liquid dairy manure applications in no-till silage and haylage rotations on surface and subsurface water quality and 2) to evaluate initial and residual availability of N and P from dairy manures as a function of rate and frequency of application.

MATERIALS AND METHODS

Field plots were established at the University of Tennessee Dairy Experiment Station in Lewisburg, TN in April 1992. The site is located in the valley and ridge province in Tennessee on a Huntington silt loam (fine, silty, mixed mesic Fluventic Hapludalf) wh a slope less than 2%. The soil is over a fractured phosphatic limestone bedrock. The depth to bedrock varies from 1 to 2 m. The site has received manure applications periodically for at least 35 years.

Total annual N treatments include three rates of liquid dairy manure (126, 252, and 504 kg N ha^{-1}), one NH_4NO_3 rate (218 kg N ha^{-1}), and a control (0 kg N ha^{-1}). These rates are split into spring and fall applications. Spring N treatments are 84,168, and 336 kg N ha^{-1} as manure, 168 kg N ha^{-1} as NH_4NO_3, and the control. Fall treatments are 42, 84, and 168 kg N ha^{-1} as manure, 50 kg N ha^{-1} as NH_4NO_3, and the control. The application rates cover the deficient to excessive N range; however, the high application rate is not uncommon for dairy operators in this area. All treatments are replicated three times and arranged in a randomized complete block design. Each plot is 7.3 x 13.7 m and is cropped to no-till corn silage/winter wheat 1-year rotation. Tension-free pan lysimeters (60 x 75 cm) were installed at the lower end of each plot at a depth of 90 cm as described by Tyler and Thomas (1977) and Tyler et al. (1992). The lysimeters were installed at the end of April 1992 prior to the first manure applications. Tensiometers were installed in the control plots at 75, 224375,525, 675, and 82.5 cm to monitor soil water potential.

A manure sample was collected the day before application and analyzed for N to calculate the volumes to apply for each treatment. Manure was transported to the field using a 1500 L tank and pumped to the plots through a hose using a submersible sewage pump. An agitator was used in the tank to keep the slurry mixed during the application. The volume applied was determined from a calibrated stick in the tank. Manure samples were also collected from each plot during the application and later analyzed for dry matter, total N, P, and K, and NH_4-N. Manure analyses for the spring and fall applications are shown in Table 1.

Table 1. Manure analyses, Lewisburg, TN, 1992.

	Dry matter	Total N	NH_4-N	P	K
	------------------------(%)------------------------				
Spring	8.46	0.43	0.27	0.085	0.38
Fall	2.80	0.11	0.05	0.028	0.11

No-tillage corn was planted in 91 cm rows during the first week of May. Plant populations averaged 44,000 plants ha^{-1}. Corn grain and silage were harvested from each plot. A 3-m length of row was harvested from each plot for both grain and silage yield data. Subsamples were taken for moisture and N, P, and K analyses. Soil profile samples were taken immediately following harvest. Samples were taken from 0-15, 15-30, 30-45, 45-60, 60-90, and 90-120 cm. Three cores/plot were taken and composited for laboratory analyses. Soils were analyzed for NH_4-N and NO_3-N using a KCI extraction. Fall applications of manure were applied after the soil had been sampled. Winter witeat was planted within a month.

RESULTS AND DISCUSSION

Corn grain and silage yields are shown in Table 2. Although the NH_4NO_3 treatment had the highest silage and grain yield, no significant difference was detected among yields, This is attributed to high amounts of mineralized N from previous manure applications in this field. Furthermore, because of low rainfall in the spring, plant populations in the plots were highly variable, which resulted in highly variable yield data.

Leachate was collected from the pan lysimeters after each storm event beginning on 5 June 1992. Average concentrations for NO_3-N and ortho-P are shown in Figure 1 and 2, respectively. Ammonium was not detected in the leachates and, therefore, is not shown. Both nitrate and ortho-P were detected in the leachate during this sampling period, and nitrate concentrations exceeded 10 mg L^{-1} throughout most of this sampling period. Nitrate concentrations in the leachate were highest where 168 kg N ha^{-1} as NH_4NO_3 and 336 kg N ha^{-1} as manure were applied. Nitrate concentrations from the control plot ranged from 10 mg L^{-1} to 30 mg L^{-1} during this sampling period, whereas concentrations from the high manure treatment ranged from approximately 23 mg L^{-1} to 40 mg L^{-1}. Ortho-P was generally only detected where manure had been applied and was greatest at the highest application rate.

Cumulative NO, leached (kg NO_3-N ha^{-1}) is shown in Figure 3. Nitrate loss was the greatest from the inorganic N treatment. During the corn growing season, approximately 140 kg N ha^{-1} was leached where 168 kg N ha^{-1} as NH_4NO_3 had been applied. Approximately 60 kg N ha^{-1} leached from the control plot. Total NO_3-N leached during this time period (5 June 1992 to 1 December 1992) ranged from approximately 100 to 200 kg N ha^{-1} among the treatments. These high levels are partly attributed to residual N from previous manure applications and are expected to diminish over time. The nitrate leached from the control plot over time will serve as a measure of this effect.

Table 2. Corn yiel I and N concentration, Fall 1992, I wisburg, TN.

Nitrogen Source	N Rate		Silage N Conc.(%)	Grain Yield (Mg ha^{-1})	Grain N Conc. (%)
Control	0	21.8	1.10	10.12	1.48
Manure	84	22.1	1.13	9.49	1.63
	168	20.5	1.08	8.79	1.47
	336	20.9	1.16	7.47	1.59
NH_4NO_3	168	23.0	122	10.22	152

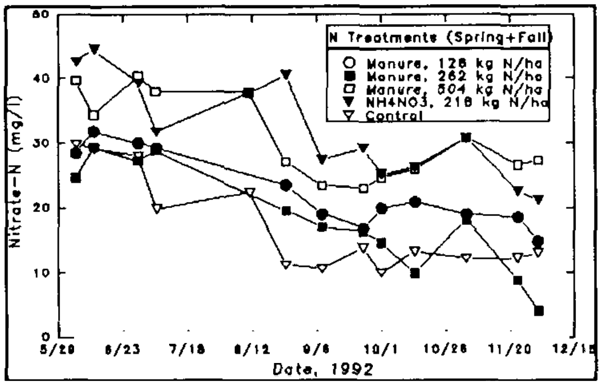

Fig. 1. Soil water NO_3-N concentrations collected in pan lysimeters from June through December 1992, Lewisburg, TN.

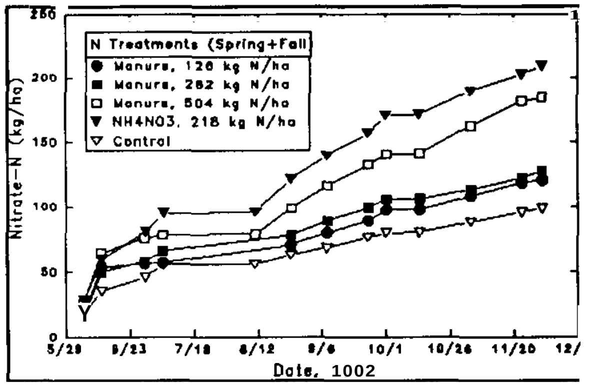

Fig. 3. The effect of manure and NH_4NO_3 applications on cumulative NO_3-N loss in leachate, Lewisburg, TN 1992.

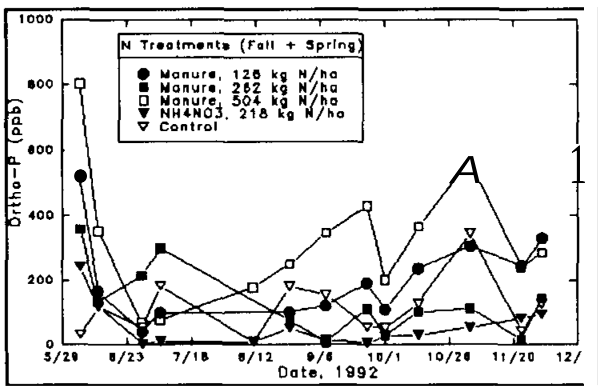

Fig. 2. Soil water ortho-P concentrations collected in pan lysimeters from June through December 1992, Lewisburg, TN.

The soil profile NO_3-N for Fall 1992 is shown in Figure 4. The increase in soil nitrate at the lower depths where NH_4NO_3 was applied is consistent with the higher amounts of NO_3 leached from this treatment. However, significant differences among the treatments were not detected.

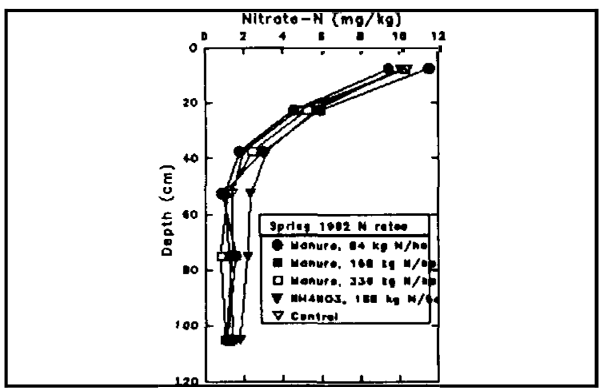

Fig. 4. The effect of manure and NH_4NO_3 applications on fall soil profile NO_3-N concentrations, Lewisburg, TN, 1992.

Although definitive conclusions should not be drawn after one site year of data, continuous applications of manure appear to have elevated nitrate concentrations in the leachate, leaving the vadose z.one at this site. At a similar experimental site in Martin, Tennessee, which had not received previous manure applications (see Mullen et al., this proceedings), nitrate concentrations were not as high the first year of the study and a statistically significant response in corn yield to N applications was observed. Both these comparisons suggest that the build-up of organic N in the soil profile from long-term manure applications is a significant source of N to the corn crop and is susceptible to nitrate leaching. However, recommendations for nutrient management on previously manured sites cannot be made until more site years have been completed.

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EVOLUTION OF CONSERVATION TILLAGE SYSTEMS FOR TRANSPLANTED CROPS -- POTENTIAL ROLE OF THE SUBSURFACE TILLER TRANSPLANTER (SST-T)

Ronald D. Morse[1], David H. Vaughan[1], and Linford W. Belcher[2]

EVOLUTION OF CONSERVATION TILLAGE SYSTEMS IN THE UNITED STATES

Conservation Tillage Versus Conventional Tillage - The Farmer's Dilemma

In the early 1900s, moldboard plowing, excessive secondary tillage operations, and multiple cultivations led to serious erosion problems and the "much-talked-about" flooding and dust storms (Phillips and Phillips, 1984).1n 1943, Edward Faulkner boldly challenged the validity and wisdom of using the moldboard plow (Faulkner, 1947). Faulkner asserted: "The truth is that no one has ever advanced a scientific reason for plowing. The entire body of reasoning about the management of the soil has been based upon the axiomatic assumption of the correctness of plowing. But plowing is not correct. Hence, the main premise being untenable, we may rightly question the validity of every popularly accepted theory concerned with the production of any crop, when land has been plowed in preparation for its growth." Although Faulkner was considered a "fanatic" by the academic community of his time, the wide acceptance of conservation tillage systems today throughout the world is a fitting testament to the "self-sufficiency of the soil" ("sustainability") he so avidly proclaimed.

With the advent of pre-emergent herbicides in the 1940s, agriculture began a slow but steady movement toward incomplete, reduced, or minimum tillage--only tilling the soil enough to facilitate plant establishment and subsequent plant growth. Conservation tillage is a form or extension of minimum tillage. Conceptually, conservation tillage is defined as "any tillage sequence, the object of which is to minimize or reduce loss of soil and water; operationally, it is a tillage or tillage and planting combination which leaves a 30% or greater cover of crop residue on the surface" (SSSA, 1987). No-tillage (NT) is the extreme form of conservation tillage where the soil is left undisturbed prior to planting. Planting is accomplished in a narrow seedbed or slot created by coulters, row cleaners, disc openers, in-row chisels, or roto tillers (CTIC, 1992). The term "no-tillage" is in reality a misnomer since some tillage or soil loosening occurs from the coulter and the soil-opening devices of the planter (Phillips and Phillips, 1984). Therefore, the fact that some tillage occurs in NT systems leads to the central question or focus in this article--"how much soil loosening or tillage is necessary to reduce the compaction of an undisturbed soil to a level that will not deleteriously affect crop establishment and yield potential?" The answer to this question depends on a) the severity of the existing soil compaction, b) the crop species being grown, and c) the extent to which the advantages of using NT systems offset or counter-balance soil compaction and other disadvantages in the particular abiotic and micro-climatic conditions in question.

