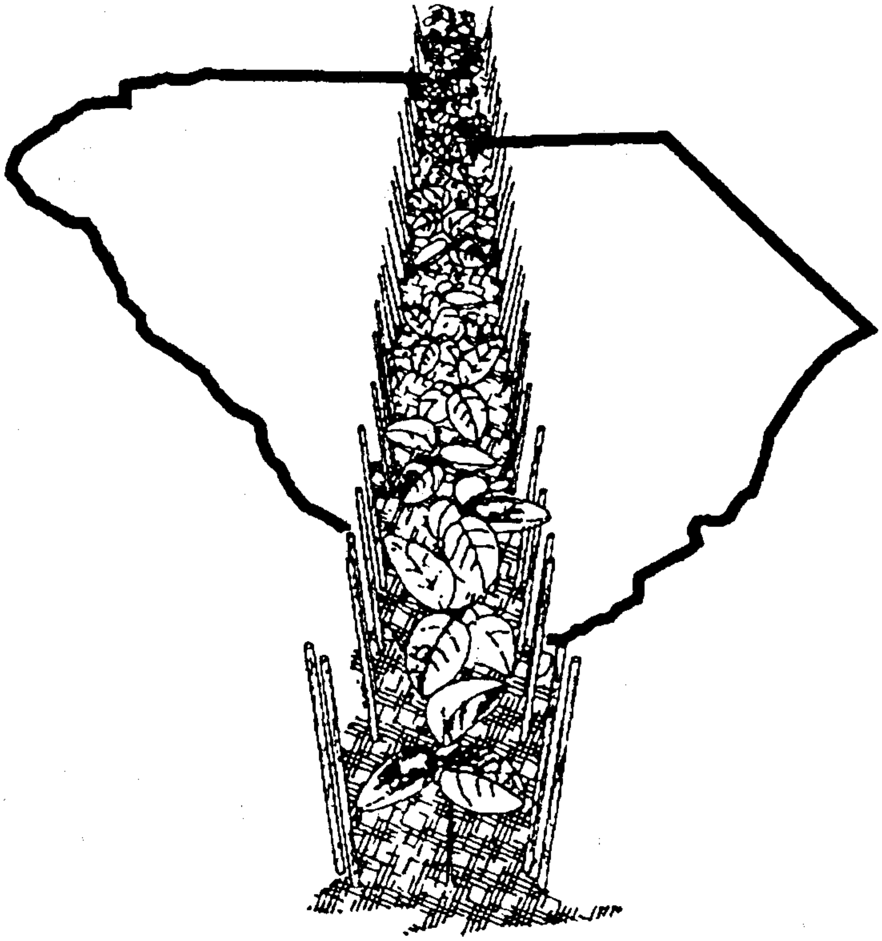
Proceedings of the

1994 Southern Conservation Tillage Conference for Sustainable Agriculture

Conservation Tillage for Improving Profitability



Columbia, South Carolina June 7-9, 1994

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FOREWORD

Adoption of conservation tillage by growers is increasing throughout the South. Compliance with the soil erosion control provisions of the 1985 Food Security Act is one reason for the growing popularity of conservation tillage systems. Conservation tillage can also potentially reduce production costs and increase yield. This year's conference theme, "Conservation Tillage for Improving Profitability," was chosen to emphasize that conservation tillage is not just an option for controlling soil erosion. It is a management technique farmers can consider to improve the financial aspects of their business.

As in the rest of the region, conservation tillage acreage is increasing in South Carolina. In 1993, about 25% of double-cropped soybeans and over 17% of the corn grown in the state were produced with some form of conservation tillage. Acreage for other crops will undoubtedly increase as optimal conservation production practices are determined and the technology is transferred to growers. For example, conservation tillage cotton research has increased considerably during the last few years. As recent as the late 1980's. this proceedings contained only one or two papers each year dealing with cotton. In this volume, 12 of the 39 papers discuss conservation tillage cotton research.

Protecting the environment and ensuring a sustainable agriculture are priority issues for Americans in the 1990's. South Carolina appreciates the opportunity to host this annual meeting about farming systems that can help both.

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CONSERVATION TILLAGE – A NATIONAL PERSPECTIVE

David L. Schertz [1]

ABSTRACT

Nationally, conservation tillage is alive and well. In fact, it is on the verge of becoming one of the most rapidly adopted technologies in the history of American agriculture. Never before have we seen such rapid growth in adoption. Although Conservation Compliance has had a significant impact on adoption, there are other reasons that have also impacted the rapid change in trends, such as moisture conservation, improvement in organic matter content and soil tilth. water quality, and economics. This paper presents the new terminology of crop residue management (CRM), discusses the reasons for present emphasis, lists the benefits of CRM, and presents trends in adoption.

MEANING OF THE TERM CROP RESIDUE MANAGEMENT

In response to the 1985 Food Security Act legislation, many farmers chose to comply with these provisions to maintain eligibility for U.S. Department of Agriculture program benefits. In many cases, farmers selected practices in their conservation plan that left a significant portion of crop residue on the soil surface to help them meet conservation goals. However, some of these tillage practices, especially if in combination with other conservation practices, were to leave surface residue levels that were less than the 30 percent required by the conservation tillage definition. Also, some viewed conservation tillage as meaning only no-till. Therefore, different terminology was needed to capture the impacts of leaving all or a portion of the previous crop's residue on the soil surface. As a result, the term, Crop Residue Management ICRM) evolved to allow better quantification of the benefits of surface crop residue in reducing soil erosion. Any CRM practice encompasses the total cropping year:

a) it begins with planting a crop that will provide sufficient amounts of surface residue to meet the intended management goal. Cover crops can be used to increase crop residue following low residue-producing crops;

b) emphasis is placed on crop harvest to ensure good distribution of crop residue over the width of the header;

c) tillage, when carefully planned to avoid excessive residue burial, can be used effectively to meet the surface residue goal.

In essence, CRM is defined as any tillage and planting system that utilizes practices such as no-till, ridge-till, mulch-till, or other tillage systems that retain all or some portion of the previous crop's residue on the soil surface. The percentage of surface residue that is required is determined on a site-specific basis, considering other conservation practices that may be included in the conservation plan for reducing soil erosion. The objective of crop residue management is to leave sufficient residue cover on the soil surface after planting to meet the intended purpose, whether it is for erosion reduction, increasing water infiltration or moisture conservation, improving soil tilth, or enhancing water quality. Crop residue is a valuable resource but requires special attention to optimize its benefits.

REASONS FOR EMPHASIZING CROP RESIDUE MANAGEMENT

Beginning in the early 1980's, citizens in the United States began voicing more and more concern over the amount of soil erosion and sediment reaching lakes and streams. They voiced these concerns through their congressional representatives. Concern was focused especially on highly erodible fields where growers produced crops and received U. S. Department of Agriculture program benefits.

In 1985, the United States Congress passed the Food Security Act that contained several conservation provisions or sections. One of those provisions was called conservation compliance and was directly related to reducing soil erosion on

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highly erodible croplands where farmers participated in USDA program benefits.

It required farmers who are farming highly erodible cropland to develop a conservation plan by 1990 to remain eligible for U.S. Department of Agriculture program benefits. Between 1990 and 1995, farmers must be actively applying their plan according to schedule and have that plan fully implemented by the end of 1994. In 1990, the Food, Agricultural, Conservation, and Trade Act was passed and reinforced the 1985 conservation provisions.

HOW LARGE IS THE EFFORT

From 1985 to the present, approximately 1.6 million conservation plans have been developed. These plans involve approximately 143 million acres of highly erodible cropland. As of December 1993, approximately 70 percent of the highly erodible land is considered to have all planned practices applied. Our 1993 status review results show that 97 percent of the farmers were found actively applying their conservation plan. Farmers chose some form of crop residue management as one of the practices to help meet their erosion reduction goals on about 75 percent of the acres planned under this legislation. Farmers chose crop residue management primarily because of economic benefits, as well as, for the effectiveness in reducing soil erosion.

The benefits of surface residue in reducing soil erosion is shown in Table 1 (USDA ARS, 1994). About the same reduction in soil erosion caused by the forces of wind can be obtained from crop residue as shown in Table 1 for water erosion.

Crop residue management is not the only practice available to farmers to help them control erosion and maintain their eligibility for U.S. Department of Agriculture Program Benefits. Practices, such as contouring, terracing, contour strip cropping, long-term rotations, wind strip cropping, wind barriers, and field windbreaks are also used.

MOISTURE CONSERVATION

Conserving soil moisture is crucial to agriculture in many areas of the world, especially in dryland agriculture. But even in humid areas, rainfall does not always occur when the growing crop needs it the most. The benefits of maintaining a portion of crop residue on the surface range from postponing the detrimental effects of a short term drought to significantly increasing crop yield by conserving soil moisture. For instance, in the North Central Great Plains, 2.5 to 4 inches of water can be added to soil moisture as a result of good crop residue management. But the most important aspect is that the effect of an additional inch of stored soil moisture relates to about 5 bu/ac more wheat or 7 bu/ac more barley (Bauer and Black, 1991).

The effectiveness of surface residue in reducing moisture evaporation is shown in Table 2 (Linden. et al. 1987). Even with small amounts of surface residue cover, significant reductions in potential evaporation can be realized.

TABLE I--Effect of Percent Residue Cover on Any Day in Reducing Sheet and Rill Erosion Compared to Conventional, Clean Tillage Without Residue.

Residue Cover, % on Any Day	Erosion Reduction, % While Residue is Present
10	30
20	50
30	65
40	75
50	**83**
60	88
70	91
80	94

TABLE 2–Effectiveness of Crop Residue in Reducing Surface Evaporation.

Surface Cover,	% Relative Potential Evaporation
0	10
10	0.90
20	0.78
30	0.70
40	0.67
50	0.63
60	0.61
70	0.59
80	0.58

BUILDING ORGANIC MATTER

Under intensive, continuous conventional cropping, organic matter levels of soil have decreased from their original levels. Although this decline has leveled out in many instances under long term tillage, many soils have organic matter contents that are one-half or less than existed before cultivation began (Bauer and Black, 1983).

Bringing the organic matter content back to its original level is a very slow, almost impossible. process. However, many farmers using some forms of crop residue management for several years report a rather dramatic increase in organic matter levels. One example comes from Jim Kinsella, who farms near Lexington, Illinois. He reports that organic matter levels have increased from 1.87 percent to almost 4.0 percent in about 15 years under his no-till operation (Kinsella, 1992). This dramatic increase occurred in the upper few inches of the soil, with less dramatic increases deeper in the profile. However. increasing organic matter levels in the upper few inches of the soil surface is extremely important when considering soil erosion.

Increased organic matter at the soil surface will reduce the impact of raindrops on the soil surface and increase soil aggregate stability and infiltration, thereby reducing soil erosion. Organic matter is an extremely important component of the soil. Without it, we are left with a less productive, more erodible condition.

WATER QUALITY

Over 50 percent of the drinking water in the United States is supplied from surface water sources, and the world's percentage is even higher. Crop residue management is a means to help maintain or improve surface water quality. Properly managing crop residue helps keep soil in place which is vital to maintaining the long term viability of agriculture, as well as, maintaining or improving surface water quality. By keeping soil in place through maintaining crop residues on the surface, soil erosion is dramatically reduced, thereby reducing the pollutants, including sediment, pesticides, nutrients, and organics that reach our streams, rivers. and lakes **by** surface water runoff. And, infiltration generally increases under crop residue management which reduces the amount of water available for runoff. Data from natural runoff studies on small watersheds show crop residue management systems effective in reducing runoff of several soluble pesticides studied with no-till reducing herbicide runoff by 70 percent compared to moldboard plow systems (Fawcett, 1994) .

ECONOMICS

Any conservation practice in today's agriculture must be economical or it simply will not be widely adopted by farmers. Recent data collected from farmers show that crop residue management systems are economical and give equal or higher net returns than conventional tillage on most soils (CTIC, et al., 1993).

One of the more enticing attributes of crop residue management is that many growers can implement this practice with their present equipment, often without any or only minor changes. Some will need to change the type points or soil engaging tool used such as switching from a twisted shovel, to a straight point, or sweep in order to leave more residue on the soil surface.

Others may need to switch to new or different types of equipment, but they are the minority. Reducing the number, depth, and speed of tillage operations, and using less aggressive soil engaging tools are the primary areas that U.S. growers are considering when implementing crop residue management. However, in the last two to three years, no-till has increased dramatically.