Role of Soil Physical Properties

The relative importance of soil compaction and poor drainage in reducing crop establishment and yield potential varies with the length of growing season and the extent to which the advantages of no-tillage are expressed during the growing season. Poor plant stands generally result in reduced crop yield, unless the particular crop grown has a strong indeterminate growth pattern and the length of the growing season is long enough to allow for crop yield-compensating effects to occur (Morse, 1990).

Even when plant stands are not affected in NT systems, crop yield potential may be reduced because of poor soil drainage (Griffith and Mannering, 1985). In general, as soil drainage decreases, the need for tillage increases. Thus, with easily compacted impermeable soils, crop yield potential is often reduced under NT systems (Griffith and Mannering, 1985). Poor drainage is most common on clayey soils (Webber et al., 1987) and/or soils with natural or man-made impermeable soil layers or "pans." This yield disadvantage associated with NT on poorly drained soils occurs most often in early plantings. Lower soil temperatures and excess wetness early in the growing season are common on poorly drained soils, and both problems are

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accentuated when crop residues are left on the surface and the soil is not loosened by tillage.

Poor drainage does not reduce yields under all conditions. In areas with long growing seasons, late spring or summer plantings on poorly drained soils under droughty conditions may result in favorable or even improved yields with NT (Griffrth et al., 1986).

Unfortunately, there is little information on long-term (many years or decades) advantages of using NT systems. However, using NT may result in lower rates of erosion and, over many years, can maintain or even increase soil productivity, crop yields, and grower profits (Crosson, 1981; Hargrove, 1990).

In-Row Tillage-A Sustainable Compromise

Compared with CT or even mulch tillage (CTIC, 1992), reducing tillage to only a narrow in-row area (strip tillage and ridge tillage) appears to be an excellent choice on compacted, erosive soils. The relative advantages of each conservation tillage system vary or interact with the degree to which soil moisture and other growth factors are limiting (Morse, 1993). Based on previous research with transplanted cabbage (Love, 1986; Morse, 1989), in-row tillage appears to be the best overall system under either ample or deficit soil moisture. The combination of in-row tillage for improved planting efficiency and soil condition and maintaining between-row surface cover for moisture and soil conservation make in-row tillage an excellent compromise between NT and CT.

EVOLUTlON OF NO-TILLAGE PLANTERS

Agronomic Crop

The first plow was a forked stick, pulled through the soil by the wife and steered by the husband. Fortunately, the wife's role has changed toddy; however, the role of the plow is not much different - only the depth of plowing and level of remaining surface residues have changed (Hayes, 1985). Until the early 1900s, the plow left field surfaces very rough with some remaining unburied residues. With advances in the industrial revolution came more powerful tractors and moldboard plows that more completely buried crop residues, leaving the soil surface exposed to wind and water erosion (Hayes, 1985). This movement to clear-tillage resulted in the serious flooding and the dust storms of the 1930s, which led to the establishment of the Soil Erosion Service in 1933 and its successor, the Soil Conservation Service in 1935. In the 1940s, Faulkner (1947) and other progressive thinkers (Sears, 1935; Scarseth, 1961) focused on the erosion hazards from using the moldboard plow. These scientists advocated less plowing and greater use of plant residues.

Acceptance of no-tillage as a viable production system and manufacturing of NT planters were practically nonexistent until the 1960s and 1970s. Prior to this period, farmers interested in NT planters were forced to modify existing equipment (Phillips and Phillips, 1984). The performance of these make-shift planters was inconsistent at best, frequently resulting in poor plant stands and low crop yields. Today conservation tillage of agronomic crops is widely accepted, and the modern NT seeders function well in undisturbed soils and chemically killed residues. Under most conditions, these NT seeders effectively prepare a mini in-row seedbed and precision-place seeds at desired depths in the soil (Hayes, 1945; Gebhardt and Fornstrom, 1985). Excellent progress is also made in developing more sustainable NT systems for corn *(Zea mays* L.) in which heavy stands of mechanically killed, cereal-legume cover crops are used to partially or even totally replace conventional inorganic herbicides and nitrogen fertilizers (Ess et al., 1992a and b; Vaughan et al., 1992).

Tobacco and Vegetables

Direct seeding of tobacco and vegetable crops using NT systems is not a commercial practice in the United States, except for a relatively small acreage of sweet corn and snap beans (CTIC, 1992). Although small-seeded species, such as broccoli, have been successfully seeded in NT systems (Schertz et al., 1986; Young, 1989), lack of precision vegetable seeders and effective registered herbicides have virtually inhibited adoption of commercial NT production systems for these crops (Standifer and Best, 1985; Putnum, 1986; Lanini, 1989). Setting vegetable and tobacco transplants in undisturbed soils have been tested for over 20 years (Moschler et al., 1971; Morrison et al., 1973; Knave1 et al., 1977; Worsham, 1985). Yield results have been inconsistent for basically the same reasons as discussed for NT production of direct-seeded agronomic crops in the 1940s and 1950s.

No-Tillage Transplanters

To meet farmer expectations and perform satisfactorily under a wide array of soil and plant-residue conditions, NT transplanters must fulfill the following basic requirements: a) be constructed heavy enough and strong enough to efficiently set plants in adverse conditions such as compacted, hard (dry), moist, or rocky soils; h) have a high clearance design and the capacity to set plants in heavy residues with minimal disturbance of surface soil and surface residues, thereby maximizing soil and water conservation and improving weed control; c) till or loosen a narrow band of soil and displace small rocks to ensure proper functioning of the transplanter shoe and placement of the transplants--the volume of loosened soil should measure 5 to 10 cm wide and 15 to 25 cm deep, depending on the species grown and soil amendments applied; d) firm the loosened soil around the transplant to ensure the necessary root-soil contact for optimum survival and growth of the plants; and e) have the capacity to precision-place requisite pesticides and fertilizers to ensure survival and rapid growth of the plants.

Currently, there are no commercially available NT transplanters that will even remotely approach the five requirements listed above (Standifer and Best, 1985; Shelby et al., 1988). Some of the major manufacturers of conventional transplanters in the United States and Europe offer up-front coulter attachments installed on their normal conventional transplanters. Under light-residue and moist, friable soil conditions, these "no-till" transplanters will function properly and plant yields are good (Wilhoit et al., 1990). However, this exacting requirement for soil moisture and soil tilth limits the usefulness of these transplanters. Furthermore, when used in excessively wet soils, the coulter and shoe of the transplanters merely part or slice open the soil without loosening or crumbling it. The root-soil contact of transplants set in these soil "wedges" or "slices" is poor, resulting in reduced plant survival and slow plant growth. In the drier, more normal conditions characteristic of hilly, well-drained soils ideal for NT systems, the efiectiveness of the existing NT transplanters has been unreliable and has slowed adoption of this technology. Under dry conditions, these transplanters are virtually nonfunctional. The shoe cannot effectively penetrate the soil, resulting in frequent mechanical breakdowns and resetting of plants.

The evolution of NT transplanters has taken a similar path, as with the NT seeders. In the late 1960s and 1970s, various researchers used locally modified conventional transplanters to set tobacco (Morrison et al., 1973; Chappell and Link, 1977; Worsham, 1985) and vegetable (Knavel et al., 1977; Knavel and Herron, 1981) transplants in undisturbed soils. The changes made consisted of three main modifications: a) attaching a coulter ahead of the standard machine to cut the surface mulch and roots of the killed sod to a depth adequate for transplanting; b) replacing the conventional shoe-type furrow opener with a double-disc opener to part the surface residues and more adequately protect the shoe; and c) adding additional weights on the press wheels and/or behind the planter to ensure adequate planting depth. Survival, growth, and yield of the tobacco and vegetables set with these early NT models were inconsistent because of erratic weed and insect control (Worsham, 1985) and poor root-soil contact (Knavel and Herron, 1981). The later problems (poor root-soil contact) can be serious in early-spring plantings (cold, wet soils) and compacted, less friable soils, principally because these transplanters do not till or loosen a narrow strip of in-row soil (Zartman et al., 1975; Knavel and Herron, 1981).

In attempts to rectify the soil compaction problems associated with the earlier NT planters, North Carolina and Virginia researchers in the 1980s experimented with two major changes. First, by replacing the double-disc shoe with a conventional shoe having a narrow cultivator-type nose or point welded in front, in-row soil was loosened and braught to the surface to facilitate improved root-soil contact by the firming action of the press wheels. This modification resulted in improved crop establishment; however, often the rigid-mounted, fragile shoe did not hold up well in dry, rocky, or compacted soils because the shoe was required to "plow" the unloosened soil. Second, a two-pass system was developed–using a Bushhog Ro-till machine (Hoyt, 1985; Morse, 1989) or a light-weight modified version of the Ro-Till (Wilhoit et al., 1990) to till a narrow strip (20 to 30 cm wide) in one operation, followed in a subsequent operation by using a conventional transplanter for plant establishment. The Ro-Till machines effectively loosened in-row soils, resulting in excellent survival, growth, and yield of the vegetables tested; however, this more expensive two-pass system did not find favor with the farmers. In the relatively wide-tilled strip, the soil was exposed and weed seeds were brought to the surface, resulting in decreased soil and water conservation and increased weed problems, compared with NT systems.

The Subsurface Tiller Transplanter (SST-T)

A strong movement in the 1990s toward a more sustainable agriculture has stimulated the development of the Subsurface Tiller Transplanter (SST-T), which was released in late May 1992 (Fig. 1). The SST-T has an upright, high-clearance design with a double-disc shoe similar to that of the 1970s' models. However, in

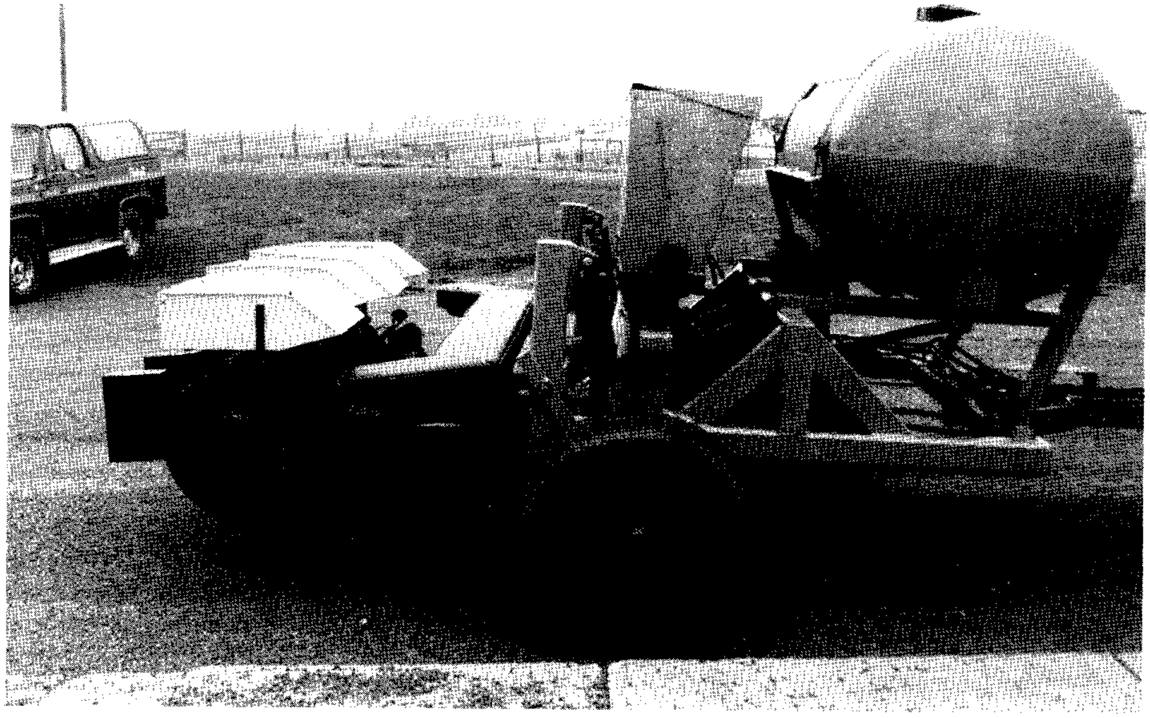

Fig. 1. The Subsurface Tiller Transplanter (SST-T). The SST-T has two main components -- the SST up-front that loosens a narrow strip with minimal disturbance of the surface soil or plant residue; and a conventional transplanter aligned behind the SST to set plants in the tilled strip. The transplanter shown in this photo is the Holland (Holland Transplanter Co.--Holland, MI) Model 1600 with a double-disc assembly added in front of the standard round-point shoe. The SST component also includes a hydraulic-driven Holland fertilizer attachment.

addition, the SST-T has a unique subsurface tiller (SST, patent pending) aligned in front of the double-disc shoe of the transplanter. The SST is composed of a DMP Tru-Tracker (Fig. 2) mounted on a 10 x 10-cm tool bar. The Tru-Tracker contains a 50-cm smooth, spring-loaded coulter and a ACRA-plant fertilizer knife with a winged point that is designed to loosen a narrow strip (5 to 10 cm wide).