THE CROP RESIDUE MANAGEMENT INITIATIVE

The Soil Conservation Service feels that crop residue management systems are one of the most economical ways to begin reducing soil erosion, and should be the first conservation practice that farmers consider when developing a conservation plan. In fact, crop residue management should be one of agriculture's highest priorities.

As a result, the U.S. Department of Agriculture implemented a comprehensive Three-Year Crop Residue Management Action Plan involving 9 USDA agencies (USDA, 1991). This plan is placing emphasis on:

* collection and distribution of economic information that comes from farmers who are practicing good crop residue management systems,
• increased technical training for USDA field staffs,
* increased contact with farmers,
* conducting more on-farm demonstrations,
* dramatically increasing the flow of information and effectively increasing support for crop residue management by building alliances involving key agricultural entities.

The USDA Crop Residue Management Initiative is in cooperation with the Conservation Technology Information Center which is leading the crop residue management marketing program. The marketing program involves formation of a national agricultural alliance between nine agencies within the U.S. Department of Agriculture, industry, farm media, commodity groups, and grower associations, to place emphasis on, and build support for, crop residue management. Over 65 key agricultural entities make-up this National Alliance. This alliance has fostered the formation of 20 similar state alliances and several local alliances with emphasis on working through agricultural dealers. As a result, growers will receive more consistent and timely information. The alliance has developed a common theme and logo. The common theme is "Crop Residue Management...gaining ground in the 90's".

CROP RESIDUE MANAGEMENT TRENDS

In 1989, crop residue management systems that left 15 percent or more of the surface covered with residue were just about equal to those systems that left less than 15 percent surface cover. Today, systems that leave greater than 15 percent make up 60 percent of the planted acres. By 1995 systems that leave greater than 15 percent will make up nearly 75 percent of the planted acres. By the turn of the century, these systems will be over 80 percent of the planted acres.

U.S. tillage trends clearly show the rapid decline in acres leaving less than 15 percent surface cover and that no-till is increasing at a much faster rate than other crop residue management systems. For full season corn, the adoption rate of no-till is rapidly outpacing the other forms of crop residue management. Mulch-till, although accounting for the largest percentage of crop residue management systems, has increased, but at a much slower rate over the last three years. The trend to no-till is even more dramatic with full season soybeans with no-till, drilled soybeans rapidly becoming the preferred method. In 1993, no-till cotton had the greatest percentage increase, but presently makes up only a small portion of the total cotton acreage. No-till cotton acreage, however, is expected to increase dramatically in the next few years ICTIC, 1993).

CONCLUSION

Crop residue management systems are economically viable and environmentally sound. The technology of crop residue management is advancing very rapidly. Equipment, herbicides, and management principles are available today to produce crops efficiently, economically, and environmentally on most soils using crop residue management systems. There is no more important time than now for agriculture to achieve its conservation mission. The degree of our success will shape future legislation that directly impacts all of agriculture.

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CONSERVATION TILLAGE DEVELOPMENT IN THE SOUTHEASTERN UNITED STATES

G. W. Langdale[1]

HISTORICAL PERSPECTIVE

Crop residues were recognized as an important renewable natural resource in the humid Southeast during the early 1700s. but European settlers did not possess the conservation expertise to successfully farm highly erodible lands of the southeast U.S. (Bennett, 1947; Soil survey, 1913; Trimble, 1974). Distinguished citizen-farmers of the eastern U.S. such as Franklin, Washington, Jefferson, Madison, and Ruffin recognized soil erodibility problems (Bennett, 1939, 1947; Ruffin, 1932). Because of poor available conservation technology, Ruffin stated that "managing legume cover crops was troublesome and imperfect."

Although the humid eastern U.S. had experienced some irreversible soil erosion prior to 1900 (Trimble, 1974; Jenny, 1961; Carr, 1911; Soil Survey, 1913). research funds to develop conservation tillage systems did not become available until the "Dust Bowl Era" (Buchanan, 1928). Ten soil erosion experiment stations were funded with the 1930 Buchanan Amendment to the Agricultural Appropriation Bill. The chief of the U.S. Interior Department's Soil Erosion Service, H. H. Bennett, apparently lobbied strongly for these research stations (Helms, 1992). Bennett's passionate soil conservation leadership led to this legislative action mandating research for control of soil erosion (Bennett, 1939, 1947). Bennett's leadership also led to federal funding that precipitated a national soil conservation thrust via the Soil Erosion Service in 1933 and the Soil Conservation Service of the USDA in 1935 (Helms, 1992). Managing crop residues at or near the soil surface has been a technological struggle, but we now have accumulated technologies to manage crop residues and restore and sustain crop production. Long-term research efforts associated with the development of conservation tillage systems account for these technologies.

BIRTH OF CONSERVATION TILLAGE RESEARCH

Beginning in the mid 1930s. a soil and water conservation research group was created within the Soil Conservation Service. The core of this research team was employed earlier by the agency. Many of these researchers were housed on or near Land Grant University Campuses and Experiment Stations. Multi-agency and multi-discipline soil and water conservation teams were developed. Hypotheses for managing cool season crop residues for the Southeast were initiated among these researchers. The first conservation tillage procedure developed to manage large quantities of crop residues on the soil surface is referred to in literature as the "Contour-Balk Method". This procedure consisted of plowing (middlebuster) furrows into winter cover crops. A ubiquitous cool season cover was crimson clover and rye grass. This tillage method was initially developed in 1932 at Tyler, Texas, location of one of the original ten soil erosion experiment stations created by the Buchanan Amendment (Barnett, 1987). This tillage research continued at Watkinsville, Georgia's Southern Piedmont Conservation Research Center via H. B. Hendrickson's transfer from Tyler, Texas to Watkinsville circa 1935 (Barnett 1987). Mr. Hendrickson was given credit for coining the method name, "Contour Balk". Near the same time, an innovative Hall County, Georgia, farmer, Mr. J. Mack Gowder, developed his stubble mulch method, called the Bull-Tongue Scooter (Martin, 1944; Middleton, 1952). This implement was a 4-inch chisel plow formed from a worn road grader blade. This hardened steel chisel tilled the soil while leaving most crop residues on the surface. His motive was to mimic forest soil observed on steep slopes.

GREAT PLAINS TILLAGE INFLUENCE ON THE HUMID EAST

In 1938, a noninversion tillage research team was formed at Lincoln, Nebraska (Allen and Fenster, 1986). This pioneering tillage team included J. C. Russell and F. L. Duley, employees of the research arm of the Soil Conservation Service. This team in cooperation with the University of Nebraska developed the Stubble

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Mulch concept. Their first subtillage manuscript submitted to Washington, D.C. for approval was entitled, "Noninversion Tillage". In the review process, the Soil Conservation Service Director, H. H. Bennett, changed the title to "Stubble-Mulch Tillage." The "Stubble-Mulch Tillage" umbrella terminology later included several conservation tillage procedures. Two innovative stubble mulch farmers of the Great Plains were Fred Hoeme and C. S. Noble (Allen and Fenster. 1986). Searching for tillage tools to control wind erosion, their names became associated with two pioneering stubble mulch tillage implements, the Graham-Hoeme Chisel and the Noble Blade Cultivator, respectively. Some of this equipment technology was important for the initial stubble-mulch research efforts in the Southern Piedmont.

Close to the same time frame that the Duley-Russell team was organized in Nebraska, the Peele-Beale team (T. C. Peele and O. W. Beale) was transferred from Spartanburg, South Carolina (Peele, 1942) to Clemson, South Carolina to conduct mulch tillage research. Peele had organized this team during the Soil Erosion Service era[2]. There is a high probability that H. H. Bennett and his research chief, M. L. Nichols were coordinating the research thrust in both South Carolina and Nebraska, as well as activities in several other states. Clearly the SCS administrators were searching for Land Grant University environments to develop mulch tillage research. Nichols was the mentor for most of these conservation tillage researchers'. He was a graduate student major professor as well as a supervisor for J. R. Carreker. At Clemson University, agricultural engineers G. W. Nutt and W. N. McAdams were recruited as mulch-tillage cooperators (Nutt et al., 1943). Because of the Southern Piedmont soil strength, the Noble Sweep did not perform well[2]. Several modifications were described by Nutt et al. (1943) and Peele et al. (1947). Obvious modifications were decreased sweep width and increased implement strength as well as the addition of a smooth coulter to sever crop residues. One modification was a notched coulter followed by 22-inch middlebuster shares. Some of these tools as well as the Graham-Hoeme (Allen and Fenster, 1986) were used on the "bench mark" Ravenel Runoff Plots (Clemson University). Research on these plots is described by Beale et al. (1955). Some of the first successful crop residue management research occurred on these plots. The runoff and sediment data were also used to develop the first soil erosion model--Universal Soil Loss Equation [Wischmeier and Smith. 19651.

During the 1950s the conservation tillage research thrust in the humid area had shifted from "Stubble Mulch" to "Plow-Plant" and "Wheel Track" procedures (McAdams and Beale, 1959; Larson and Beale, 1961). Soil strength was probably responsible for this new direction. These tillage procedures inverted soil with moldboard plows, leaving a rough soil surface to control erosion. Planters followed in tractor or implement tracks, thus becoming known as wheel-track planters. The plow-plant tillage originated in the mid-western U.S. W. E. Larson is responsible for considerable cooperative efforts associated with its adaption to the Southeastern U.S. (Larson and Beale, 1961). W. N. McAdams provided most of the modifications of these plow-plant methods for tlie Southern Piedmont. This was the first conservation tillage research experience for the author.

A second plow-plant tillage procedure was developed by J. C. McAlister and referred to as lister tillage (McAlister, 1962). This procedure used middlebuster type shares and rolling wings to sever crop residues or sods. This procedure opened a furrow for planting and covered most of the balk area with soil from the furrow. It was a light-duty version of the fire-line plow. Several implement companies manufactured a few versions. Considerable quantities of literature are associated with lister-tillage innovation (Hendrickson et al., 1963; Beale and Langdale, 1964 and 1967; Sanford et al., 1964; Adams et al.. 1973). The first major effort to transfer conservation tillage technology to the farm occurred during the early 1960s because of the availability of farm capital and power.

HERBICIDE ERA

Intensive secondary cultivation was required until selective phenoxy herbicides were introduced after World War II (Hamner and Tukey, 1944). Some secondary cultivation was required for weed control until other selective herbicides--triazines--were introduced in the late 1950s (Hance and Holly, 1955). These were simazine in 1956 and atrazine in 1958.

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[2] **Personal communication with Dr.** T. **C. Peele.**

[3] **Personal communication with** Mr. **J. R.** Carraker.

Two of the earliest studies cited in the literature that involved this family of herbicides and no-tillage occurred in Virginia (Moody et al., 1961) and Texas (Wiese et al., 1967). In the Virginia study, corn was hand-planted in holes made in cool season sods with a tube sampler. No-till corn planting into cool season sods improved immensely during the late 1960s and early 1970s when non-selective dessicant-herbicides such as paraquat became available for preplarit vegetation control and commercial fluted coulters became available (Carreker et al., 1977; Langdale et al., 1984 and 1991; McCalla and Army, 1961; Sojka et al., 1984; Phillips et al., 1980; Box et al., 1976; Reicosky et al., 1977; Spain, 1966; Triplett, 1976; Unger et al., 1988). Conservationlno-tillage research increased exponentially during the 1970s and early 1980s. The conservation tillage conference proceedings (begun in 1978) provided good visibility for this research in the Southeast U.S. Usually the research centers with the greatest investment in conservation tillage were bidding to host the earlier conferences.

SUBSURFACE TILLAGE

The no-till planter implement provided by several U.S. manufacturers performed exceptionally well on silt loam soils of the upper Southeast, particularly in cool season sods and early-killed small grains. However, restrictive B and E horizons of Ultisols of the Southern Piedmont and Southern Coastal Plains, respectively, created additional challenges to no-tillage acceptance. The coulter in-row chisellsubsoil implement was developed by a farmer, Mr. Jerrell Harden, near Banks, Alabama, beginning in 1972. The current versions of this implement is now referred to in the literature as strip or row tillage. This implement significantly increased *Graminae* crop yields and reduced runoff significantly (Langdale et al. 1990, 1992, 1981, 1983a and **b**, 1978. 1979).