The conceptual design and functioning of the SST-T is uniquely different from that of the earlier NT transplanters. With the NT models of the 1980s (NT80s), the cultivator-type shoe performs both the tilling and the planting functions. Under compacted, rocky conditions, the rigid-mounted shoe of the NT80s was easily bent or broken, which seriously reduced its usefulness for conservation tillage systems. In contrast, the spring-loaded Tru-Tracker component of the SST-T has heavy-duty construction and subsurface tills a narrow strip of soil ahead of the double disc shoe of the transplanter. The double-disc shoe moves through the residues and tilled strip with relatively little resistance and with minimal surface soil and surface residue disturbance. The SST-T is an efficient (less equipment breakdown) and effective (less resetting needed) transplanting system that, when used in heavy residues, maximizes soil and water conservation and early field reentry permitting planting, spraying, and harvesting operations to be done within a few hours following irrigation or rainfall.

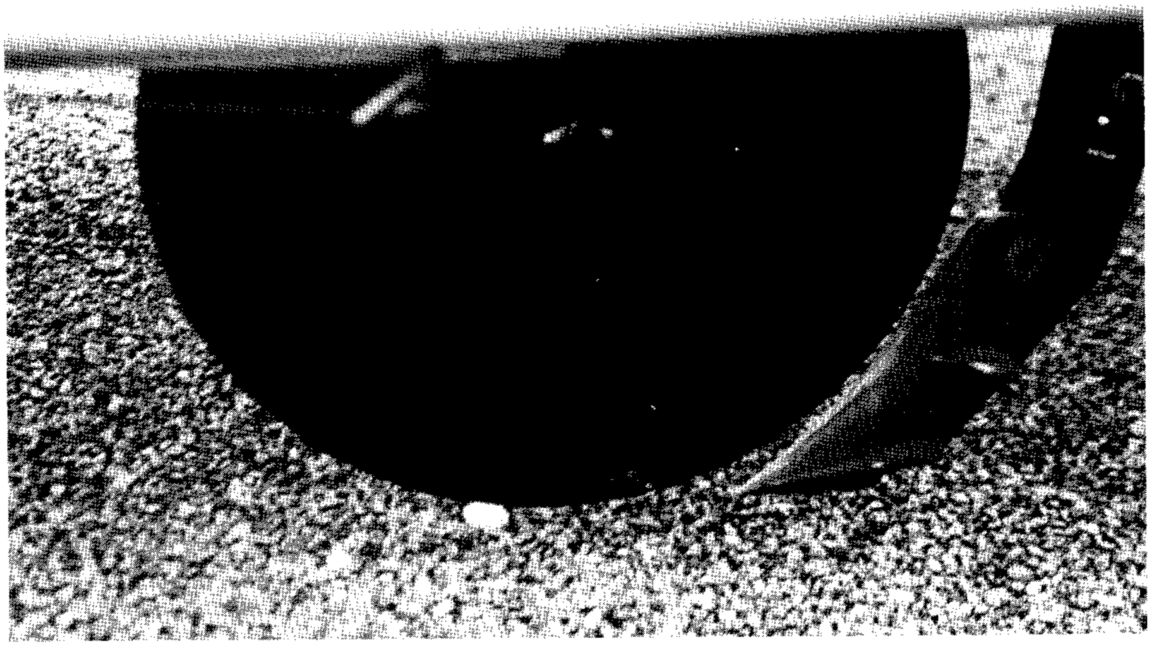

Fig. 2. A close-up of the bottom part of the soil loosening mechanism of the Subsurface Tiller (SST)--composed of a DMI (DMI, 1nc.--Goodfield, IL)Tru-Tracker and a ACRA-Plant (ACRA-Plant Sales, 1nc.--Garden City, KS) Knife with a winged point.

The single coulter and double-disc shoe of the NT models of the 1970s (NT70s) often do not loosen enough in-row soil for optimum root-soil contact, resulting in reduced plant survival and slow early growth of the improperly set transplants. Fluted or ripple coulters can loosen more in-row soil than the smooth coulters; however, they do not cut the residues as effectively as the smooth coulter and may cause hair pinning (pressing of the residues into the soil without cutting).

The SST-T is also equipped for precision placement of a) liquid starter fertilizer-pesticide solutions around the root system of the transplant, b) liquid fertilizer solutions underneath the transplant, and c) granular base fertilizers surface applied in two bands on either of the transplant rows. A combination of these treatments is expected to eventually give the most efficient use of soil amendments. In future experiments, the SST-T will be used to test various combinations of both inorganic and organic (natural) soil amendments for optimum growth of tobacco and vegetable crops.

CONCLUSION

Conservation tillage principles and practices have evolved over the past 50 years until they were widely accepted, and have a significant, annually increasing proportion of the acreage of corn, soybeans, cotton, sorghum, and cereal grains. Although NT systems for transplanted row crops are still relatively unknown and are predominantly in the experimental stages, there is considerable interest in using more sustainable production methods in areas where transplanted tobacco and'vegetable crops are grown on hillslopes and other erosive and droughty conditions.

Lack of reliable NT transplanters have been a major factor limiting the adoption of NT systems for transplanted row crops. A new transplanter, the Subsurface Tiller Transplanter (SST-T), was recently developed that incorporates the best components of previous models into an efficient one-pass planting system. The SST-T offers a viable compromise between conventional tillage (CT) and the previously tested NT transplanters of the past two decades (NT70s and NT80s). The SST-T has three major advantages over the previous models.

More efficient and effective planting. By loosening a narrow strip of in-row soil, the Tru-Tracker component of the SST improves both crop establishment and yield. Using the Tru-Tracker as the tillage instrument reduces damage to the shoe of the transplanter. In the NTSOs' models, the shoe itself is the tillage instrument and, therefore, it takes the brunt of the physical abuse in rocky and compacted soils. The Tru-Tracker works well in difficult soils, preparing a tilled strip for the shoe that follows.

Increased capacity to set plants in heavy residues, thereby. maximizing soil and water conservation. To effectively set plants in heavy residues, a high-clearance, double-disc shoe is superior to low-clearance, blunt- or round-point shoes. In some NT80s models, the side braces of the shoe catch the cover crop residues, resulting in residue clogging or build-up ahead of the shoe. With the SST-T one-pass system, the coulter and fertilizer knife of the Tru-Tracker part the residue with minimal disturbance and the double-disc shoe follows along in the tilled strip without residue build-up.

Reduced disturbance of surface residues and surface soil. thereby, improving weed control. To obtain good root-soil contact in an undisturbed soil, the in-row tillage mechanisms of the NT transplanter must adequately loosen the soil, and the press wheels must have the capacity to effectively close the narrow furrow and firm the soil around the roots. With too little soil loosening, setting and survival of plants may be impaired. Disturbing too much soil and plant residues may minimize the desired soil and water conservation and weed control benefits of NT farming. By modifying the location and the type of point on the transplanter shoe and the fertilizer knife of the Tru-Tracker, the amount and distribution of loosened soil can be altered. Although considerable progress has been made in this area, testing different subtiller and shoe designs will he continued to obtain the desired amount and distribution of loosened soil in different field situations.

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PEARL MILLET PRODUCTION IN A NO-TILLAGE SYSTEM

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ABSTRACT

Pearl millet [Pennisetum americanum (L.) Leeke] is a potentially productive, high-quality grain or silage crop that will produce grain and silage with limited soil moisture. Our objectives were to compare no-till and conventional tillage methods for pearl millet and tropical corn (Zea mays L.) planted after wheat (Triticum aestivum L.), determine pearl millet response to N fertilization rates on grain and silage yields, determine tolerance to herbicide, compare In vitro organic mater digestibility (IVOMD) of pearl millet silage with tropical corn, and evaluate pearl millet response to growth regulators. This research was conducted on a Norfolk sandy loam located on the North Florida Research and Education Center, Quincy, FL with HGM-100 (W.W. Hanna, Tifton, GA) pearl millet hybrid. Pearl millet (HGM-100) grain and total silage yields were higher in the no-till, in-row subsoil method of planting than in the conventional method in 1992, but no differences were found between methods of planting for tropical corn (Pioneer 3098) in relation to grain or silage yields. Pear1 millet grain yields increased with increasing N fertilization. Atrazine 1 1/2 qt + Prowl 1 pt + oil 1 qt is the most satisfactory chemical herbicide (not significantly different). Pearl millet silage with grain is more digestible (64.7% IVOMD) compared with silage without grain (49.4% IVOMD). In vitro organic mater digestibility of HGM-100 > Pioneer 3098 > Pioneer X304C. Although yields from growth regulator were not significantly different, Pix resulted in higher yields.

INTRODUCTION

Pearl millet is a potentially productive, high-quality (Burton et al., 1986 and Kumar et al., 1983) grain or silage crop that appears superior to sorghum (Sorghum bicolor L. Moench) in establishment (Smith et al., 1989b) and production under limited soil moisture (Smith et al., 1989a). It is the principle grain crop in the Sahel (Niger and Senegal, West Africa) and is grown under low-input management conditions (noncrusting, sandy soils with little fertilizer and limited water; Payne et al., 1990). Timing and intensity of water stress account for 70 to 85% of the variation in grain yields within and across years (India; Mahalakshmi et al., 1987 & 1988). Critical growth stages receiving stress were flowering and grain filling. Grain yield and grain number, but not grain size, were affected by time of stress onset in relation to flowering. Effects of timing are also dependent on the intensity and duration of the stress period (Mahalakshmi and Bidinger, 1985).

Hattendorf et al, (1988) has published measured ET/reference ET for pearl millet, which shows the greatest water use at 0.52 of the growing season, about when 50% bloom occurs. Boot stage occurred at 0.42 and soft dough stage at 0.69 of the growing season. Water use values during the season were similar for sorghum and pearl millet and less than corn, soybean, or sunflower. However, pearl millet had a higher daily water use rate than corn or sorghum. This indicates that pearl millet has a greater rooting depth and density (Davis-Carter, 1989) than corn or grain sorghum. Since greater available water usually results in greater evaporation and aboveground biomass of crops (Teare, 1977), it follows that pearl millet should produce a large aboveground biomass. Hattendorf et al. (1988) report that pearl millet had the greatest leaf area index of all the crops studied, and only corn produced a significantly greater aboveground biomass. The corn seed yield was three times greater than the pearl millet yield. Aboveground dry matter was 20.1, 15.7, and 15.6 Mg ha^{-1} and seed yield was 7.6, 63, and 2.5 Mg ha^{-1}, respectively for corn, sorghum [Sorghum bicolor (L.) Moench] and pearl millet. Average emergence dates were 26 May, 10 June, and 10 June, respectively.

Bationo et al. (1990) have shown that increases in fertilization and plant density increase grain yield of pearl millet in average or wet years and only reduce yield slightly in a drought year. Alagarswamy and Bidinger (1987) assessed the differences for nitrogen use efliciency among 20 diverse pearl millet genotypes from a field study. These genotypes differed little in total N uptake, but considerable differences existed in the amount of biomass produced, hence, nitrogen use efliciency.

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In vitro organic matter digestibility is a reliable estimate of in vivo digestibility of forage harvested from sandy soils (Moore and Mott, 1974). Pearl millet has been shown to be highly digestible by swine (Haydon and Hobbs, 1991), beef cattle (Hill and Hanna, 1990), poultry (Smith et al., 1989b), and catfish (Burtle et al., 1992). Hanna et al. (1974) have shown that hairy pearl millet leaves were more digestible than trichomeless pearl millet (33.5 and 25.5% IVOMD, respectively). Monson et al. (1986) found that lines of pearl millet resistant to rust (Puccinia substriata var. indica) were more digestible than rust-infected, rust-susceptible lines (rust-resistant IVOMD means were 64.6 and 57.6%, respectively, for 1981 and 1982). They also compared leaves for rust-resistant and rust-infected, rust-susceptible lines of pearl millet and found IVOMD 58.8 and 54.5%, respectively.

Pearl millet (Pennisetum glaucum L) has been shown to reduce root-lesion nematode [Pratylenchus penetrans (Cobb) Filipjev & Schur-Stekhoven] populations in soils for following crops of alfalfa (Petersen et al., 1991). This aspect should be investigated with Pennisetum americanum Leeke in relation to reducing other nematode populations in southern soils for the following soybean or peanut crops.

The objectives of this study were to 1) compare no-till and conventional methods of planting pearl millet with tropical corn in a double-crop system after wheat, 2) determine N influence on pearl millet grain and silage yields, 3) determine pearl millet tolerance to herbicide, 4) to evaluate the IVOMD of pearl millet silage with and without grain and heads for comparison with tropical corn, and 5) determine irrigation and growth regulator effects on pearl millet.

MATERIALS AND METHODS

These studies were conducted in 1992 on a Norfolk sandy loam (fine, loamy siliceous, thermic Typic Kandiudult) located on the North Florida Research and Education Center, Quincy, Florida. The soil has a compacted layer located 8 to 14 inches below the surface. The pearl millet hybrid used was HGM-100, developed as a grain pearl millet by W.W. Hanna (1991), Tifton, Georgia.

The planting method comparison for tropical corn (Wright et al., 1990) and pearl millet was planted in a split plot arrangement on 25 June. Seed of pearl millet were planted % inch deep at 3 Lb/A and tropical corn seed were planted 3/4 inch deep and 20,000 plants/a. The split was tropical corn vs. pearl millet within each replication, but the no-till vs. conventional tillage methods were allocated at random. Each plot had eight rows 36 inches apart and 25 feet long. The conventional method of tillage consisted of four separate operations; harrow, chisel, harrow, and plant with a Brown Ro-Ti1 implement with KMC planters. The no-till consisted of planting in wheat stubble with a Brown Ro-Ti1 implement with KMC planters. Starter fertilizer (19-9-3 LB/a) was applied tothe side of the row. Nitrogen was sidedressed at 120 lb/A on 16 July. Atrazine at 2 qt/A + Gramoxone at 1pt/A + X-77 surfactant was used for burndown of weeds. Harvest date for pearl millet was 4 Sept and 21 Oct for tropical corn. Much rain occurred throughout the growing season (Fig. 1) and only six irrigations were necessary (described in irrigation-growth regulator methods).

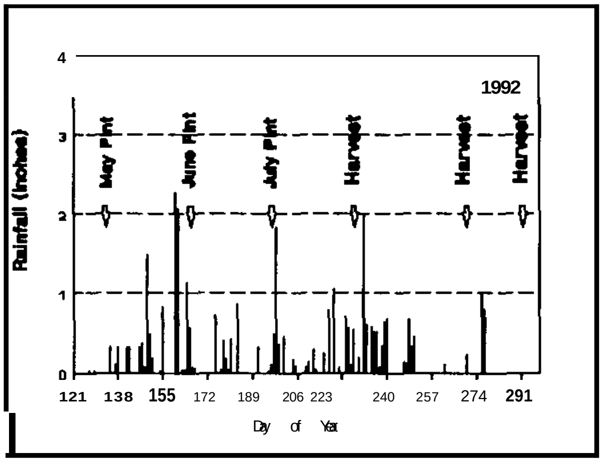

Figure 1. Rainfall during the 1992 pearl millet growing season in relation to rainfall amounts and dates of events.

The nitrogen study was planted conventionally after chisel plowing and harrowing on 20 May. Fertilizer was broadcast after chiseling at the rate of 0-40-60 Ib/A for P_2O_5 and K_2O, respectively. Atrazine at 1% qt + crop oil was applied when millet was 3 to5 inches tall. The N treatments were applied a few days after emergence. Nitrogen treatment rates were 0, 50, 100, and 150 lb/A Three planting dates were planted for grain and silage yields, hut only the 20 May planting had harvestable grain (harvested on 19 Aug) because of bird damage on later plantings.

The herbicide study was conventionally prepared by chisel plowing on 19 May with fertilizer applied after chiseling at the rate of 20-40-60 lb/A broadcast and harrowed. Pearl millet seed was planted at a 1/2-inch depth at 3 lb seed/A on 20 May. Millet emerged on 25 May, and herbicides were applied (Table 1) on 6 June when millet was 3 to 5 inches tall. Pearl millet grain and silage (with and without grain) were harvested on 19 Aug to determine the grain yield and silage yield components. Grain harvesting was accomplished by raising the combine header to maximum height and threshing the heads and grain. Then silage yields were taken by chopping the remainder of the plant with a small plot silage harvester. The reason for this method of harvest was to study the management option of harvesting the heads for seed and the remainder of the plant for silage or all for silage. By correcting for chaff and upper stalk loss, total silage was computed for other comparisons in Table 1. Silage was corrected to 35% DM.

Four silage replicates were taken of each pearl millet herbicide treatment and two tropical corn hybrids (Pioneer 3098 and Pioneer X304C) for IVOMD analysis as described in Moore and Mott (1974). The two tropical corn hybrids were in an adjoining corn hybrid experiment with similar planting dates (14 May, but with later harvest date of 5 Oct).

An irrigation-growth regulator study was conventionally prepared and planted on 17 June to determine 1) irrigation response of grain millet and 2) yield response to growth regulators. Irrigation was scheduled when tensiometers at a 6-inch depth reached 20 cb and applied in 0.33-inch quantities on 15, 18, 21, 22, 26 May and 10 July with an overhead sprinkler system (total = 2 inches). This is in addition'to the 20 inches of rainfall received during the pearl millet growing season (17 June to 21 Sept, 1992) (Fig. 1). Fertilizer was applied at the rate of 20-40-60 lb/A of N, P_2O_5, K_2O, respectively. Nitrogen was sidedressed soon after emergence at 100 lb/A. Atrazine at 1% qt + oil was applied when millet was in the 3- to 5-leaf stage (this herbicide treatment killed some of the millet plants). Growth regulator treatments (Pix at 3/4 pt/A), Cerone at 3/4 pt/A) were applied on 24 July when millet was about 2 ft tall. By 1 Sept, hundreds of blackbirds were in these plots before harvesting on 2 Oct 1992. Since there was little grain left in the heads, grain yields were calculated from silage data with grain. Silage ratios of the Atrazine 1/2 qt + Prowl 1 pt + oil 1 qt treatment are given in Table 3. Since there was some bird damage to the May planting, the estimates are conservative.

RESULTS AND DISCUSSION

Grain and total silage yields of grain millet and tropical corn grown following wheat under different tillage methods are shown in Table 1. The components of silage yield are also shown for pearl millet. The no-till plus in-row subsoiling method of planting significantly increased pearl millet grain and silage yields, but had no significant effect on tropical corn yield.

Optimum N rates may not have been reached in the N study since grain yields continued to increase with N application to 150 lb/A (Table 2). The study was harvested on 19 Aug, about 90 days after planting, with some bird damage evident. Further studies will be conducted in larger fields in the future to avoid this damage.

The herbicide study (Table 3) showed that best yields lor both silage and grain were obtained from the hand-weeded check Treatments with Atrazine + oil and Atrazine + Prowl + oil were not different from the hand-weeded check Adding Pursuit herbicide did not affect silage yield dramatically but did significantly reduce grain yields. Accent herbicide gave 100% control of the grain millet and should never be applied to a production field. The Atrazine, Prowl, and oil treatments used on corn may be satisfactory for millet; however, more work over a wider range of environmental conditions needs to be completed along with normal labeling procedures for pesticides before making large scale recommendations. Ratios of grain and total silage are of interest when evaluating silage for ruminant animals. Our range of ratios are similar to the 0.11 to 0.19 range calculated for the Nebraska pearl millet grain type experimentals used in their experiment.

In vitro dry matter digestibility values show that pearl millet silage with grain (64.7%) was more digestible than silage without grain (49.4%) (Table 4). HGM-100 silage (64.7%) was more digestible than Pioneer 3098 (61.9%) or Pioneer X304C (59.9%) tropical corn silage.

The growth regulator Pix was not different from the control, but Cerone produced less silage yield than the other treatments (Table 5).

Rust (Puccinia substrata var. indica) occurs on pearl millet in most years (Monson et al., 1986). We have not observed the rust problem on HGM-100, but have observed some anthracnose and fall armyworm

Table 1. Influence of planting method (planting date 25 June) to compare tropical corn [harvested 21 Oct, 43" rainfall (rf)] and pearl millet [harvested 4 Sept, (30" rf)], Quincy, FL, 1992.

Method of Planting	Pearl Millet'				Tropical Corn[2]		
	Grain[3]	silage'			Grain[3]	Silage[4]	
	-bU/A-	-----ton/A-----			bu/A	--ton/A--	
No-till and in-row subsoil	64.9	2.7	10.9	18.5	43.4	1.8	9.5
Conventional	55.9	2.3	9.5	16.1	43.0	1.8	9.4

[1] Pearl millet grain was not harvested because of bird damage, but calculated according to Table 1 ratios.
[2] Pioneer Brand 3098.
[3] Corrected to 35% DM.
[4] Corrected to 15.5% moisture.

Table 2. Influence of nitrogen rate on grain moisture, grain yield, and seed weight of pearl millet planted 20 May and harvested 19 Aug (24" rf), Quincy, FL, 1992.

N Rate (lb/A)	Grain Moisture (%)	Grain Yield' (bu/A)	Seed wt (gm/200 seed)
0	13.8	29.5	1.08
50	13.6	55.3	1.42
100	13.4	65.6	1.31
150	13.5	81.5	1.37

[1] Corrected to 15.5% moisture

Table 3. Influence of herbicide on millet grain and silage yields at the 20 May date of planting. Harvest date was 19 Aug., Quincy, FL, 1992.

Treatments	Grain[1,2] yield (bu/A)	Silage Yield[3] (ton/A) Grain only	Top only	Sil w/o G&T	Total Silage	Gr:Sil[3] Grain/ Total
Hand-weed check	64.6a	2.6	6.7	10.9	20.2	0.13
Atraeine 1½ qt + oil 1 qt	55.9a	2.3	4.2	11.8	18.3	0.13
Atrazine 1½ qt + Prowl 1 pt + oil 1 qt	60.0a	2.5	4.6	10.3	17.4	0.14
Unweeded Control	63.8a	2.6	4.9	8.7	16.2	0.16
Atrazine 1½ qt + Pursuit 2 oe + oil 1 qt	38.8b	1.6	6.3	8.3	16.2	0.10
Atrazine 1½ qt + Accent ⅔ oz + oil 1 qt	0.0c	0.0	0.0	0.0	0.0	0.0
$LSD_{.05}$	16.7					

[1] Weans in a column followed by different letters are significantly different at the 5% level of probability.
[2] Corrected to 15.5% moisture.
[3] Corrected to 35% DM (G = grain, T = top)

Table 4. In *vitro* organic matter digestibility (IVOMD) of pearl millet silage samples with and without grain and top and tropical corn (Pioneer 3098). Pearl millet for silage and grain was planted 20 May and harvested on 19 Aug. Tropical corn for silage, including grain, was planted 14 May and harvested 5 Oct (43" rf), Quincy, FL, 1992.

	IVOMD %[1]	
Pearl Millet (HGM-100)	Silage w/grain	Silage w/o grain
Hand-weed check	67.6 a	42.8 b
Atra. 1/2 qt + Prowl 1 pt + oil 1 qt	65.4 ab	49.2 ab
Unweeded control	64.0 ab	49.5 ab
Atra. 1/2 qt + Pursuit 2 oz + oil 1 qt	63.4 b	56.4 a
Atra. 1/2 qt + oil 1 qt	63.1 b	48.9 ab
HGM-100 mean	64.7 A	49.4 B
Tropical Corn		
Pioneer 3098 mean	62.3 B	---
Pioneer X304C mean	60.4 C	---

1 Means with the same letter are not significantly different with the Duncan's multiple range test.

Table 5. Influence of growth regulators and irrigation on silage yields (w/o grain) of grain millet (planted 17 June and harvested 21 Sept, 20" rf), Quincy, FL. 1992.