TECHNOLOGY TRANSFER

In the Southeast U.S., J. T. McAlister (1962). a Soil Conservation Service engineer who studied under Nutt and McAdams, was a lone plow-plant crusader in the late 1950s to mid 1960s. However, Kentucky must be credited with the first holistic approach to persuade growers to adopt conservation tillage (Philips et al., 1980). This team included the University of Kentucky researcherslextension staffs as well as several state and federal action agencies. Many of these researchers were introduced to no-tillage techniques as graduate students at Virginia Polytechnic Institute (Shear, 1968; Shear and Moschler, 1969). This team attracted not only the Southeastern farmer, but global attention. The University of Tennessee was first in the development of a no-till experiment station at Milan, Tennessee, under Mr. Tom McCutchen's leadership, to transfer this technology (Southern Conservation Tillage Proc. 1983). Newer innovations such as inter-cropping developed at Clemson University and no-till drilling of both cool and warm season annuals are documented in the Southern Conservation Tillage Proceedings from 1978-1993. The soil erosion control value of tillage procedures described herein is presented in the 1983 proceedings by Langdale et al. (pp. 56-611.

CURRENT STATUS AND FUTURE

More than 30% of the crop acreage in the 13 southern states, represented by the Southern Conservation Tillage Conference, is currently conservation tilled. Both total acreage and percentage must increase in the humid east as water deficits develop on western irrigated lands. Currently conservation tillage technologies are slowly accumulating. However, farm market depressions are suppressing adoption.

Conservation tillage and surface crop residue management terminologies are essentially synonymous. Crop residues are the most globally abused renewable natural resource. Crop residues are the only renewable natural resource that man can successfully manage in order to conserve nonrenewable natural resources--soil and water. Over 50 years of research in the U.S. have proven the value of wise management of these natural resources (Langdale et al., 1994; Unger et al., 1988).

Civilization has suffered immensely because of resource abuse (Lowdermilk, 19531. Currently, disastrous resource degradation is occurring on tropical and semi-arid tropical landscapes. The human population explosion accounts for considerable natural resources pressure, thus accelerated degradation of these resources. The humid Southeastern U.S. may represent the last frontier for agriculture in North America. Urbanization and unwise management are beginning to create considerable pressure on our natural resources. One of the greatest abuses is federal policies that diminish crop rotation incentives. The first soil erosion model, The Universal Soil Erosion Equation (Wischmeier and Smith. 1965, Wischmeier, 1973), included row-crop rotations with a meadow. A recent government opportunity to provide a sod-based crop incentive was scrubbed in favor of pine trees for most of the lower South (Food Security Act, 1985). Much of the current success of conservation tillage in the Southeast U.S. may be attributed to a federal, state, and industry research and technology transfer team effort. The complex environmental quality phenomena create a renewed challenge for conservation tillage researchers. Securing future funds to continue this conservation thrust may be our greatest challenge.

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INFLUENCE OF NO-TILL ON SOYBEAN CULTURAL PRACTICES'

Richard R. Johnson[1]

Conservation Provisions of the 1985 Farm Bill required farmers who want to continue participating in government programs to control erosion on land with high erosion rates. Farmers had to begin implementing conservation plans for the 1990 cropping season. Plans must be fully implemented by January 1, 1995. No-till became a significant part of these conservation plans, because current erosion models give little credit for full-width tillage systems that leave residue on the soil surface (Alberts et al., 1985). A rapid rise in the proportion of U.S. crop acres planted to no-till began with implementation of conservation plans (Figure 1). Growth in no-till has been more rapid in soybeans that other crops. At least part of the reason for this is that soybeans produce a soil condition that is more erosive than other crops (Alberts et al., 1985).

Acreage not designated as highly erosive is also increasingly being planted to no-till. The desire to use similar machinery systems on a farm unit accounts for a portion of this adoption. Lower herbicide costs, a greater array of herbicides, improved seeding equipment, and aggressive marketing by pesticide manufacturers have also contributed to growth of no-till.

"Musts" With No-Till

Growing soybeans without tillage requires a couple obvious changes compared to using full-width tillage prior to planting. First, either a burndown or early preplant herbicide program must be used before planting. This will kill established weeds normally eliminated with tillage and should be designed to control the particular weed species present.

A second change involves equipment choices. Most important is the need for a planter or drill capable of penetrating and preparing a seedbed under the higher residue and firmer conditions associated with no-till. Combine attachments that uniformly spread residue aid chemical performance and ease of seeding. With headers less than 15 to 17 feet wide, a simple straw spreader is often adequate. With wider headers, chaff spreaders and straw choppers greatly improve residue spreading. If row crop cultivation is planned, a heavier-duty cultivator is also required for no-till.

Beyond these obvious changes, other changes in culture often involve fine tuning the system. Considerable research suggests that soybean production practices used to maximize yields in conventional tillage systems are often the same practices needed to maximize yields in mulch-till or no-till systems (Oplinger and Philbrook, 1992; Lueschen et al., 1992). This is not to imply that no-till is an easier system to use or best in all situations. In fact, there is often a higher risk with no-till, and it is not the system of choice for all situations. The remainder of the discussion will focus on these "finer points" of no-till.

Seed-Related Considerations

The best yielding varieties in no-till systems are generally the same varieties giving highest yields in tilled systems. Elmore (1987 and 1991) has confirmed this relationship in 30-inch row widths. Philbrook et al. (1991) have confirmed this relationship in drill row widths. In a few instances, no-till has caused unique changes in pest levels, creating significant variety interactions. For example, during one year Vasilis et al. (1988) observed greater Phytopthora root rot *(Phytopthora megasperma)* under no-till. Using a variety with lower resistance caused a 44% loss in final stand and an associated yield loss. In Tennessee, cyst nematode *(Heterodera glycines* Ichinohe) populations were lower in no-till than in systems using tillage (Tyler et al., 1987). Varieties with single and multirace resistance produced similar yields in no-till, but with tillage the variety with single race resistance yielded less if cyst counts were high. The clear message is to choose varieties with the best resistance to pests known to be present.

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[1] Also presented at The Soybean Seed Research Conference at the Annual Meeting of the American Seed Trade Association in Dec. 1993 in Chicago, IL.

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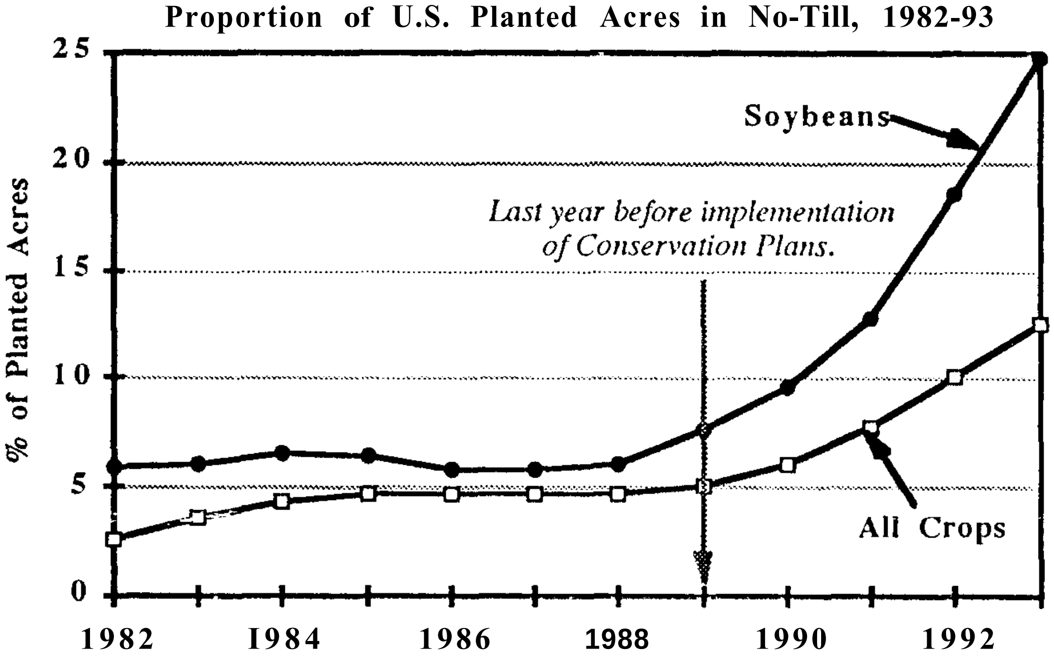

Figure 1. Use of no-till in soybeans and all planted crops (CTIC, 1993).

Cooler and moist seedbeds associated with no-till encourage many to promote greater use of seed treatment pesticides (Grooms, 1993). Phytopthora and pythium are two common pathogens more prevalent in no-till soils. In Wisconsin, Guy and Oplinger I19891evaluated two seed treatments on six varieties grown in moldboard, mulch- and no-till seedbeds at two locations over 2 years. Moldboard plow soybeans averaged 8 bu/acre higher than no-till. Apron seed treatment tended to increase yield in no-till, but not in other tillage systems. Vitavax 200 seed treatment caused both yield enhancement and reduction for some varieties. The authors concluded that seed treatments should be especially considered in no-till. In contrast, Lueschen et al. (1991) found that seed treatments were not necessary to obtain adequate stands, even in no-till seedbeds. Thus, where high vigor seed is used there is not strong research evidence supporting the need for seed treatment, but many consider it a cheap insurance to help assure adequate stands.

Between 140,000 to 200,000 seeds per acre is sufficient to maximize yields where tillage has been used (Johnson. 1987). Using 30-inch row widths in Nebraska, Elmore (1991) found this same range of seeding rates to be effective in both conventional and no-till. Using solid seeded rows in Wisconsin, Oplinger and Philbrook (1992) found that 176,000 seeds per acre maximized yields with tillage whereas 15 to 32% higher seeding rates were required with no-till (up to 232,000 seeds per acre). Pioneer Hi-Bred (1992) recommends a seeding rate of 200,000 to 225,000 viable seeds per acre where soybeans are drilled into corn residue. There is little evidence that higher final stands are required in no-till. However, given cooler seedbeds, higher residue conditions, and a greater likelihood of pests, it seems logical to increase seeding rates by 10 to 25% with no-till. especially in drill row widths.

Fertilizer Placement

Phosphorus and potassium are relatively immobile nutrients. They remain near the soil surface if not band-injected or mixed into the soil with tillage. Band and broadcast applications of potassium resulted in similar yields on two Illinois soils with relatively high exchangeable rates of potassium (Vasilas et al., 19881. In contrast, Mississippi researchers found band placement of P and K was better than broadcast placement on two of three soils testing low in these elements (Hairston et al., 1990). Benefits of band placement occurred with no-till but were not evident where full-width tillage had been used. In both of these studies, no-till yields were lower than where full-width tillage had been used, but band placement could not overcome yield reductions associated with no-till.

Where no-till is used, it would seem advisable to either include occasional tillage to incorporate nutrients or consider deep band injection of P and K, especially if soil tests are low to medium for these elements. Getting P and K into the surface soil will prevent them from being positionally unavailable if dry conditions occur for extended periods. Occasional tillage would have the added benefit of mixing lime into the surface layer. Several herbicides can cause significant injury if pH becomes too high.

Planting Dates and Row Width

Optimum planting dates and row widths do not generally change with tillage system. Where narrow rows yield more with tillage, no-till beans also yield more in narrower rows (Oplinger and Philbrook, 1992; Lueschen et al., 1992). Likewise, environments not showing any advantage to narrow rows do not seem to respond differently if no-till is used (Mclsaac et al., 1990). Use of row widths less than 30 inches has grown steadily and now accounts for nearly 50% of the planted acreage (Fig. 2). During the past 4 years adoption of drill row widths has been greater than intermediate row widths. This may be at least partially due to greater use of no-till. Soybeans planted no-till grow slower after emergence and tend to provide better early season weed competition if planted in narrow row widths.

Crop Rotations and Soil Types

Over half of U.S. soybeans are grown in rotation with corn. A majority of the remainder are rotated after wheat or cotton. A few acres of continuous soybeans are grown, mainly in the south. Although some research fails to show a yield advantage for crop rotation (Wagger and Denton, 19921, most studies show 5 to 15% increases in yield where crops are grown in rotation (Dick et al., 1986a. 1986b; Johnson, 1987; Lund et al. 1993). If a soil is not well adapted to limited tillage, crop rotation often helps bring reduced- or

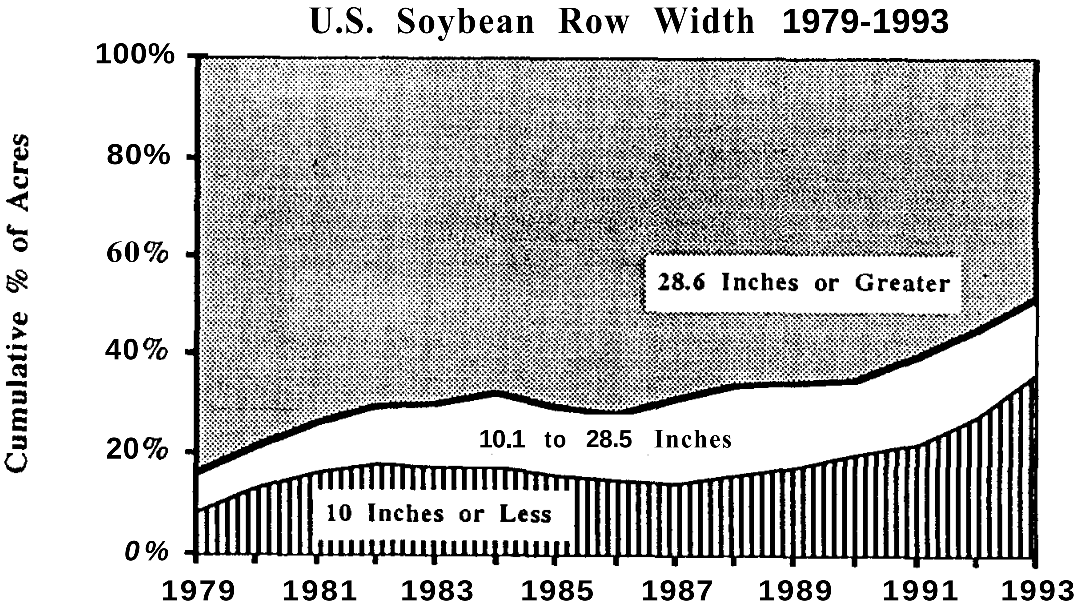

Figure 2. Proportion of U.S. soybean acreage planted in different row widths (Crop Reporting Board, 1981-1993).

Table 1. Effect of tillage system on soybean yields when grown in a cornlsoybean rotation. Summarizes 18 research reports published in the last decade (see appendix for sources).

Tillage System	Favorable Soils	DroughtylPan Soils
	---Bu/Acre---	
Moldboard plow	44.0	'33.2
Reduced-Till	43.1	35.6
No-till	41.1	38.1
Locations	11	7
Location-years	86	53

• The moldboard yield is based on only four locations, but if the number of locations is restricted to four for all tillage systems, mean yields are essentially the same as shown.

no-till yields closer to those of more conventional tillage systems.

From the earliest days of reduced tillage research, it has been obvious that optimum tillage systems are site specific. Droughty soils that are well drained tend to produce the highest yields with limited tillage or no-till systems. In contrast, moderate to poorly drained productive soils tend to yield most with some type of full-width tillage system. As shown in Table 1, modern research continues to validate this lesson. To avoid variations due to crop rotations, Table 1 considers only corn-soybean rotation studies that included a no-till, moldboard plow, and some form of reduced-till treatment–usually a disk or chisel system. An attempt has been made to include published studies from throughout the major soybean producing areas, somewhat in proportion to planted acres. Many more studies could be cited, particularly on favorable soils–for example, an additional five research locations in both Iowa and Illinois with 6 years or more of data showing similar results.

No-till produced yields 2.5 bushels/acre higher than reduced-till and nearly 5 bushels higher than moldboard plow on sandy soils or soils having a restrictive pan near the soil surface (Table 1). These soils can easily cause crop drought stress early in the growing season. The protective mulch of no-till surface cover reduces early season moisture loss. After a crop canopy develops, a surface mulch is of little help in moisture conservation, but higher yields often result from the greater early season moisture. On deep soils that are moderate to poorly drained, moisture conservation from a surface mulch is seldom of benefit. These soils are generally not subject to early season moisture stress, and surface mulch is detrimental because it delays early-season field operations and slows early crop growth. On deep soils no-till yields averaged about 3 bushels/acre below moldboard and 2 bushels below reduced-till.

Enthusiasts who promote no-till use for all situations often suggest that it takes 3 or 4 years for soils to adapt to no-till. They state that, given patience, no-till yields will approach or exceed those of where tillage is practiced. Table 1 includes only research conducted for 4 or more years–two sites included more than 20 years. In none of these 18 locations did yield response to tillage improve significantly with advancement of time, with either corn or soybeans. Thus, widespread experimental evidence does not support soils "adapting" to no-till. Small plot research places no-till in its best "light" because large combines, chemical trucks, and other transport vehicles are generally not used. These machines cause deeper compaction and provide farmers with a major incentive to use tillage.

Weed Control

In small plot research, as tillage is reduced or eliminated, small seeded annual grass species and perennials become more difficult to control. In contrast, large seeded broadleaf weeds are less

Table 2. Weed density in southwestern Ontario fields managed with various tillage systems (Frick and Thomas, 1992).

	Tillage System		
Weed life cycle	Moldboard	Reduced-till	No-till
	---number of weeds per m^2---		
Annual broad-leaved	4.7	9.4	9.9
Annual grass	4.5	8.2	8.3
Perennial	5.1	3.9	7.4
Total density	17.0	24.7	31.7

affected by tillage or become easier to control as tillage is eliminated. Overall number of weed species and weed densities tend to increase as tillage intensity is reduced (Buhler et al., 1990; Cardina et al., 1991). These conclusions are largely confirmed with on-farm experience. Frick and Thomas (1992) surveyed 593 soybean, corn, and winter wheat fields in southwestern Ontario during 1988 and 1989. They confirmed that weeds were present at highest densities in fields with no-till (Table 2). Both annual grass and broad-leaved weeds were at about equal population in reduced and no-till systems, but were double the density of those found in moldboard plowed fields. Perennial weed densities were highest in no-till and lowest in reduced-till systems. Thus, in spite of intense herbicide use, weeds continue to present a significant problem to modern soybean producers. If the trend continues toward less intense tillage, weed problems are likely to become greater.

Economics

I would like to illustrate the economics of no-till with a personal anecdote. Benefits of no-till have often been summarized with the catchy phrase of "saving soil, oil and toil." I'm not sure who first coined this phrase, but I first heard it in speeches given by John Block when he was Secretary of Agriculture. Last summer I visited Block Farms in Knox County, Illinois. After several years of trying no-till on a sizable acreage, they had settled on a reduced-till system for most of their acreage. In visiting with Jack's son Hans, I reminded him of his father's statements. Hans stated that they did experience reduced erosion, less use of diesel fuel and fewer hours in the field when they used no-till practices. He then went on to point out that tradeoffs included spraying more herbicides, paying additional costs for other chemicals and seeds, and accepting lower/more variable crop yields. Simply put, we might say the benefits of "saving soil, oil, and toil" were offset by more "spraying, paying, and praying."

The Block Farms have settled on reduced-till as the best compromise for conservation, management, and profits. No-till will be used only where mandated in their conservation plans. The Block's experience is not unique. Many who initially tried no-till enthusiastically have now altered their approach using a variety of modifications. This experience is given because it summarizes most of the recent research analyzing economic returns of various soybean tillage systems.

McIsaac et al. (1990) and Chase and Duffy (1991 calculated economic returns for small-plot research trials using similar chemical treatments for each tillage system, with the exception of additional burn down herbicides used for no-till. Brown et al. (1989) analyzed large field scale research plots using chemical treatments for each tillage system that were selected by a farm manager. Chemical treatments varied from field to field and year to year. Martin et al. (1991) used small, research tillage plots to evaluate several alternative weed control systems. Stephens et al. (1992) used a machinery selection program to evaluate several alternative herbicide and fertilizer systems commonly used with alternative tillage systems.

All of the above research analysis found no-till to result in the lowest machine and fuel costs as well as the lowest labor requirements. However, no-till was never the most profitable system because herbicides and other variable costs increased enough to offset machine-related savings. In some cases yields also decreased enough with no-till to significantly reduce profits. The most profitable systems involved full-width tillage of reduced-till and/or moldboard systems.

Most of the above studies involved soils classified as favorable in Table 1. If no-till were to result in several bushel/acre yield increases. it could easily be the most profitable system. The research also showed that where soil conservation is necessary, many of the reduce-till systems give profits similar to moldboard. If no-till is mandated, careful selection of fertilizer and herbicide options can help minimize costs making no-till cheaper than adopting unusual crop rotations or terraces.

The Chemical Issue

An opinion poll conducted by the Center for Communication Dynamics showed that, nationwide, nearly 60% of respondents (80% of college-educated respondents) agreed with the statement that “farmers use too many pesticides.” Only 23% were willing to accept that drinking water was safe if it met government standards but still contained small amounts of chemicals (Batie et al.. 1986). Public sentiment continues to be strongly in favor of agriculture using fewer farm chemicals that stay on fields, and out of food and drinking water supplies. Recent legislation such as endangered species. safe drinking water, and coastal zones are all aimed at addressing this public sentiment.

The economic research papers cited above document that greater amounts of herbicides are used in no-till. Tillage can also affect use of other pesticides such as insecticides and rodenticides. One measure of pesticide use is annual sales. From the late 1970s through 1988, pesticide sales were either stable or declining, depending on whether measured in current or 1987 dollars (Fig. 3). Beginning in 1989 pesticide sales began a steady trend upward. This corresponds with the rapid growth in no-till acreage (Fig. 1) and implementation of conservation plans.

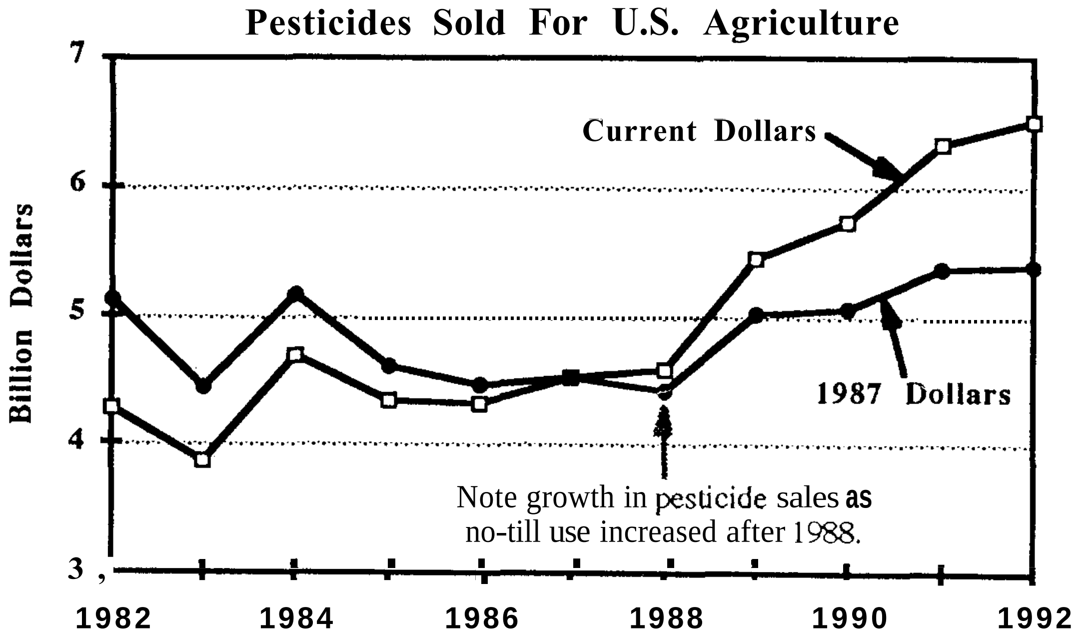

Figure 3. Pesticide sales in current and 1987 dollars (USDA. ERS, 1993b).

Table 3. Average number of pesticide treatments used with different tillage systems (USDA/ERS RTD Updates, 1992 and 1993a).

Tillage System	Soybeans	Corn	Cotton
	-Number of	Treatments-	
1991:			
Conv. w Moldboard	1.41	1.37	3.70
Conv. wo Moldboard	1.48	1.63	5.48
Mulch-Till (>30% cover)	1.54	1.76	4.68
No/Ridge-Till	1.67	1.75	7.46
1992:			
Conv. w Moldboard	1.50	1.57	3.72
Conv. wo Moldboard	1.61	1.70	6.25
Mulch-Till (>30% cover)	1.57	1.85	•
No/Ridge-Till	1.73	1.71	*

• Insufficient data.