	Silage Yield 35% D.M. (ton/A)			
Treatment	control	Pix	Cerone	Avg.
Irrigated	21.0	21.0	19.7	20.5
Not Irrigated	21.9	22.2	17.6	20.5
Avg.	21.4	21.6	18.6	

[Spodoptera frugiperda (J.E Smith)] damage on pearl millet, but the damage was minor compared with that on tropical corn in 1992.

Again, more work needs to be conducted at locations where bird damage will be less of a problem (larger fields of pearl millet). Much more research needs to be done with the grain millet to determine silage and grain yield potential, management, and its effect on nematode populations on crops in rotation, i.e., peanut and soybean.

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STUBBLE MANAGEMENT, PREPLANT TILLAGE, AND ROW SPACING FOR DOUBLE-CROPPED SOYBEANS

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INTRODUCTION

Growers in Arkansas double-crop almost all the wheat acreage with soybeans. The most accepted practice has been to burn the wheat straw, disk, and plant. State laws were passed in 1990 making a grower liable for automobile accidents caused by burning wheat straw. Conservation compliance has caused many growers to begin Investigating alternatives to burning of wheat straw. Federal clean air standards make burning of wheat straw illegal. These clean air standards have not been rigorously enforced. Limited research has shown substantial yield increases to narrowing rows from 38 to 19 inches (Mascagni et al., 1992). Different yield responses were obtained on different soil types, depending on whether straw was removed or left on the soil surface.

The objective of this study was to investigate 1) narrower row spacings similar to that obtained by grain drills versus that needed to physically cultivate or direct spray herbicides (17 to 22 inches), 2) straw managements of incorporation by disking versus straw burning versus no-till planting into undisturbed straw behind the combine, 3) no-till seedbed preparation versus disking for previously stated row spacings and straw managements.

MATERIALS AND METHODS

Experimental sites were selected at two Arkansas locations: the Cotton Branch Experiment Station (CBES) at Marianna and Little Rock. Experiment design was split, split, split plot with four replications. Main plot was disk twice or no-till. First split was row spacing of 19 or 22 inches versus 6 to 10 inches (drilled). Second split was stubble management, i.e., burn or no burn. Third split was post plant cultivation, yes or no. Dates for performing selected cultural practices and other site characteristics are shown in Table 1. Soil types at CBES and Little Rock were Loring silt loam and Rilla silt loam, respectively. All preplant no-till plots received a burndown treatment of glyphosate (Roundup) at 0.9 Ib ai/A Tilled plots were disked once with imazaquin (Scepter) at 0.28 lb ai/A being incorporated on the second disking or do-alling. Weed control followed Arkansas Cooperative Extension recommendations on a plot by plot evaluation of the need to apply herbicides. At Little Rock and CBES, postemergence applications of fomesafen (Reflex) at 0.375 lb ai/A and fluazifop-P (Fusilade 2000) at 0.188 lb ai/A were applied as needed for least cost weed control. Yields were adjusted to 13% moisture.

Table 1. Selected experimental sites and crop developmental characteristics.

	Little Rock	CBES
Soil Type	Loring silt loam	Rilla silt loam
Burndown Date	6-24-92	6-25-92
Disking Date	6-24-92	6-25-92
Planting Date	6-24-92	6-25-92
Row Spacing Wide	22.5	19
Row Spacing Narrow	7.5	9.5
Harvest Date	10-23-92	10-21-92

RESULTS AND DISCUSSION

For the 1992 growing season, no interaction between any of the main effects was found. As a result, each effect is additive and will be addressed separately.

Narrowing the rows resulted in a 10 and 14 bushel yield increase (Table 2). Previous results have shown yield increases by narrowing row spacing from 38 to about 20 inches to be as much as 60%. From a practical implementation, a row spacing of 17 to 22 inches is about as narrow as can be cultivated or herbicides directed under the canopy. This test goes one step further, narrowing rows to 10 inches or less. This could become very important if planting after wheat harvest.

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Table 2. Yield results for double-cropped soybeans at Little Rock and CBES, 1992.

	Row Spacing		Preplant Tillage		Straw Burning		Post-Plant Tillage[2]	
Location	**Wide[1]**	**Narrow**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
	(bu/A)							
Little Rock	**24**	**38**	**38**	**23**	**32**	**29**	**23**	**24**
CBES	16	26	22	20	22	20	17	16

[1] Row spacings were 22.5 and 7.5 or 19 and 9.5 inches at Little Rock and CBES, respectively.
[2] Post-plant cultivation was conducted only in wide rows.

Preplant tillage resulted in a 2- to 15-bushel yield increase. Little Rock had a thin stand of wheat, resulting in a light straw load. Consequently, partly because of the wet spring, partly because of the thin stand, vegetation was very heavy and older at Little Rock. Large broadleaf weeds and grasses were not completely controlled with the chemical burndown. Consequently, Scepter over top (OT) was used on some plots. Additionally, preplant tillage at Little Rock controlled all weeds, and we feel this preplant weed control is the primary reason preplant tillage resulted in a yield increase.

For this one year, burning wheat straw gave an advantage over unburned. This is contrary to results we have obtained in drier years. The straw burn was very poor at Little Rock, leaving several large broadleaf weeds and grasses. TheCBES was normal with a good straw load and relatively light weed pressure. The fire was hot enough during the straw burn to completely kill all existing aboveground vegetation.

Post-plant cultivation resulted in a nonsignificant change of -1 bu/A at Little Rock and +1 bu/A at CBES. No previous work is available for reference.

Operating and ownership expenses, as well as profits, were estimated using crop production budgets (Windham et al. 1991a and 1991b). These costs and profits are reported in Table 3. A savings of preplant tillage was offset by the cost of burndown chemicals. The yield response at Little Rock from the preplant tillage resulted in dramatic profit increases. The burning offset the burndown herbicide cost during this wet year. Post-plant cultivation reduced profits at Little Rock about $10.00/A but made essentially no change in profit at Marianna.

Yield component analysis was performed to assign values to various management options (Table 4). By analyzing the options in this way, a Best Management Practices (BMPs) package can be developed. The cost of different management options can also be determined. The base yield is the lowest obtained in the test. There is a minimum cost of production that can be associated with the base yield. Note, there was a net loss if no practices were used to improve profitability. If all of the BMPs were followed, the net profit was improved from -$8.70 to $148.09 and -$22.14 to $41.09 at Little Rock and CBES, respectively.

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Table 3. Costs and profits associated with different cultural practices for double-cropped soybeans.

Specification	Location: Little Rock		CBES	
	---$/A---			
Row Spacing	**Wide**	**Narrow**	**Wide**	**Narrow**
Cost'	**$71.24**	**$81.22**	**$70.10**	**$79.48**
Profit'	**$60.36**	**$125.98**	**$19.50**	**$65.98**
Preplant Tillage	**Yes**	**No**	**Yes**	**No**
cost	**$80.44**	**$68.69**	**$78.22**	**$68.24**
Profit	**$114.63**	**$49.84**	**$34.71**	**$33.50**
Burning	Yes	No	Yes	No
cost	$74.64	$74.49	$73.41	$73.05
Profit	$84.96	$7951	$40.46	$27.75
Cultivation	Yes	No	Yes	No
cost	$74.47	$74.61	$73.49	$73.10
Profit	$5433	$96.19	$18.91	$41.70

[1] Cost are variable costs adapted from crop production budgets of Windham et al., 1991a and 1991b.
[2] Profit is defined as yield times $5.60/bu minus cost.

Table 4. Component analysis of best management practices to produce the most economical yield.

Cultural Practice	Little Rock: Yield	Total Cost'	Profit Above T.C.[2]	CBES: Yield	Total Cost'	Profit Above T.C.[2]
	-bu/A-	---$/A---		-bu/A-	---$/A---	
Base Yield Contrib.	13.7	61.65	16.75	113	6120	0.40
From Nar. Rows	132	9.98	6953	9.6	938	43.82
From Preplant Till	14.9	11.75	64.97	1.6	9.98	121
From Burning Straw	2.8	0.15	5.45	1.4	036	12.71
From Post-plant'	--	0.00	0.00	--	**0.00**	**0.00**
Total	44.6	83.53	156.70	232	80.92	58.14

[1] Total ownership cost is adapted to cultural practices actually used from the production budgets of Windham et al. 1991a and 1991b.
[2] Profit is defined as yield times $5.60/bu minus cost.
[3] Best system was narrow rows, and there is no post-plant tillage with narrow rows.

SILAGE EVALUATION OF TROPICAL CORN IN A STARTER-MINIMUM TILLAGE SYSTEM

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ABSTRACT

The greatest economic value from a corn (Zea mays L.) crop is obtained when it can be used as silage rather than for grain only. The objectives were to study tropical corn silage yield and quality in relation to starter fertilizer, planting date, corn hybrid, and fall armyworm stress. This study was conducted in the field at Quincy and Jay, Florida during 1991 and 1992. Results have shown the interaction of tropical corn silage to starter fertilizer and hybrids. Pioneer X304C was a positive changer, DeKalh DK 9101 was a no-changer, and Pioneer 3099 and Cargill X70lTR were negative changers. In 1992, the fall armyworm migrated to Quincy 1 month earlier than usual. Some hybrids were not as tolerant to the fall armyworm as others. Late-planted tropical corn resulted in high yields of corn silage. Feed quality 1% CP and in vitro organic matter digestibility (IVOMD)] of tropical corn grain and silage varied in relation to planting date and hybrid.

INTRODUCTION

The greatest economic value from a corn crop is obtained when it can be used as silage rather than only for grain. Recently, in the "Sunbelt" of this area, there has been a surging growth of population accompanied by increased sales of milk and milk products and significant growth in dairy farming. Increased dairying has been most notable in Florida, Georgia, and Texas, with a concomitant increase in the demand for corn silage of highly digestible dry matter (DM).

Most of the high yielding (temperate) corn hybrids in the U.S. produce silage in which nearly 50% or more of the DM is grain. Feeding silage, high in non-structural carbohydrates (starch), to ruminants, such as production stressed cows, can cause severe problems in the digestive tract unless the total feed is formulated to compensate for the high proportion of starch.

If corn silage with lower starch contents was used (no more than 40% of the DM as grain, i.e., tropical corn), it would be easier to maintain lactating cows with normal healthy digestive systems. Thus, corn silage containing lower proportions of grain would be more desirable for dairy farmers provided high digestibility could be maintained or increased without any reduction of silage intake by cows (Johnson, 1991).

Legislated disposal of dairy waste and the recycling of waste as fertilizer for the year-round production of dairy forage (sequential-cropping) may become the driving force for the use of tropical corn or pearl millet as a late summer-crop (Teare et al., 1991a) during the hot summer months in the southeast.

Struink (1982) showed that when harvested at similar maturities, the digestibilities within corn genotypes were fairly constant when grown in a wide range of environments. However, other plant characteristics, such as yielding ability, were strongly influenced hy differences in climatic conditions and associated cultural practices.

Tropical corn hybrids are most useful where prevailing environmental conditions usually are unfavorable for adapted domestic temperate cultivars (Teare and Wright, 1991). Tropical hybrids have been selected for their adaptation for short days, high temperatures, and high humidity; moderate yields at moderate fertility levels; and disease and insect resistance. In contrast, temperate hybrids have been selected for maximization of yields (high fertility rates and adequate soil moisture), early planting (cooler weather), and northern latitudes (longer days and lower humidity) (Wright and Rhoads, 1980; Wright et al., 1988). Thus, we have two corn hybrid groups that are used in different environments, depending on the planting date and degrees latitude. All tropical corn hybrids may not perform well under Southeastern conditions. Pioneer X304C is tolerant to fall armyworm and southern rust (Puccinia polysora) invasion (Teare et al., 1990), hut some tropical hybrids have been noted to have no more tolerance than temperate. hybrids. Therefore, tropical corn hybrids must be evaluated for each area/use before reliable recommendations can be made.

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Tropical corn hybrids can be no-till planted and multiple-cropped after winter grains, vegetables, or early-planted temperate corn harvested for silage (Wright et al., 1990). Early-May planting of tropical corn allows the escape of heavy infestation of fall armyworm [Spodoptera frugiperda (J. E. Smith)] that can devastate tropical corn planted after 10 June (Teare et al., 1991b).

Much of the "Sunbelt" of the southeastern United States is suitable for sequential-cropping (Wright et al., 1988) because silage crops do not require full maturity. It is possible to produce on the same land in the southeast: one winter crop of cereal grains, followed by an early-spring temperate corn crop, then a mid-summer planted tropical corn crop.

The objectives were to: 1) study tropical corn silage yields in relation to starter fertilizer and no-starter, 2) observe tropical corn silage yield in relation to planting date and fall armyworm stress, and 3) measure grain and silage quality in relation to grain and silage yields, planting date, and corn hybrids.

MATERIAIS AND METHODS

All tropical corn studies reported herein were conducted under a medium-energy-input system defined by Wright et al. (1990) as a no-till planting system following wheat harvest, fertilized with < 134 kg N ha^{-1} and grown under natural-rainfall conditions. The experiments were conducted at two locations: 1) North Florida Research and Education Center on a Norfolk sandy loam soil (fine-loamy, siliceous, thermic, Typic Kandiudult) and 2) Agricultural Research Center, Jay, FL on a Orangeburg sandy loam. The plot sizes were 7.6 m long by 6 m wide (eight rows). Row spacing was 0.76 m. The previous crop in each experiment was Fla 303 winter wheat, harvested in mid-May.

Fourteen tropical corn hybrids were compared in a starter vs no-starter silage yield experiment. Experimental design was a randomized complete block with four replications. It was planted on 18 June and harvested for silage on 16 Sept. Interactions are illustrated according to the technique of Teare and Wright (1990).

Fourteen tropical corn hybrids were planted no-till into the small grain stubble with a Brown-Harden Ro-Til planter (Brown Co., Ozark, AL 32630) at a population density of 20,000 plants ha^{-1}. The experimental design of was a randomized complete block with four replications (Table 2). Planting, silage harvest, and grain harvest dates were 19 May, 18 June, and 5 Oct, respectively.

The late-planted tropical corn experiment was planted on 17 June and 6 July at Jay, FL, 1992. Both planting dates were fertilized with 134 kg N ha^{-1} and a population density of 20,000 plants ha^{-1}. The rows were 7.6 m long by 3 m (four rows) with 0.76 m between rows. The previous crop was winter wheat harvested in late May. The experimental design was split plot with four replications. Whole plots were the planting dates. The sub-plots were 14 tropical hybrids (Table 3). Tropical corn grain yield and grain crude protein (CP) % [dry matter basis (DM)] comparison was conducted as a measure of grain quality of 27 tropical corn hybrids in 1991 (Table 4). Planting date was 1 July and harvest date was 31 Oct. The experiment was a completely randomized block with four replications.

Silage yields from five hybrids in the 31 May planting of the previous experiment were measured on 5 Sept (four replications) and subsampled for IVOMD analysis (Table 5). This harvest was badly damaged by fall armyworm and the other hybrids were not harvested.

In vitro organic matter digestibility and silage yield were also studied to compare two tropical corn hybrids and one high yielding temperate corn at four planting dates at Quincy, 1991. Planting and harvest dates are shown in Table 6.

RESULTS AND DISCUSSION

The interaction of temperate corn hybrid grain yields in relation to small amounts of starter fertilizer application at time of planting was described by Teare and Wright (1990). This explained the highly variable temperate corn yield results from starter fertilizer experiments reported throughout the United States (Wright, 1989). It also provided another management tool for farmers to consider in their selection of seed corn for optimization of yield (Rhoads, 1993). In 1992, a starter fertilizer experiment was conducted on tropical corn hybrids for the first time in relation to silage yield. Silage yields of 14 tropical hybrids are shown in relation to starter and no-starter application at planting (Table 1). The interactions are shown in Figure 1. Pioneer X304C showed the greatest range as the "positive changer" and Pioneer 3099 and Cargill X701TR, the greatest ranges, as the "negative changers." DeKalb DK 9101 showed the least change as a "non-changer."

Table 1. Silage yield of 14 tropical corn hybrids in relation to starter fertilizer, Quincy, Florida, 1992. Planting and silage harvest dates were 18 June and 16 September, respectively.

Hybrid	Starter at planting	Ton/A (35%DM)
Cargill **X701TR**		l2.6
Pioneer **3099**		**113**
Pioneer **X304C**	+	**11.2**
Pioneer **3069**	+	**11.1**
Cargill **X70lTR**	+	**10.9**
Pioneer **3072**	+	**10.8**
DeKalb DK **X9052**		**10.8**
Pioneer **3069**		**10.5**
Pioneer **3072**		**105**
DeKalb DK **X9152**		**10.4**
Dekalb DK **X9052**	**+**	**103**
Pioneer X304C	**-**	**9.9**
Dekalb DK **X9152**	**+**	**9.7**
Pioneer **3099**	**+**	**9.7**
Pioneer **4098**	**+**	**9.5**
Pioneer **3098**		**9.2**
Dekalb DK **XL510**		**8.9**
Dekalb DK **XL510**	+	**8.5**
DeKalb DK **XL678C**		**8.0**
DeKalb DK **XL678C**	+	**7.6**
DeKalb DK **XL520**	+	**7 5**
DeKalb DK **XL520**		**6 . 8**
Cargill **C955**		**4.1**
DeKalb DK **9101**	+	**3.9**
DeKalb DK **9101**		**3.8**
Cargill **C955**	+	**3.6**
Cargill **9197**		**3.0**
Cargill **9197**	+	**2.7**
MD.,		**1.7**

Table 2. Grain and silage yield' of 14 tropical corn hybrids, Quincy, FL, 1992. Planting, silage, and grain harvest dates were 19 May, 18 June, and 5 Oct, respectively.

Hybrid	Grain yield[2] (bu/A)	Silage yield' (ton/A)
Pioneer 3099	136.9 A	10.5 B
Pioneer 3069	124.5 AB	10.8 AB
Pioneer 3072	119.9 ABC	10.6 AB
Pioneer 3098	106.7 BCD	9 3 CD
DeKalb XL678C	105.2 BCD	7.8 EF
Pioneer X304C	99.4 CD	10.5 B
Cargill C955	96.8 D	3.9 G
DeKalb XL510	96.7 D	8.7 DE
Cargill X701TR	93.9 D	11.8 A
DeKalb X9052	93.2 D	10.6 B
DeKalb 9101	91.9 D	3.8 G
DeKalb X9152	90.7 D	10.0 BC
Cargill 9197	88.4 D	2.8 G
DeKalb XI520	87.2 D	7.1 F

[1] Yield in columns followed by the same letter are not significantly different at the 5% level of probability.
[2] Corrected to 15.5% moisture.
[3] Corrected to 35% DM.
[4] Comparison for 35% DM.

Table 3 Grain yield[1] of late-planted' tropical corn hybrid trials at two planting dates at Jay, FL., 1992.

Hybrid	Planting Date June 17	July6
	(bu/A)	(bu/A)
Pioneer 3072	114.1	115.4
Pioneer 3099	98.5	109.5
Pioneer 3069	95.3	100.5
DeKalb X9152	77.1	89.5
Cargill X701TR	78.4	81.0
Pioneer 3098	80.4	79.1
DeKalb X9052	62.9	77.1
Pioneer X304C	50.6	70.7
DeKalb XL678C	50.6	609
DeKalb XL510	382	42.8
DeKalb XL520	32.4	35.7
Cargill C955	18.1	169
DeKalb 9101	14.9	13.0
Cargill 9197	12.3	11.0
Means	59.0	64.2
$LSD_{.05}$	18.8	169

[1] Correct to 15.5% moisture.

[2] **Rainfall Distribution (Inches)**

June	9.10
July	8.71
August	7.99
September	6.91
October	2.08
November	10.73
TOTAL	4552

Table 4. Tropical corn grain yield and percentage grain crude protein (DM) for 27 hybrids at Quincy, Florida, 1991. Planting and harvest dates were 1 July and 31 October, respectively.

Hybrid	Grain yield (bu/A)	% CP (DM)
Pioneer 3078	16.6	11.7
Pioneer 3098	39.8	11.6
Cargill C525	6.9	11.4
Cargill C381	19.7	11.3
Gallaher FL5-1990	21.5	11.3
Asgrow A6798	15.7	11.3
Cargill C511-A	10.0	11.2
Cargill T-321	5.0	11.1
Gallaher FL1-41-1990	13.8	11.0
Pioneer 3086	21.6	11.0
Cargill C606	16.2	10.9
Pioneer 3214	17.0	10.9
Cargill C801	2.9	10.9
Asgrow XM7759	35.3	10.9
Pioneer 6875	9.0	10.8
Cargill Semiden 5	--	10.8
Cargill C901	21.3	10.8
DeKalb XL678C	28.9	10.6
Pioneer 3292	8.4	10.5
Pioneer X304C	16.3	10.5
Cargill c633	21.5	10.5
Cargill C385	18.2	10.5
Pioneer 3210	14.7	10.4
Cargill C701	30.1	10.2
Cargill C33	20.8	10.0
Asgrow A667	5.1	10.0
Cargill C905	21.6	9.9
$LSD_{.05}$	10.9	0.9

Early (May) planting of tropical corn has been shown to be an escape management tool for evading fall armyworm damage (Teare et al., 1990 and 1991). Planting date studies in 1992 show unique weather influences not observed in the previous 8 years of tropical corn research. Weather during the winter of 1992 was very mild and spring temperatures and rainfall were higher than normal. As a result, fail armyworm migrations north from Puerto Rico and southern Florida were about a month earlier than usual. This was the first time significant fall armyworm damage occurred to grain yield in May planted tropical corn at this location. Grain and silage yields of 14 tropical corn hybrids are shown for the 19 May planting at Quincy in Table 2. Grain yields were good, but some silage yields were low showing the effect of fall armyworms on some low tolerance tropical hybrids. The low silage yielding hybrids for the May planting was what would be expected for June planting dates.

Table 3 shows the grain yields of two late plantings of the same tropical corn hybrids at Jay. The high grain yields for the mid-June and early-July planting dates (the highest in our 9 years of tropical corn research) indicated that the fall armyworm migrated north earlier than usual and allowed the tropical corn hybrids to express their grain yield potentials late in the growing season without heavy insect damage. Early-July planted tropical corn grain yields for 27 hybrids in 1991 (Table 4) are shown as the more "normal" low grain yields from later migrating fall armyworms to compare with Table 3.

Grain and silage feeding quality for ruminant animals is estimated by measurements of percent crude protein on a dry matter basis and IVOMD (Moore and Mott, 1974). Table 4 shows the percent crude protein of 27 tropical corn hybrids grown at Quincy in 1991 along with corresponding grain yields.

In vitro organic matter digestibility and silage yields are shown in Table 5 for five tropical corn hybrids at Quincy in 1991.

In vitro organic matter digestibility and silage yield are shown for another study that compared two tropical corn hybrids and one high yielding temperate corn variety from four planting dates at Quincy, 1991. The May planting was in a very vulnerable vegetative stage when the fall armyworm invaded in June, which resulted in the decision to harvest early and reduced the silage yields of the May-planted silage crop of all hybrids. *In vitro* organic matter digestibility was also reduced because of the reduced leaves and grain.

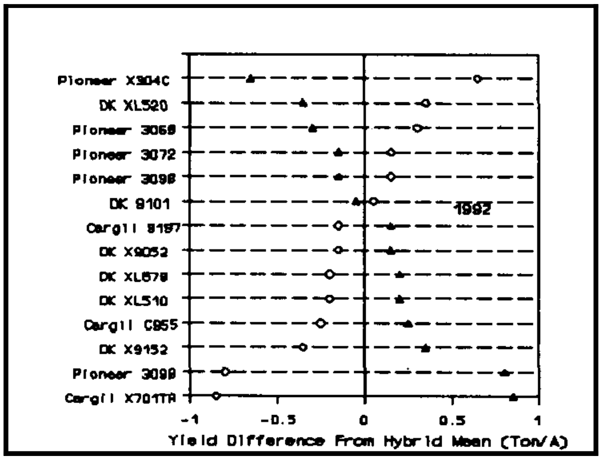

Figure 1. Silage yield difference from hybrid mean (ton/A) showing interaction with starter (0) and no-starter (A) during 1992 for 14 tropical corn hybrids (listed on y-axis). Hybrid mean is the sum of the silage yields of starter and no-starter treatments for each corn hybrid divided by two and is represented here by 0, so that silage yield differences from hybrid means can be shown, illustrating the interaction curves and the range of silage yield for starter and no-starter.