The number of pesticide treatments for soybeans and crops commonly grown in rotation with soybeans is shown in Table 3. As tillage systems progress from moldboard plow to no-till, about 10 to 30% greater number of pesticide applications are used in corn and soybeans. In cotton the number of applications nearly double. Thus, one of the major challenges facing agriculture is to learn how to use fewer pesticides as the intensity of tillage is reduced.

A second challenge is to keep agricultural chemicals in place. During the severe flooding in 1993, extraordinarily large amounts of herbicides and nitrate were flushed into the Mississippi River. Even though extremely high streamflows were recorded during the flood, concentration of herbicides such as atrazine, alachlor, cyanazine, and metolachlor were similar to maximum concentrations measured during much lower streamflows in 1991 and 1992 (Goolsby et al., 1993). The total atrazine load transported to the Gulf of Mexico from April through August 1993 was 1.2 million pounds or about *80%* higher that the same period in 1991 and 235% higher than in 1992. The total load of nitrate transported to the Gulf during the same 1993 period was over 900,000 tons, 37% larger than in 1991 and 112% larger than in 1992.

Reduced amounts of application are one of the most effective methods available to reduce chemical contamination. Several alternatives exist to use pesticides more efficiently. Long-term, the seed industry will play an important role in reducing need for insecticides. Initial success has already occurred by incorporating some genetic insect resistance into crops such as cotton and corn. However, genetics can play only a minor role in controlling weeds because they do not feed on the crop. Yet, herbicides alone account for about 80% of the tonnage of US. pesticides sold.

Pesticides can be reduced by scouting and applying only where needed. Recent research is showing that small amounts of mechanical cultivation will allow greatly reduced herbicide application. During a two-year study in Minnesota, herbicide rates were reduced 50 to 75% by banding or using a broadcast application at half labeled rates (Fig. 4). A single cultivation following a reduced herbicide application was generally sufficient to produce yields equal to or greater than those obtained for the full-rate broadcast application without cultivation. Similar results have been obtained at three Missouri locations (Steckel et al., 1990). Herbicide cost savings more than offset the cost of cultivation, and improved weed

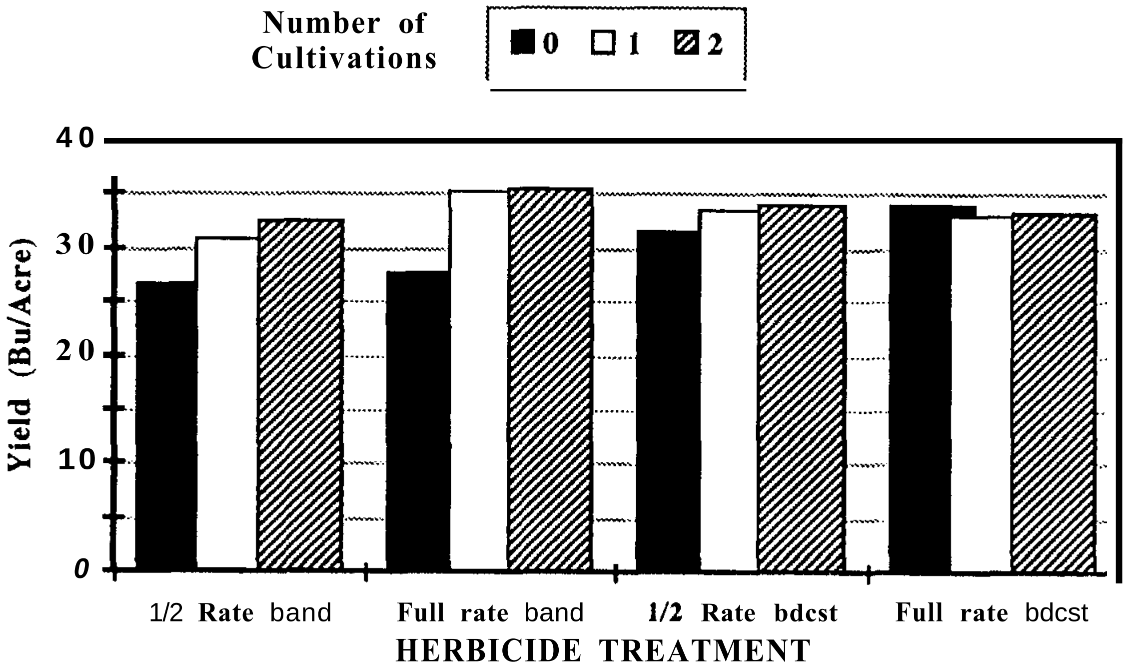

Figure 4. Two-year average soybean yields obtained with herbicide treatments of full-rate broadcast, half-rate broadcast, full-rate band, and half-rate band treatment. All were used with 0. 1 or 2 cultivations (Buhler et al. 1992).

control or yield gains add to profits. Environmental benefits include less chemical use.

A few pesticides are strongly adsorbed onto soil particles, while most developed since 1960 are only weakly to moderately adsorbed (Baker. 1992). Soil erosion control will reduce loss of strongly adsorbed pesticides. In contrast, erosion control will only have a limited effect on those weakly or moderately adsorbed to soil since they move primarily in runoff water (Baker, 1992). Christensen et al. (1992) summarized several different experiments using various Best Management Practices (BMPs) to reduce herbicide movement off fields (Fig. 5).

The reference line in Figure 5 (100% runoff1 used surface herbicide application in a moldboard plow system. Surface herbicide application in three forms of conservation tillage (no-till, ridge-till and chisel plow) reduced average herbicide runoff to about 30 to 50% that measured with surface application in moldboard tillage. The incorporation treatment was done with moldboard plow tillage and compared surface herbicide application with preplant incorporation. Incorporating herbicides in moldboard tillage was as effective at reducing herbicide runoff as was surface application in conservation tillage.

In no-till, no option exists other than surface herbicide application. Much of the chemical is applied to surface residue or growing weeds. If the first rain after application is intense, herbicide never gets a chance to move into or attach to the soil making it vulnerable to high rates of runoff. This is why no-till has such a large range in herbicide runoff and can exceed loss experienced with surface application in moldboard plow tillage (Figure 51. Combining preplant incorporation with surface preserving tillage provides an opportunity to reduce herbicide runoff, but the challenge becomes obtaining good incorporation while maintaining surface residue (Baker, 1992; Christensen et al., 1992). Many newer secondary tillage machines, especially field cultivators and combination machines, have been redesigned with more residue handling capability. A new tillage concept specifically designed for incorporation in high residue is also available (Johnson et al., 1992). These new machines provide producers the capability of incorporating herbicides for reduced runoff while retaining surface cover for erosion

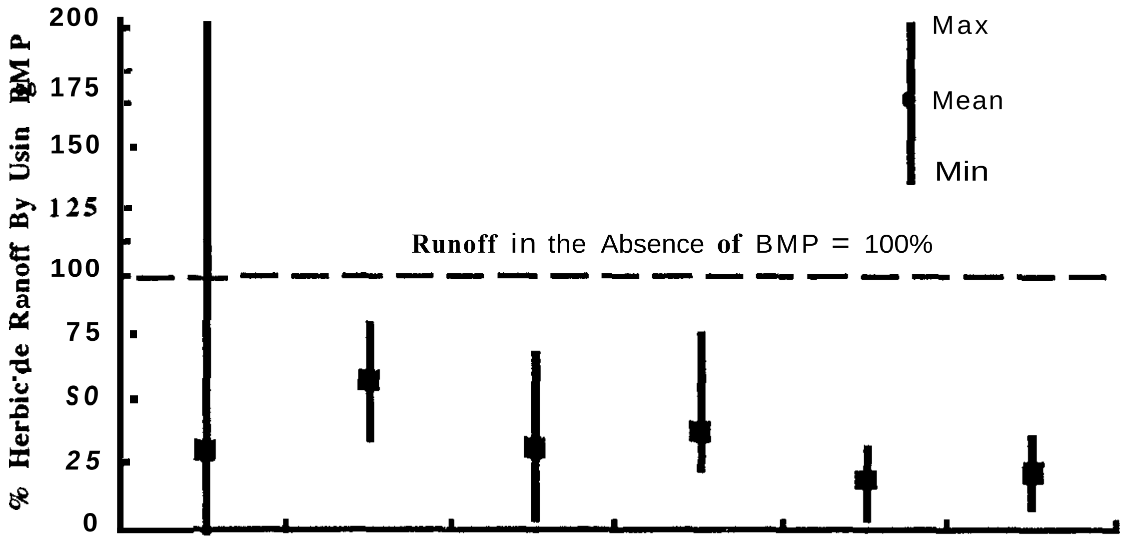

Figure 5. Herbicide runoff with various Best Management Practices (BMP), Christensen et al., 1992. The dashed line represents runoff relative to surface applications with moldboard.

control. These water quality advantages of tillage are important to weigh against soil erosion benefits of no-till.

Summary

Soybean no-till culture has greatly expanded with implementation of conservation provisions of the 1985 Farm Bill. Compared to other tillage systems, no-till requires burndown or early preplant herbicides to control weed growth occurring before planting. Combine attachments to uniformly spread residue and a rugged enough planter to provide precise seed placement are other unique requirements. Most other cultural practices are similar to those used with full-width tillage systems. No-till does have some tendency to require higher seeding rates and a greater need for seed treatment pesticides. Injection of nutrients or occasional use of tillage can also make no-till nutrient management much easier.

No-till often yields highest on soils prone to early season drought, while it generally yields less on more favorable soils. If a yield advantage does not occur with no-till, economics favor use of tillage. No-till is also often the least-cost system where highly erosive lands mandate extreme erosion control. A downside of no-till has been use of greater amounts of pesticides that are more vulnerable to surface runoff. Integrated weed management systems offer potential to greatly reduce herbicide use if combined with small amounts of row cultivation. Incorporation of herbicides while maintaining surface cover offers much of no-till's soil erosion control, yet provides potential for reduced herbicide runoff.

Appendix

Favorable soils in Table 1 are at Morris and Waseca, MN (Lueschen et al., 1992), Arlington, WI (Oplinger and Philbrook, 1992). Champaign, Perry, and Monmouth, IL (Univ. of Illinois, 1992), Custer, OH (Dick et al., 1986a). Lafayette, IN (Kladivko et al., 1986). Burlington, IA (Brown et al., 1989). Nashua, IA (Chase and Duffy, 1991), and Ames, IA (Erbach, 1982). The droughty soils include results from Northeast, AL (Edwards, et al., 1988), Brownstown and Kilborne, IL (Univ. of Illinois, 1992), Wooster, OH (Dick et al., 1986b). Reidsville and Rocky Mount, NC (Wagger and Denton, 1992), and Southeast, IN (Kladivko et al., 1986).

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EFFECT OF LONG-TERM ROTATION AND TILLAGE PROGRAMS ON PLANT-PARASITIC NEMATODES

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

ABSTRACT

Effects of tillage and crop rotation on nematode densities in tropical corn (*Zea mays* L. Pioneer Brand X304C) were determined in each of three seasons (1990-1992) in north Florida. Treatments in the factorial experiment consisted of conventional or no tillage and rotation with sorghum (*Sorghum bicolor* [L.] Moench) or soybean (*Glycine max* [L.] Merr.). Tillage and rotation treatments were maintained for 14 previous years, including the 1989 season. In subsequent corn crops (1990-1992). effects of treatments depended on nematode species. The most serious nematode pest in the site, the root-knot nematode (*Meloidogyne incognita* [Kofoid & White] Chitwood) was lower in plots rotated to sorghum and remained so for three seasons, but was not affected by tillage practices.

INTRODUCTION

Plant-parasitic nematodes are serious pests of many crops grown in the southeastern United States (Christie, 1959; Johnson, 1982: Taylor and Sasser, 1978). As nematicide usage becomes more limited, it will be necessary to develop alternative methods for managing nematodes. Two alternatives which can often be implemented easily and inexpensively are crop rotation and changes in tillage practices (McSorley and Gallaher, 1991; Minton, 1986). Crop rotation can be effective against root-knot nematodes (*Meloidogyne* spp.), which are major pests in the Southeast (Johnson, 1982; McSorley and Gallaher, 1991, 1992, 1993a; Rodriguez-Kabana et al., 1989). Effects of tillage practices on nematode populations have been less consistent (McSorley and Gallaher, 1993b; Minton, 1986). The objective of the current research was to compare the effects of crop rotation and tillage on population densities of plant-parasitic nematodes, in a location where both methods had been practiced for many years.