Table 5. *In vitro* organic matter digestibility and silage yields of five tropical corn hybrids, Qulncy, 1991. Planting date 1.

Hybrid	Yield[1] (ton/A)	IVOMD[1] (%)
Pioneer 3098	9.2 A	38.8 A
Pioneer 3214	7.4 A	38.7 A
Pioneer X304C	8.8 AB	38.6 A
Pioneer 3210	6.0 B	37.2 A
Pioneer 6875	6.4 B	35.5 A

[1] Means in row or columns followed by the same letter are not significantly different at the 5% level of significance.

Table 6. In vitro organic matter digestibility and silage yields of two tropical[1] corn hybrids and one hlgb yielding temperate[2] corn at four planting dates at Quincy, Florida, 1991.

Planting Date	Harvest Date	Pioneer 3098[1] Silage (ton/A)	Pioneer 3098[1] NOMD (%)	Pioneer X304C[1] Silage (ton/A)	Pioneer X304C[1] NOMD (%)	Sunbelt 1876[2] Silage (ton/A)	Sunbelt 1876[2] NOMD (%)	Mean[3] Silage (ton/A)	Mean[3] NOMD (%)
22 April	13 Aug	14.9	62.1	143	60.9	22.9	53.3	17d a	58.8 b
15 May	13 Aug	10.9	61.6	10.1	58.5	10.6	45.5	105 c	553 c
14 June	23 Sept	14.7	56.6	13.1	553	16.9	45.4	14.9 b	52.1 c
22 July	6 Nov	14.8	68.9	18.2	67.0	18.9	61.9	173 a	65.9 a
	Mean[3]	13.8 b	62.3 x	13.9 b	60d x	173 a	51s y		

[1] Tropical corn.
[2] Temperate corn.
[3] Means in row or columns followed by the same letter are not significantly different at the 5% level of significance.

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SOIL WATER CONTENT AND CROP YIELD UNDER CONSERVATION TILLAGE

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ABSTRACT

Cotton *(Gossypium hirsutum* L.) was grown for 5 years on Decatur silty clay loam (clayey, kaolinitic, thermic Typic Paleudults) at the Tennessee Valley Substation of the Alabama Agricultural Experiment Station. Treatments included conventional tillage (CT), reduced tillage (RT), and reduced tillage with a winter wheat (Tritium aestivum L) cover crop (RTC). Soil water was measured biweekly by the neutron scatter method at 20-, 40- 60-, 80-, and 100-cm depths in the soil profile during the 1987 growing season (May 1 - September 30). The 5-year average yields of seed cotton were 2, 261, 2, 364, and 2,296 kg ha^{-1} from CT, RT, and RTC, respectively. There was no significant difference among the yields. Soil water content at the measured soil depths was the lowest for CT throughout the growing season. At 20-cm depth, soil water content was the highest for RTC, but RTC had lower soil water content at depths below 40 em than that of RT. The CT plots showed the lowest potential to hold soil water in all depths measured. A prolonged dry period during the growing season in 1987 caused extremely low soil water content at all depths for all treatments. The depleted soil water was recharged to the level of soil water content during the early part of the growing season after an unusually high rainfall event occurred late in the growing season.

INTRODUCTION

Interest in conservation tillage has been strong for the past decade because it affects soil erosion, soil water conservation, and crop yield. It also appeals to farmers because it conserves time, fuel, and labor (Phillips et al., 1980). Plant residue left on the soil surface is the most important feature of conservation tillage. Residue left on the surface protects the soil, reduces evaporation, slows runoff, and increases infiltration (Blevins et al., 1983; Mannering and Fenster, 1983). Understanding soil water behavior under conservation tillage is important since it directly influences crop yield, as well as runoff and soil erosion. Information regarding interaction between soil water content and crop yield, however, is limited.

Spomer and Hjelmfelt, Jr. (1984) found that soil water was best related with rainfall and crop stage of growth. Jones et al. (1969) measured soil water content under no-tillage systems and found that no-tillage systems effectively reduced evaporation and runoff from the soil surface compared with conventional tillage systems. They found that the average soil water content in the top 15 cm was higher under no-tillage than that for conventional tillage. Johnson, et al. (1984) reported that less water was depleted from no-tilled fields than other conservation tillage fields. The highest depletion by evapotranspiration and drainage was found from the conventionally tilled fields during periods of no rainfall. Spomer and Hjelmfelt, Jr. (1984) also found that soil water storage was not different for conservation and conventionally tilled corn fields.

A study by Shanholtz and Lillard (1969) reported that no-tillage provided higher corn yields mainly due to its efficient use of water. Blevins et al. (1971) indicated that no-tillage systems generally produced higher corn yields due to the different water withdrawal patterns from no-tilled and conventionally tilled soils. They found that no-tilled soils contained more water than conventionally tilled soils. Munawar et al. (1990) found that corn yield for conservation tillage systems was equal to or better than that for conventional tillage systems for a study in Kentucky. Several researchers reported that yield increases with conservation tillage systems were attributed to favorable moisture conditions in soil (Triplett et al., 1968; Jones et al. 1968; Unger, 1978). It was found that additional soil water, along with higher infiltration and lower evaporation during the growing season preserved by high straw mulch rate, increased grain sorghum yield (Unger, 1978). Very little information is available about the effect of soil water content on seed cotton yield under conservation tillage systems. The purpose of this paper is to present soil water content measured in 1987 and seed cotton yields for 5 years (1985 to 1989) under three tillage systems in the Tennessee Valley area of northeast Alabama.

MATERIALS AND METHODS

The study was conducted from 1985 to 1989 under natural rainfall conditions at the Tennessee Valley

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Substation of the Alabama Agricultural Experiment Station at Belle Mina in northeast Alabama. The soil was Decatur silty clay loam. Each plot, sized 305 x 305 m (100 x 100 ft), was on a 2% slope. The experimental design was a randomized complete block design of three tillage treatments of cotton ('McNair 235') with two replications. The treatments were conventional tillage (CT), reduced tillage (RT), and reduced tillage with a winter wheat ('Coker 747') cover crop (RTC). Cotton was planted on the contour in a 1.02-m (40-inch) row width at a seeding rate of 20 seeds/m (6 seeds/ft). For all tillage systems, the crop residue was shredded and distributed evenly on the soil surface after harvest. Soil test results from the Soil Test Laboratory of the Alabama Agricultural Experiment Station were used as a guide for fertilizer and lime applications.

In 1985 and 1986, both RT and RTC plots were planted with a John Deere Maxsmerge planter attached to a Brown-Harden Rotill subsoiler. After 1987, these plots were planted with a John Deere. Flex-71 no-till planter. All conventional tillage plots were planted with a John DeemMax-emecge planter. A combination of 5.6 kg ha^{-1} (active ingredient) of Temik (aldicarb) and 112 kg ha^{-1} of Terrachor Super X {Pentachloronitrobenzene (PCNB), 28% + 5-Ethoxy-3-(trichloromethyl)-1,2,4-thiadiazole, 5.8%) were applied on all plots during planting. The RTC plots were tilled with a chisel plow and disked prior to planting winter wheat. Acombination of 1.7 kg ha^{-1} of prowl and 1.7 kg ha^{-1} of cotoran on all plots and 0.6 kg ha^{-1} of paraquat (1, l'-dimethyl-4, 4'-bipyridinium ion) on RT and RTC plots were broadcast to kill the cover crop and control weeds prior to planting cotton. Seed cotton yield was determined by hand-picking 10 ft of the center four rows of each plot. Cotton was harvested twice in 1985 and 1987 and once in the other years. Table 1 shows cultivation practices and dates for the three tillage systems in 1987. All other years had very similar cultivation practices to those of 1987, except for cultivation dates.

Physicalcharacteristics of the surface 10 cm of soil are: 13% sand, 54% silt, 33% clay, and 13% organic matter. Soil water content was measured on each plot during the growing season of 1987 by the neutron scatter method. No soil water data were collected for other study years. Access tubes were installed near the center of the plots, and neutron probe readings were recorded on a weekly basis from planting until the first harvesting. The readings were made at the 20-, 40-, 60-, 80-, and 100-cm depths. Gravimetric soil water determinations were made at each depth with 103 cm^3 soil samples. The results were used to calibrate the neutron probe by developing regression equations to calculate volumetric water content (θ) in cm^3 water cm^{-3} soil. The regression equations are (Missildine, 1988):

for 20-cm depth

θ = (relative count · 022) ÷ 2.1

and for the 40-, 60-, 80-, and 100-m depths

θ = (relative count · 035) ÷ 1.9

where, relative count = field count/ standard count

Rainfall was measured at the site using a tipping bucket rain gauge with a 0254-mm (0.01 in.) sensor. Thegauge was read and recorded at 5-min intervals by a data logger (CR7X, Campbell Sci. Inc., Logan, Utah). Other climatic data collected at the site were ambient temperature, wind direction and speed, and pan evaporation.

RESULTS *AND* DISCUSSION

Seed **Cotton** Yield

Table 2 shows total rainfall during the growing season (May 1 to September 30) and seed cotton yields for the three tillage systems. Yields were high in 1985 and 1989 and extremely low in 1987 and 1988. This trend followed the amount of rainfall during the growing season. The low yields also were attributed to poorly developed roots. The high yield in 1985 was attributed to well distributed rainfall during the growing season. Average yield for the 5 years was the highest for RTC and the lowest for CT. However, yields from the three treatments were not significantly different ($P < 0.05$).

Soil water

Comparisons of the soil water content distribution with depth for the tillage treatments are presented in Figures 1, 2, and 3. Figure 4 shows the distribution of daily rainfall during the growing season in 1987. These figures represent three field conditions; planting, drought, and heavy rainfall, respectively. Figure 1 shows volumetric soil water content measured 25 d after planting (May 5). There was a total of 16 mm of rainfall during this period. Soil water content values at the 20 cmdepth were very close for all treatments. The RT had the highest water content followed by RTC and CT at depths greater than 20 cm.

In 1987, the total rainfall for the period of July 14 until September 5 was only 35 mm, which decreased the soil water content to very low levels (Fig. 2). Soil water

Table 1. Cultivation dates for the three tillage systems in 1987. Cultivation for other years are similar except for dates.

Date	CT	RT	RTC
3/4			Broadcast **36** kg N ha”
4/6	Chisel, disk		
4/20[a]	Broadcast **78** kg N ha^{-1} and Planting cotton	Broadcast **78** kg N ha” and Planting cotton	Broadcast **78** kg N ha^{-1} and Planting cotton
6/24	Cultivate		
9/1	Defoliate	Defoliate	Defoliate
9/9[b]	1st harvest	1st harvest	1st harvest
9/23[b]	2nd harvest	2nd harvest	2nd harvest

[a] John Deere Flex-71 for RT and RTC and John Deere Max-emerge for CT.
[b] Harvested by hand pick.

Table 2. Total rainfall and seed cotton yield for the 1985, 1986, 1987, 1988, and 1989 growing season (May- 1September 30) at the Tennessee Valley Substation of the Alabama Agricultural Experiment Station in northeast Alabama.

Year	Rainfall (mm)	Tillage	Yield[a], kg ha^{-1} Plot 1	Plot 2
1985	**591**	CT	**2,814**	**4,241**
		RT	**3,912**	**3,692**
		RTC	**4,131**	**3,518**
1986	**551**	CT	**1,682**	**2,195**
		RT	**1,756**	**1,975**
		RTC	**2,487**	**1,462**
1987	**509**	CT	**1,901**	**1,528**
		RT	**1,785**	**1,656**
		RTC	**1,593**	**1,122**
1988	**318**	CT	**1,426**	**1,829**
		RT	**1,682**	**1,829**
		RTC	**1,975**	**1,280**
1989	**784**	CT	**2,323**	**2,670**
		RT	**2,816**	**2,542**
		RTC	**3,255**	**2.140**

	5-year average yield[b] CT	RT	RTC
Rainfall **550** Yield	**2,260**	**2.364**	**2.296**

[a] Average yield of seed cotton in the study area ranges from **2,400** to **2,600** kg ha^{-1}.
[b] Not significantly different ($P \leq 0.05$).

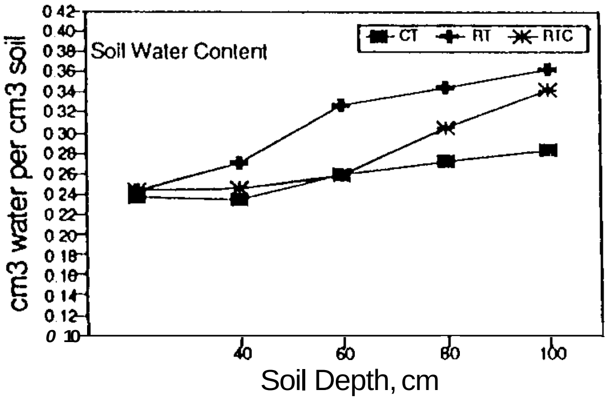

Figure 1. Soil water content distrihution with deplh for three tillage systems 25 d after planting (May 5) in 1987.

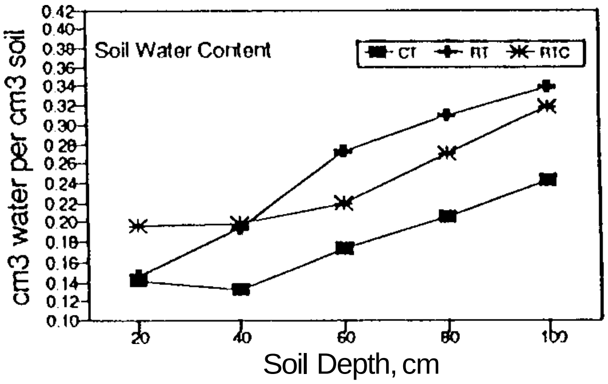

Figure 2. Soil water content distribution with depth for three tillage systems 133 d after planting (August 31) in 1987.

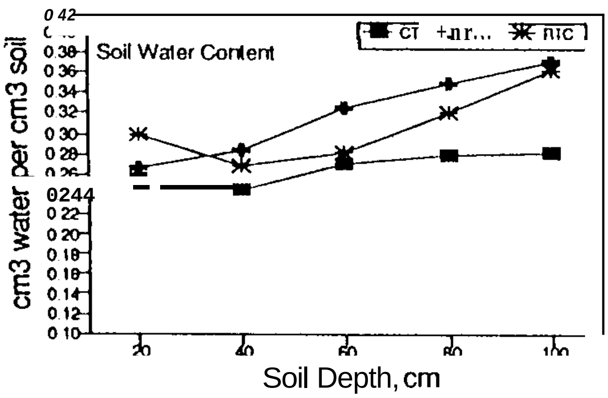

Figure 3. Soil water content distribution with depth for three tillage systcms 147 d after planting (Septemher 14) in 1987.

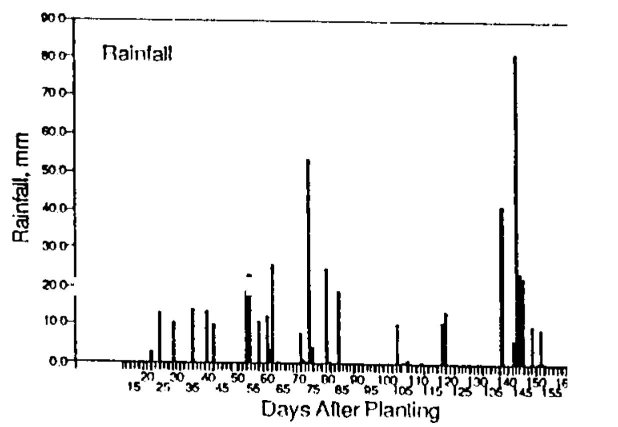

Figure 4. Daily rainfall distribution during the growing season (May 1 - Scptcniher 30) in 1987.

content measured 133 d after planting (August 31). Soil water content at 20-cm depth for RTC was the highest but was extremely low for all treatments. This indicates that the residue left in the field was effective, reducing evaporation losses from the shallow soil during the dry period. At depths below 40 cm, RTC and CT showed lower soil water content values than that of RT. This order of soil water contents is similar to that of 25 d after planting but very low. Most of the soil water reduction occurred in the upper two soil depths. At 80- and 100-cm depths, very little or no soil water was lost, indicating minimum root development in these depths.

A few high intensity rainfall events occurred during September following the long dry period, giving a total rainfall of 211 mm (Fig. 4). As shown in Figure 3, soil water content values measured 147 d after planting (September 14) had increased above or equal to those of May 5 at all depths for all treatments. The total rainfall after the last soil water measurement (August 31) was 175 mm (6.9 in.). The level of soil water contents shown in Figures 1 and 3 indicate that CT plots had the lowest potential to hold soil water in all depths. The soil water contents shown in Figure 3 were the highest values measured in this study. The pattern of the soil water content was very similar for all three measurements; highest for RTC at 20-cm depth, highest for RT at depths below 40 cm, followed by RTC and CT. This is due to lower percolation into the deep soil depths in RTC and CT plots than that of RT.

The observations of soil water content after a long dry period followed by high rainfall events indicated that all treatments responded well to recharging of the soil profile (Fig. 3). RT and RTC plots maintained higher soil water contents at all depths throughout the growing season. Average surface runoff during the growing season in 1987 was the highest for CT (66 mm (2.6 in.)} followed by RTC {20 mm (0.8 in.)} and RT (13 mm (0.5 in.)}, indicating higher infiltration into the soil depths in the RTC and RT plots than that of CT plots.

Figure 5 shows the seasonal variation of soil water content under the three tillage treatments. The RTC showed the highest volumetric water content at 20-cm depth throughoul the season. At this depth, the water content values for the RT and CT treatments were close but both were lower than that for the RTC treatment. The high soil water content of the RTC treatment reflected additional residue left from the cover crop, which reduced evaporation and increased infiltration into the shallow soil depths. At 40-cm depth, water content values of RT and RTC were close and higher than that of CT. The RT treatment had the highest water content values at the depths below 40 cm followed by RTC and CT. Water content values at 60 and 80 cm for RTC were lower than RT and was attributed to the water used by the cover crop. All treatments quickly responded to the high rainfall events during late in the growing season.

The CT sbowed the lowest water content throughout the growing season, except at the 20-cm depth where soil water content of CT was close to that of RT. The higher soil water content for the conservation tillage systems agrees with the findings of Jones et al. (1969) and Johnson (1984). Seasonal variation of soil water content was similar for RT and CT at 20-cm depth and for RT and RTC at 40- and 100-cm depths. The favorable water content of RTC at the shallow soil depths was not reflected in the seed cotton yield. Seed cotton yield from RTC was the lowest among the three treatments in 1987. It was observed that the crop in these plots did not have well developed roots.

SUMMARY

Conservation tillage systems for cotton were studied for their effects on soil water content and seed cotton yield. Seed cotton yields in conservation tillage systems were equal to or better than in conventional tillage on a Decatur soil even though there were no significant differences. Soil water content at soil depths below 20 cm were lower for the conventional tillage (CT) treatment throughout the growing season than for the reduced tillage (RT) and reduced tillage with cover crop (RTC) treatments. During the early part of the growing season, soil water contents at 20-cm depths were close for all treatments. Winter wheat cover crop of RTC caused lower soil water content at the intermediate depths (60- and 80-cm) than those of RT. However, RTC maintained the highest water content at the 20-cm depth throughout the growing season. Additional residue left from the cover crop decreased the evaporation losses and increased infiltration from the shallow soil depth more for the RTC than for the RT and CT treatments. During a prolonged dry period, the soil profiles of all treatments were extremely depleted of soil water, which caused the low seed cotton yield in 1987. The depleted soil water was recharged from heavy rainfall events late in the growing season, which increased the soil water content to higher values than those shown shortly after the planting time when soil water content was high.

ACKNOWLEDGEMENTS

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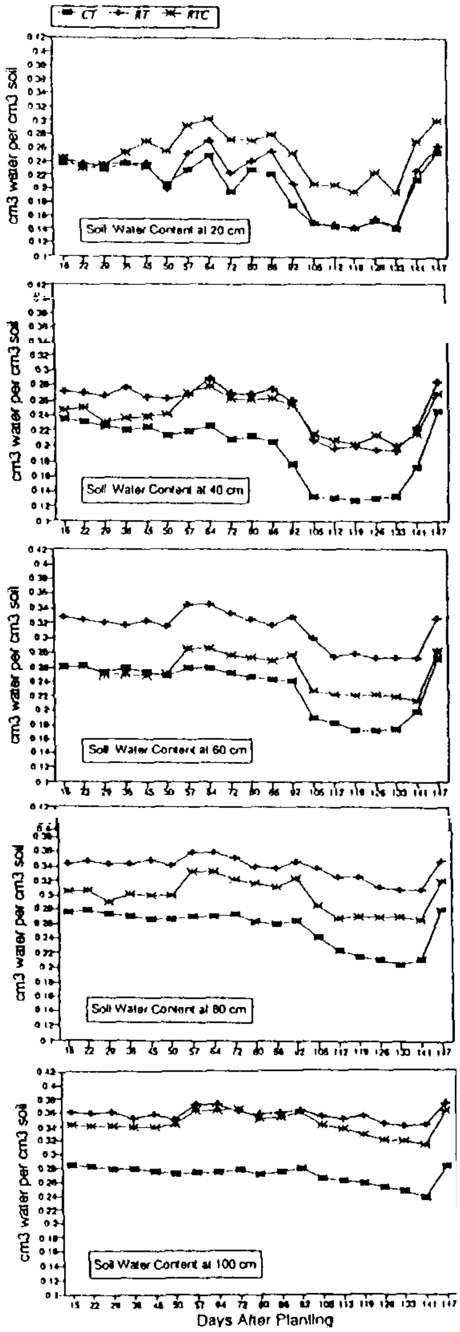

Figure 5. Soil water content with soil depth during the growing season under three tillage systems on a Deratiir soil in 1987. Each data point represents the mean of two plot measurements.

APPENDIX

Past Conferences and Contact Persons

Year	Locatlon	Contact
1978	Griffin, GA	W.L Hargrove Agronomy Department Georgla Statlon **1109** Experlrnent Street Grlffln, GA **30223-1797** **(404) 228-7330**
1979	Lexlngton, **KY**	W.W. **Frye** Agronomy Department Unlverslty of Kentucky Lexlngton, KY **40546** (606) **257-1628**
1980	Gainesville, FL	David Wrlght N. Florlda **Res.** & Educ. ***Ctr.*** Route **3 Box 4370** Oulncy. **FL 32351** **(904) 627-9236**
1981	Ralelgh, NC	M.G. Wagger **Sol1** Sclence Department North Carollnr State Unlv. Ralelgh. NC **27650** **(919) 737-3285**
1982	Florence, SC	**Jim** Palmer Agronomy Department Clemson Unlverlsty Clemson, SC **29634** **(803) 656-3519**
1983	Milan, TN	Don Tyler West Tennessee Ag. **Exp. Stn.** Jackson, TN **(901) 425-4747**
1984	Dothan, ***AL***	Joe Touchton Agronomy Department Auburn Unlverslty Auburn, AL **38301** **(205) 844-4100**
1985	Grlffln, GA	W.L Hargrove Agronomy Department Georgla Statlon **1109** Experlment Street Grlffln, GA **30223-1797** **(404) 228-7330**

Year	Location	Contact
1988	**Lexlngton, KY**	W.W. Frye, Agronomy Department Unlverslty of Kentucky Lexlngton, KY **40546** ***(606)* 257-1628**
1987	College Statlon, **Tx**	Tom Gerik Blackland Research Center Temple, **TX 76501** **(817)** ***770-6603***
1988	Tupelo, MS	**Normie Buehring** Northeast **Miss.** Branch **Stn.** Verona, **MS 38879** **(601) 566-2201**
1989	Tallahassee, FL	David Wrlght **N.** Florlda **Res.** & Educ. ***Ctr.*** Rout. **3 Box 4370** **Oulncy, FL 32351** **(904) 627-9236**
1990	Ralelgh, NC	M.G. Wagger **Sol1 Science** Department **North** Carolina **State** Unlv. Ralelgh, NC **27650** **(919) 737-3285**
1991	N. **Little** Rock, AR	Terry C. Keisling Soil Testlng & Resaarch Lab. P. **O.** Drawer 767 Marianna, ***AR*** **72360** **(501) 295-2851**
1992	Jackson, TN	Paul Denton University ***of*** Tennessee P. O. **Box 1071** Knoxville, **TN 37901** **(615) 974-7208**