MATERIALS AND METHODS

The experiment was conducted at the University of Florida Green Acres Agronomy Research Farm in Alachua County, on an Arredondo sand (94% sand, 3.5% silt, 2.5% clay; pH 6.2; 1.7% organic matter). As of 1989, conventional and no-till plots had been maintained at this site for 14 years as part of a double-cropping rotation with soybean (*Glycine max* [L.] Merr.) or sorghum (*Sorghum bicolor* [L.] Moench) in the summer and oat (*Avena sativa* L.) in the winter. In the spring of the 15th year (1990). a factorial experiment with tropical corn (*Zea mays* L., Pioneer Brand X304C) was initiated on the site. The factorial involved two crop rotation treatments soybean cv. (Centennial and sorghum cv. DeKalb BR64 during the previous year, 1989) and two tillage treatments (conventional and no-till). All treatment combinations were replicated four times, and the experiment was repeated in 1991 and 1992 in the same plots.

A winter cover crop of oats cv. Florida 501 was planted in all plots in late November-early December each year. Oats were harvested and mowed in early May. In conventional-till plots, the soil was rototilled twice before planting corn. In May of each year, tropical corn was planted directly into no-till or conventional-till plots with a two-row Brown-Harden Superseeder. Individual plots consisted of four rows, 10 m long and 0.75 m apart. Fertilizer and herbicide usage is described elsewhere (McSorley and Gallaher, 1993b).

Plots were sampled for nematodes each year at the planting of the corn crop in May and the harvest of the corn crop in September. Each soil sample consisted of six cores 2.5 cm in diameter x 20 cm deep collected within plant rows in a plot in a systematic pattern. 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,, [x + 1]) before conducting an analysis of variance (ANOVA). but arithmetic means rather than transformed means are presented in the tables.

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Table 1. Effects of tillage and rotation crop on population densities of root-knot nematodes (*Meloidogyne incognita*) at planting and harvest of tropical corn crops, 1990-1992.

		Nematodes per 100 cm^3 soil					
	Rotation crop	1990		1991		1992	
Tillage	(1989)	May	Sept.	May	Sept.	May	Sept.
No-till	Soybean	1	3	10	26	1	112
No-till	Sorghum	0	0	0	2	0	0
Conventional	Soybean	0	10	1	104	3	91
Conventional	Sorghum	0	0	0	1	0	3
ANOVA effects:							
Tillage		ns	ns	ns	ns	ns	ns
Rotation		ns	*	ns	*	ns	•
Tillage x rotation		ns	ns	ns	ns	ns	ns

• Analysis of variance (ANOVA) effect significant at $P \leq 0.05$;
ns = not significant.

Table 2. Effects of tillage and rotation crop on population densities of ring nematodes (*Criconemella* spp.) at planting and harvest of tropical corn crops, 1990-1992.

		Nematodes per 100 cm^3 soil					
	Rotation crop	1990		1991		1992	
Tillage	(1989)	May	Sept.	May	Sept.	May	Sept.
No-till	Soybean	40	138	361	374	374	552
No-till	Sorghum	98	202	160	234	460	643
Conventional	Soybean	20	246	149	291	448	1178
Conventional	Sorghum	138	314	391	647	965	999
ANOVA effects:							
Tillage		ns	ns	ns	ns	ns	ns
Rotation		*	ns	ns	ns	ns	ns
Tillage x rotation		*	ns	ns	•	ns	ns

* Analysis of variance (ANOVA) effect significant at $P \leq 0.05$;
ns = not significant.

RESULTS AND DISCUSSION

The root-knot nematode *(Meloidogyne incognita* [Kofoid & White] Chitwood) was not affected by tillage practices, but each year in September, population densities of *M. incognita* were lower in corn plots in the sorghum rotation than in plots in the soybean rotation (Table 1). These results are consistent with those obtained previously (McSorley et al. *1993a)* with DeKalb BR64 and certain other sorghum cultivars which are beneficial in rotations against *M. incognita.* It is interesting to note that the significant effects of sorghum rotation on *M. incognita* lasted for three years in the tropical corn crops examined here (Table 1). In contrast, reductions of *M. arenaria* (Neal) Chitwood in a rotation with sorghum and susceptible peanut *(Arachis hypogaea* **L.)** lasted only a single season (Rodriguez-Kabana and Touchton, 1984).

Densities of ring nematodes *(Criconemella* spp.) were affected by treatments in the first season, when they were greater following sorghum rotation (Table 2). However, ring nematodes are not major pests of most crops in Florida, where root-knot nematodes are the key nematode pests on most crops (McSorley and Gallaher, 1991). The stubby-root nematode *(Paratrichodorus minor* [Colbranl Siddiqi) was unaffected by the treatments in this series of experiments, and its population densities increased during the three seasons of corn (Table 3). Effects of treatments on lesion nematodes *(Pratylenchus* spp., primary *P. scribneri* Steiner) varied, but lesion nematode numbers were greatest in Sept. 1990 in conventional-till plots following soybean and in Sept. 1991 in plots which had received conventional tillage (Table 4). Alby et al. (1983) also observed higher densities of *P. scribneri* in conventional-till compared with no-till soybean plots.

It is clear from our results that effects of tillage or crop rotation depend on the nematode species involved. The most damaging nematodes occurring in our study site are probably root-knot and stubby-root nematodes (Christie, *1959;* McSorley and Gallaher, *1991).* Therefore any incentive to use tillage or crop rotation for nematode management would depend on results expected with these two species. Little effect from rotation or tillage on *P. minor* would be expected. Rotation with sorghum was much more important than tillage for management of *M. incognita.* Therefore the choice to change tillage practices should not be expected to have much impact on *M. incognita* populations, and should be made for reasons other than nematode control.

Table **3.** Effects of tillage and rotation crop on population densities of stubby-knot nematodes (Paratrichodorus minor) at planting and harvest of tropical corn crops, 1990-1992.

		Nematodes per 100 cm³ soil					
	Rotation crop	1990		1991		1992	
Tillage	(1989)	May	Sept.	May	Sept.	May	Sept.
No-till	Soybean	4	2	20	24	45	39
No-till	Sorghum	3	3	34	48	40	40
Conventional	Soybean	3	4	24	64	*52*	23
Conventional	Sorghum	3	*5*	49	*52*	48	38
ANOVA effects:							
Tillage		ns	ns	ns	ns	ns	ns
Rotation		ns	ns	ns	ns	ns	ns
Tillage x rotation		ns	ns	ns	ns	ns	ns

* Analysis of variance (ANOVAI effect significant at $P \leq 0.05$:
ns = not significant.

Table 4. Effects of tillage and rotation crop on population densities of lesion nematodes (Pratylenchus spp.) at planting and harvest of tropical corn crops, 1990-1992.

		Nematodes per 100 cm^3 soil					
	Rotation crop	1990		1991		1992	
Tillage	(1989)	May	Sept.	May	Sept.	May	Sept.
No-till	Soybean	5	**338**	**48**	**608**	**199**	**1866**
No-till	Sorghum	**6**	**196**	**186**	**440**	**144**	**1964**
Conventional	Soybean	**3**	**734**	**221**	**1350**	**341**	**2164**
Conventional	Sorghum	**0**	**56**	**189**	**1325**	**241**	**2487**
ANOVA effects:							
Tillage		*	ns	ns	*	ns	ns
Rotation		*	*	ns	ns	ns	ns
Tillage x rotation		ns	*	ns	ns	ns	ns

* Analysis of variance (ANOVA) effect significant at $P \leq 0.05$;
ns = not significant.

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YIELD AND NUTRIENT CONCENTRATION AND CONTENT IN RESPONSE TO NITROGEN FERTILIZATION IN FORAGE AND GRAIN SORGHUM

C.R. Chase, G.M. Henry, and R.N. Gallaher[1]

ABSTRACT

Dairy farmers are looking for forage crops that can remove large amounts of N from spray fields. With this concern in mind two cultivars of sorghum (Sorghum bicolor), 'Asgrow Chaparral' (Grain Sorghum) and 'DeKalb FS25E' (forage sorghum), were used in a study to determine their response to seven N rates (0. 40, 80, 120, 160, 200, 240 lb N/ac). The third leaf from the flag was sampled at the early bloom stage of maturity and analyzed to determine plant health. Plant concentrations showed that N and K were below sufficiency levels with Mn, Fe and Ca being accumulated at sufficient levels and P, Mg, Cu, and Zn accumulated at levels above sufficiency. Whole plant samples were collected to determine nutrient content and yield. Nitrogen accumulation in the whole plant increased with N fertilization rate from 26.7 to 63.4 lb N/ac for the O and the 160 lb N/ac rate, respectively, while N accumulation decreased with additional N. Dry matter accumulation increased with increasing N fertilization rates and peaked at 160 lb N/ac. Grain samples were also collected to determine grain mineral concentration and yield. Grain yield was highest in the Asgrow Chaparral, however both cultivars showed a response in grain yield to N fertilization up to the 120 lb N/ac level.

INTRODUCTION

Determination of nutrient removal by plants is important for three reasons. First, this information can be used to find the uptake ratios of nutrients by various species of plants so that plant requirements can be met. Secondly, nutrient removal information can be helpful for determination of animal nutrient intake. The third reason, nutrient removal has become a major concern due to the risk of environmental pollution. Dairymen, feedlot operators, and poultry producers have all been faced with new environmental regulations that have forced them to control the nutrients N and P in manure wastes. One method that these producers are using to dispose of excessive nutrients is to recycle them through crops. This is one of the most economical and efficient strategies for nutrient removal because plants take up large quantities of N and other nutrients and the plants can be used for livestock feed.

Florida is unique when compared to other areas of the country because crops can be grown year round. Double or triple cropping is a common practice that is used to take up manure nutrients on dairy spray fields throughout the year. Sorghum (Sorghum bicolor L. Moench) can be used in a double cropping system to remove N by following itself or corn (Zea mays **L.).** Gallaher, et al. (1991) in a double cropping study in Central Florida found that forage sorghum varieties take up 96 to 235 lb N/ac for 2 April planting and 121 to 242 lb N/ac for 20 July plantings. Some sorghum varieties exhibit a large potential to take up nutrients which suggests that sorghum is a good crop to use for excess manure nutrient removal.

Perry and Olson (1975) found that grain N increased with N fertilization rates (0.80, 160, and 240 lb N/ac) in corn and grain sorghum with response in grain yield up to the 80 lb N/ac. Heron, et al. (1963) found that N content of both forage and grain increased for all application rates of N fertilizer (0. 40, 80, and 120 lb N/ac). The greatest accumulation of N occurred between the soft dough and hard dough stages of maturity. Total recovery of N in above ground parts of plant averaged between 37 to 83% with the greatest recovery in the 40 lb N/ac treatment, suggesting diminishing returns with increased N application. Vanderlip (1979) reported that N and dry matter accumulation in the leaves and stalks begins to decrease 50 days after emergence due to diversion for grain production. Nitrogen recovery efficiency of plants will have a large impact on the use of plant varieties in excessive nutrient recovery systems. More research is needed to determine the ability of crop varieties to effectively take up nutrients. This study will look at the effectiveness of two cultivars, grain sorghum and forage sorghum, to take up **N** under varying N levels, as well as the effect of N levels on other essential

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nutrients and plant health. Jones, et al. (1991) published the sufficiency ranges for minerals in the third leaf below the head (diagnostic leaf) during the bloom stage with head visible.

MATERIALS AND METHODS

Two cultivars of sorghum, 'DeKalb FS25E' (forage sorghum) and 'Asgrow Chaparral' (grain sorghum) were planted at the Green Acres agronomy farm in Gainesville, Florida. The cultivars were no-till with subsoil planted on 27 May 1993 into an area of soil type Arredondo fine sand (Sandy siliceous thermic Grossarenic Paleudult) following a crop of 'Wrens Abruzzi' rye (Secale cereale L.) grain. The following day, 2 qtslac of Glyphosate and 12 Ibslac of Corbofuran 15G were applied. The plot was irrigated to ensure germination of seed. A N study was setup using a split plot design laid off in blocks. Three blocks were formed using the two cultivars as the whole plots and seven N rates (0, 40, 80, 120, 160, 200, and 240 lb N/ ac) as the split plots. On 12 June, one half of the split N rates was applied. On 17 June, 1.5 qtslac of Lanate was applied and on 18 June. 2 qtslac Atrazine and 0.75 qtlac of 2-4D were applied. On 1 July, 0.75 qt/ac Gromoxone was postdirected and the second half of the N was applied. Irrigation was used during the growth period to insure adequate moisture for normal growth.

On 4 August (at early anthesis), 5 diagnostic leaves per plot (3rd from the flag) were sampled per plot from the Asgrow Chaparral plots. Samples were dried and ground for analysis. Two 16 ft row samples of Asgrow were collected to determine grain yield and whole plant yield on 18 August. The samples for grain yields were dried, thrashed, weighed to determine yield then ground for analysis. Sub-samples of whole plants were dried for dry matter determination, then chopped and ground for analysis. This same procedure was repeated on the DeKalb FS25E with the diagnostic leaves collected as plant heads emerged and the grain yield and whole plant samples taken on 21 September.

Samples were analyzed for N and mineral concentration. Nitrogen analysis was performed using the procedure developed by Gallaher, et al. (1975) using an aluminum digestion block and an auto analyzer (Agronomy Lab, UF), Mineral concentration was determined for P, K, Ca. Mg. Cu, Fe, Mn. Na and Zn using the procedure described by Gallaher, et al. (1991). Mineral analysis was conducted in the University of Florida Soil Testing Laboratory by using flame emission spectrophotometry for K; colorimetry for P; and atomic absorption spectrophotometry for Ca, Mg, Cu, Mn, Fe, Na and Zn.

Results were placed in a QUATRO-PRO 4.0 (1987) spreadsheet for nutrient content transformations and manipulations. Statistical analysis (MSTAT, 1987) and regression analysis were also performed.

RESULTS AND DISCUSSION

Diagnostic Leaf Nutrient Diagnosis

Evaluation of the results from the analysis of the diagnostic leaf showed many characteristics of crops grown on sandy soils. Nitrogen concentration in the plant material was below the sufficiency level for all levels of N fertilization as defined by Jones, et a1. (1991). However. there was significant differences in N accumulation between N levels (Table 1). Diagnostic leaf N accumulation increased significantly from the 0 to 40 lb N/ac level (increasing 0.19 Yo N for the grain sorghum, and 0.34 Yo N for the forage sorghum), and the 80 to 120 lb N/ac level (increasing 0.31 % N for the grain sorghum and 0.16 Yo N for forage sorghum). The deficiency of N in the diagnostic leaf was assumed to be caused by N-leaching through the sandy soils used in the experiment. Application of N in 3 or 4 splits has aided in preventing N-leaching on sandy soils (Lord, 1991). However, the two applications of N in this study did not correct the problem and suggest that N should be split into 4 or more applications to decrease N-leaching.

Phosphorus concentration levels were high in diagnostic leaves at all levels of N fertilization. There were significant differences in P among the levels of N fertilization (Table 1). There was also a significant difference in the concentration of P between the two cultivars, the grain cultivar had significantly higher concentrations of P compared to the forage cultivar (grain sorghum, 0.67 Yo P; forage sorghum, 0.46 % P).

Potassium concentration, like N concentration. was low at all levels of N fertilization. There were

Table 1. Nitrogen, P, Mg, K. Ca. Mn, Zn, Cu. and Fe concentrations in the third leaf from the flag at early flowering in two sorghum hybrids.

	Hybrid			Hybrid			Hybrid		
N Rate	Asgrow Chapar	DeKalb FS25E	Mean	Asgrow Chapar	DeKalb FS25E	Mean	Asgrow Chapar	DeKalb FS25E	Mean
lb N/ac	---------- % N ----------			---------- % P ----------			----------% Mg ----------		
0	1.46	1.14	1.30 c	0.72	0.49	0.61 a	0.40	0.25	0.33 c
40	1.65	1.48	1.57 b	0.70	0.43	0.57 abc	0.39	0.31	0.35 bc
80	1.67	1.55	1.61 b	0.71	0.41	0.56 abc	0.48	0.30	0.39 abc
120	1.98	1.71	1.85 a	0.62	0.42	0.52 c	0.47	0.35	0.41 abc
160	2.03	1.68	1.86 a	0.63	0.46	0.55 bc	0.46	0.35	0.41 abc
200	2.03	1.79	1.91 a	0.67	0.50	0.59 ab	0.50	0.37	0.43 ab
240	2.18	1.78	1.98 a	0.68	0.48	0.58 ab	0.52	0.40	0.46 a
LSD =			0.16			0.058			0.089
MEAN	1.86	1.59**		0.67	0.46**		0.46	0.33	
CV =	8.03			8.52			18.7		
	---------- % K ----------			---------- % Ca ----------			-------- ppm Mn --------		
0	1.20	1.30	1.25 a	4.3	2.6	3.5 d	21.0	24.0	22.5 c
40	1.34	1.20	1.27 a	4.7	3.6	4.1 cd	21.3	31.0	26.2 c
80	0.88	1.29	1.09 a	6.0	3.2	4.6 bc	25.0	27.3	26.2 c
120	1.08	1.15	1.12 a	6.8	3.8	5.2 b	26.7	32.0	29.3 bc
160	1.20	1.29	1.24 a	6.7	4.0	5.3 ab	27.7	35.0	31.3 bc
200	0.82	1.05	0.94 a	7.0	3.9	5.4 ab	34.0	37.7	35.8 ab
240	0.70	1.07	0.88 a	7.9	4.4	6.1 a	51.3	36.7	44.0 a
LSD =			NS			0.85			0.91
MEAN	1.03	1.19 NS		6.1	3.6 *		29.6	32.0 NS	
CV =	40.82			14.18			24.8		
	-------- ppm Zn --------			-------- ppm Cu --------			-------- ppm Fe ----------		
0	40.3 b	43.0 a	41.7	10.3	10.7	10.5 a	73.3	50.0	61.7 b
40	39.0 b	35.3 b	37.2	11.0	10.3	10.7 a	76.7	63.3	70.0 a
80	41.3 ab	30.0 c	35.7	10.0	9.7	9.8 a	83.3	53.3	68.3 ab
120	39.3 b	32.0 bc	35.7	10.3	9.7	10.0 a	86.7	53.3	70.0 a
160	41.7 ab	31.3 bc	36.5	11.3	9.7	10.5 a	90.0	56.7	73.3 a
200	41.7 ab	33.0 bc	37.3	11.7	11.0	11.3 a	86.7	63.3	75.0 a
240	45.7 a	31.3 bc	38.5	12.3	9.3	10.8 a	90.0	60.0	75.0 a
LSD =	5.1	5.1				NS			7.9
MEAN	41.3	33.7 *		11.0	10.0 +		83.8	57.1 *	
CV =	8.03			16.89			9.4		

+, *, and ** = Significant at the 0.10. 0.05 and 0.01 levels of P, respectively. NS = not significant. Values in columns among N rates for each element not followed by the same letter are significantly different at the 0.05 level of P according to LSD. Chapar = Chaparral.

no significant differences in the averages of K accumulation between the cultivars or the N levels (Table **1).** Low levels of K in the plant material were attributed to the low levels of soil K. Increased K fertilization would be recommended in future studies conducted at this location. Potassium deficiency may have resulted from leaching of fertilizer and the K deficiency may have reduced the yield response to N fertilization. Calcium concentrations in the diagnostic leaf were sufficient at all N rates except the 0 N rate for the forage sorghum. There were significant differences in the Ca concentration at different N rates with Ca increasing with increasing N rate (Table 1). There was 0.25 % higher concentration of Ca in the grain sorghum compared to the forage sorghum.

Magnesium concentrations were high at all N fertilization levels with significant differences between the N levels **(p=.10)** (Table 1). Manganese concentrations were sufficient at all levels of N fertilization with no significant differences in accumulation due to cultivars or N fertilization rate (Table 1). Zinc concentrations were above sufficiency levels for both cultivars (Table 1). There was no trend in the Zn accumulation in either of the cultivars (Table 1). Copper was also above sufficiency levels at all levels of N fertilization with no significant differences in Cu accumulation among the N fertilization levels (Table 1). Iron accumulation was sufficient at all levels of N fertilization with the grain cultivar having a higher accumulation of Fe than the forage cultivar (Table **1).**

There were several common mineral relationships that held true in this study. With increasing N rate, N concentration in the diagnostic leaf increased, while P concentrations decreased showing the inverse relationship between N and P. The relationship between N, K, Mg, and Ca was supported by the results of this study. As the N rate was increased K concentration in the diagnostic leaves decreased while the concentrations of Mg and Ca increased.

Yield and Nutrient Content

Grain sorghum showed a 258% greater propensity to accumulate grain than did forage sorghum (p=.10) (Table 2). However, both Cultivars increased **155%** in grain yield from N fertilization to peak at 120 lb N/ac with no further response to increased N rate (Table 2). Forage sorghum accumulated **107%** more whole plant dry matter than grain sorghum (p= **.10).** Both cultivars increased 87% from N fertilization to peak at **160** lb N/ac (Table 2).

Meeting sufficiency levels in this study location has been difficult in the past (Lord, **1991).** The low K levels may be the limiting agent of insufficient N concentrations in the diagnostic leaf even though high levels of N fertilization were used. Potassium fertilization (possibly split applications) and more awareness of nutrient availability in the soil will aid with future N studies done in this location. The effects of varying the N rate on N accumulation was studied for yield and grain content and whole plant content (Table 2). There was no statistical difference between cultivars in whole plant N accumulation rate at increasing N rates (p=.05) or in the average **N** accumulation (p=.10. As N rate was increased in both cultivars, the whole plant N accumulation increased **138%** to peak at **160** lb N/ac. Beyond **160** lb N/ac, N content remained constant (Table **2).** There was also no statistical difference in N accumulation rate at increasing N rates **(p= .05)** in the grain between forage sorghum and grain sorghum. However, grain sorghum accumulated an average of **300%** (p=0.10) more total N in its grain than forage sorghum. With an increasing N rate, N accumulation increased 275% to peak at **160** lb N/ac (Table **2).** There was no significant change in N accumulation beyond **160** lb N/ac.

CONCLUSION

Plant health was defined by sufficiency ranges for the diagnostic leaf (Jones, **1991).** At all levels of N fertilization, N and K were below sufficiency ranges; Mn, Fe and Ca were within the sufficiency ranges and P, Mg, Cu and Zn were above the ranges. There were no significant changes in nutrient sufficiency with N fertilization. The results of this project suggest that both cultivars will work equally well in nutrient recycling. However, forage sorghum should better utilize the recycled nutrients as a crop for cattle operations interested in feed production.

The effect of varying N fertilization rate on N accumulation, dry matter production and nutrient concentration and content in forage and grain sorghum was studied. Under conditions of **K** deficiencies in this study, the data suggests there is no difference between the two cultivars of

Table 2. Grain and total plant dry matter yield and N and K content of two sorghum hybrids: ANOVA and regression analysis.

	N Rate							
Hybrid	0	40	80	120	160	200	240	Mean
Grain yield, lb dry matter/acre								
Asgrow Chaparral	949	1649	1433	1785	2001	1825	1678	1617*
DeKalb FS25E	15	298	378	674	601	560	636	452
Average	482 c	974 b	906 b	1230 ab	1301 a	1193 ab	1157 ab	
LSD = 325								
Asgrow Chaparral	$y = 1027.9 + 10.47x - 0.032x^2$	$r^2 = 0.80$						
DeKalb FS25E	$y = 30.5 + 6.58x - 0.017x^2$	$r^2 = 0.92$						
Grain N content, lb N/acre								
Asgrow Chaparral	12.2	24.2	20.7	28.0	35.9	32.0	33.2	26.6*
DeKalb FS25E	0.3	5.2	6.3	11.8	10.7	11.0	11.0	8.0
Average	6.3 d	14.7 bc	13.5 c	19.9 ab	23.3 a	21.5 a	22.1 a	
LSD = 6.2								
Asgrow Chaparral	$y = 13.28 + 0.182 - 0.00041x^2$	$r^2 = 0.86$						
DeKalb FS25E	$y = 0.04 + 0.117x - 0.00031x^2$	$r^2 = 0.94$						
Grain K content, lb K/acre								
Asgrow Chaparral	4.3	6.8	6.0	7.0	7.3	8.2	6.2	6.5*
DeKalb FS25E	0.1	1.4	1.8	3.0	2.5	2.6	2.9	2.0
Average	2.2 c	4.1 ab	3.9 b	5.0 ab	4.9 ab	5.4 a	4.5 ab	
LSD = 1.4								
Asgrow Chaparral	$y = 4.57 + 0.0362x - 0.00011x^2$	$r^2 = 0.69$						
DeKalb FS25E	$y = 0.22 + 0.0279x - 0.00001x^2$	$r^2 = 0.92$						
Whole plant yield, lb dry matter/acre								
Asgrow Chaparral	3231	4904	3880	5589	5821	5215	4984	4803"
DeKalb FS25E	5554	9327	9950	11721	10671	11659	10751	9948
Average	4393 c	7116 ab	6915 b	8655 a	8246 ab	8437 ab	7868 ab	
LSD = 1545								
Asgrow Chaparral	$y = 3347 + 25.5x - 0.077x^2$	$r^2 = 0.67$						
DeKalb FS25E	$y = 6080 + 67.3x - 0.203x^2$	$r^2 = 0.91$						
Whole plant N content, lb N/acre								
Asgrow Chaparral	23.1	40.8	32.4	48.8	62.6	47.0	56.3	44.4NS
DeKalb FS25E	30.2	41.6	51.8	57.4	64.2	57.1	52.7	40.5
Average	26.7 c	41.2 bc	42.1 bc	53.1 ab	63.4 a	52.1 ab	54.5 ab	
LSD = 8.8								
Asgrow Chaparral	$y = 24.24 + 0.2754x - 0.00062x^2$	$r^2 = 0.73$						
DeKalb FS25E	$y = 29.12 + 0.3903x - 0.00121x^2$	$r^2 = 0.97$						
Whole plant K content, lb K/acre								
Asgrow Chaparral	26.6	56.2	40.3	74.4	36.7	53.8	40.7	47.0NS
DeKalb FS25E	30.2	48.0	65.2	54.3	62.9	50.0	49.4	51.4
Average	28.4	52.1	52.8	64.4	49.8	51.9	45.1	
LSD = NS								
Asgrow Chaparral	$y = 31.96 + 0.377 - 0.00145x^2$	$r^2 = 0.33$						
DeKalb FS25E	$y = 32.96 + 0.416x - 0.00151x^2$	$r^2 = 0.78$						

ANOVA = analysis of variance; +, *, and ** = Significant at the 0.10, 0.05 and 0.01 levels of P, respectively. NS = not significant. Values in columns among N rates for each element not followed by the same letter are significantly different at the 0.05 level of P according to LSD.

sorghum in their ability to accumulate total N in the whole plant. Forage sorghum was found to have a greater propensity to produce dry matter, however grain sorghum had much higher grain yields. The higher grain yield combined with higher N content in the grain of grain sorghum enabled it to overcome the higher dry matter yield of forage sorghum to give an equal ability to accumulate N for both cultivars. This is contrary to the popular belief, which suggests that forage sorghum will be more effective at total N accumulation as well as dry matter production. For the dairyman interested in recycling nutrients, both cultivars appear equally capable of removing N from agricultural wastes. However, the forage sorghum with its higher dry matter yield would likely be the preferential crop for silage production.

Responses in production to increasing N rate suggest that the optimal N fertilization rate for both cultivars should be 160 lb N/ac at this site. Beyond this 160 lb N/ac, there was no significant change in dry matter accumulation, N content or grain yield. The lack of plant response to fertilization above the 160 lb N/ac suggests that the added N is not being taken up by the plant to the same degree as at lower N rates, possibly due to the K deficiency, and may contribute to environmental pollution.

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COMBINING MANURE AND CONSERVATION TILLAGE FOR PROFITABLE YIELDS

C.S. Stoddard, J.H. Grove, and W.O. Thom[1]

INTRODUCTION

Few studies have combined conservation tillage with manure use. Conservation tillage maintains crop residue at the soil surface to reduce erosion, yet most recommendations for surface application of manure on cropland suggest incorporating the manure as soon as possible to limit nutrient loss, especially volatilization of ammonia (Lauer et al., 1976). Additionally, the combination of conservation tillage and manure use may result in increased N losses due to denitrification in some soils (Pratt et al., 1976: Grove, 1992, unpublished data). Nitrogen losses may be especially dependent on the time of manure application, as the seasonal timing of manure application has been found to be important in nitrate leaching and the recovery of N in the target crop in European studies (Bertilsson, 1988). Thus it would appear that conservation tillage and manure use may not be compatible.

Kentucky has approximately 206,000 dairy cows that produce about 3.1 million wet tons of manure every year (KY Ag Stats., 1991). This results in the production of about 25 million pounds of nitrogen. Approximately one-half of this production is collected and applied to crop land in the fall or spring. Because Kentucky has relatively mild winter temperatures combined with abundant precipitation, the nitrogen from fall manure application may have little or no effect on the following seasons' crop yields.

No-tillage and other forms of conservation tillage systems are widely used in Kentucky; therefore, an experiment was initiated to observe the effects of combining conservation tillage methods (no-till or chiselldisk) with surface applied dairy manure on corn *(Zea mays,* L.) yields. The objectives of this study were to (a): examine the yield response of a continuous corn production system to manure application timing, tillage, and fertilizer N rate, and (b): determine the economic value of manure application.

MATERIALS AND METHODS

This experiment was established in the fall of 1991 at the Kentucky Agricultural Experiment Station Farm in Lexington, KY. The soil is a Maury silt loam (fine, mixed mesic Typic Paleudalf), a well drained soil formed in the residuum of phosphatic Ordovician limestone. The area had been in blue grass pasture for several years prior to the initiation of this experiment. The experimental design is a randomized block split-plot with three replications. Treatment structure is a complete factorial with six manure-timing-tillage treatments and three nitrogen fertilizer rates. Main plots consist of 1) no-tillage, no manure: 2) no-tillage, fall manure: 3) no-tillage, spring manure; 4) no-tillage, fall plus spring manure: 5) chiselldisk, no manure; and 6) chiselldisk. spring manure. Subplot treatments are 0, 75, or 150 lb N A^{-1}, using ammonium nitrate as the N source. Subplot size is 12 ft wide (four rows) by 30 ft long.

Fresh dairy manure was surface applied with a commercial spreader to selected plots before planting in late April to early May for the spring manure treatments, and post harvest in early to mid-November for fall manure treatments. The manure source was a nearby dairy farm operated by the University of Kentucky. As such, no hauling costs were incurred during this experiment. The manure spreader was calibrated to deliver approximately 9000 lbs A^{-1} (dry weight) (30,000 lbs A^{-1} wet weight). As a check, 14" by 18" flat trays were randomly assigned throughout the plots before manure application for sample collection. After spreading, the sample trays were collected, dried, and weighed to determine the application rate. The dried manure was analyzed for % N to estimate the nitrogen application rate for each application. Nitrogen concentration and calculated application rates are listed in Table 1.

Immediately following spring manure application, chisel/disk treatments were implemented, chiseling and then disking twice to incorporate the manure over a depth of 0 to 6 inches. No cultivation was performed in the no-till system, including those that received manure.

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Table 1. Average actual rate, %N, and calculated N rate for each manure application.

Date	avg. dry wt. lb A^{-1}	%N	SD^1 of %N	N rate lb A^{-1}
Fall 1991	8970	1.99	0.24	179
Spring 1992	6200	2.20	0.37	136
Fall 1992	8780	2.19	0.16	192
Spring 1993	18590	2.11	0.22	392

1. Standard deviation.

Table 2. Corn response to tillage, manure, and N fertilizer treatments for 1992 and 1993.

Treatment		Fertilizer N, lb A^{-1}			
$tillage^1$	manure	0	75	150	$MEAN^2$
		------------- bu A^{-1}	-------------	-------------	-------------
			1992		
NT	none	174.5	192.0	186.1	184.2 c
NT	fall	184.3	197.1	196.1	192.8 ab
NT	spring	192.2	197.8	196.6	195.8 a
NT	fall+spring	194.4	191.4	183.5	189.8 abc
CD	none	175.8	196.0	184.0	185.3 bc
CD	spring	195.5	201.6	192.7	196.4 a
	$MEAN^2$	186.2 b	195.9 a	190.0 ab	
			1993		
NT	none	89.6	149.1	167.4	135.3 cd
NT	fall	116.6	149.8	146.6	137.7 bc
NT	spring	145.4	147.6	159.1	150.7 ab
NT	fall+spring	137.5	161.7	147.9	149.0 ab
CD	none	89.0	129.8	145.5	121.4 d
CD	spring	153.9	156.4	148.2	152.8 a
	$MEAN^2$	122.0 b	149.1 a	152.4 a	

1. NT = no-tillage CD = chisel/disk
2. Means followed by the same letter are not significantly different ($P \leq 0.1$).

Corn cultivar Pioneer 3140 was planted on 29 April, 1992 at 21,800 seeds A^{-1} in 36 inch rows with a ripple coulter no-till planter. Corn cultivar Pioneer 3279 was planted on 21 May 1993 at 23,100 seeds A^{-1}. Glyphosphate, 2,4-D atrazine, and alachlor were tank mixed with a non-ionic surfactant and water, at University of Kentucky Extension Service recommended rates, and applied at planting for weed control. Nitrogen fertilizer, as ammonium nitrate, was top-dressed by hand five to six weeks after planting. Corn yields were measured by hand harvesting 20 ft lengths from the middle two rows of each plot in mid-October in both 1992 and 1993. Yield data were corrected to 15.5% moisture.

Statistical analyses were performed with the use of the Statistical Analysis System (SAS Institute, 1989). The General Linear Model (GLM) procedure was used for the analysis of variance, and mean separations among treatments were determined by least significant difference (LSD 0.10).

RESULTS AND DISCUSSION

Corn grain yields for 1992 are presented separately from 1993 because of the large yield difference due to the growing season. Figure 1 illustrates the differences in precipitation and evaporation that occurred. including long-term average values for comparison. 1992 was a better growing season in Kentucky, with precipitation exceeding or matching evapotranspiration in July and August. Corn yields, averaged across all treatments, were 191 bu A^{-1}. 1993 was a fairly normal growing season, in that potential evaporation generally exceeded precipitation. Average corn yields were 141 bu A^{-1}.

Statistical analysis of 1992 and 1993 yield data showed significant differences ($P \leq 0.1$) to the main effect of manure-timing-tillage treatments and N fertilizer rate treatments. In 1993 the manure-timing-tillage by N rate interaction was also significant, but this was not the case in 1992. Tillage method alone (chisel/disc vs. no-tillage) did not have a significant effect on corn yield in either year.

The spring manure treatments resulted in significant ($P \leq 0.1$) average yield increases over the non-manured controls in both years (Table 2). In 1992 and 1993, no significant differences were found due to the timing (fall, spring, or fall plus spring) of manure application, though there was a trend for higher yields with the spring manure application. This is especially apparent in 1993 (Table 2). The no-tillage fall plus spring manure treatment was not significantly different from the fall only or spring only treatments in either year. Yields at 150 lb N A^{-1} were depressed more consistantly by the excessive fertilizer N availability in this system (Table 2). and this may account for the lower average yield in both seasons. This suggests that doubling up on manure in one season offered no added benefit to the corn crop.

Nitrogen fertilizer caused a significant ($P \leq 0.1$) average yield increase in both years, but the yields obtained at the 75 lb and 150 lb N A^{-1} rate were not significantly different from one another (Table 2). A significant N rate by manure interaction occurred in 1993. In that year, plots receiving manure showed very little response to fertilizer application, while unmanured plots did respond to fertilizer N. In 1992 the interaction was not significant, possibly because of the abundant precipitation in the summer and because this was the first year of the study and considerable N mineralization occurred when the killed grass sod decomposed. To illustrate the N rate by manure interaction, regression equations were calculated for the observed yield response in yield to fertilizer N in manured and non-manured plots (Table 3). Because neither tillage nor time of manure application had a significant effect in either year, only the manured and the non-manured yield responses are shown (Figure 2).

Based on the yield response curves shown in Figure *2,* maximum yields and the amount of fertilizer N needed to achieve maximum yields were calculated (Table 4). The nitrogen fertilizer equivalency (NFE) of the manure was estimated by determining the difference in the amount of N fertilizer needed to attain maximum yields with and without the manure application, as suggested by Smith et al. (1987). In 1992 and 1993, the NFE was 50 and 28 lb A^{-1}, respectively. The rather low NFE in 1993 is interesting in that the spring manure application that year had an estimated N content of 392 lb A^{-1} (Table 1). This suggests that a substantial loss of nitrogen occurred, probably through volatilization, denitrification. and/or leaching, before the corn was mature enough to utilize the extra nitrogen.

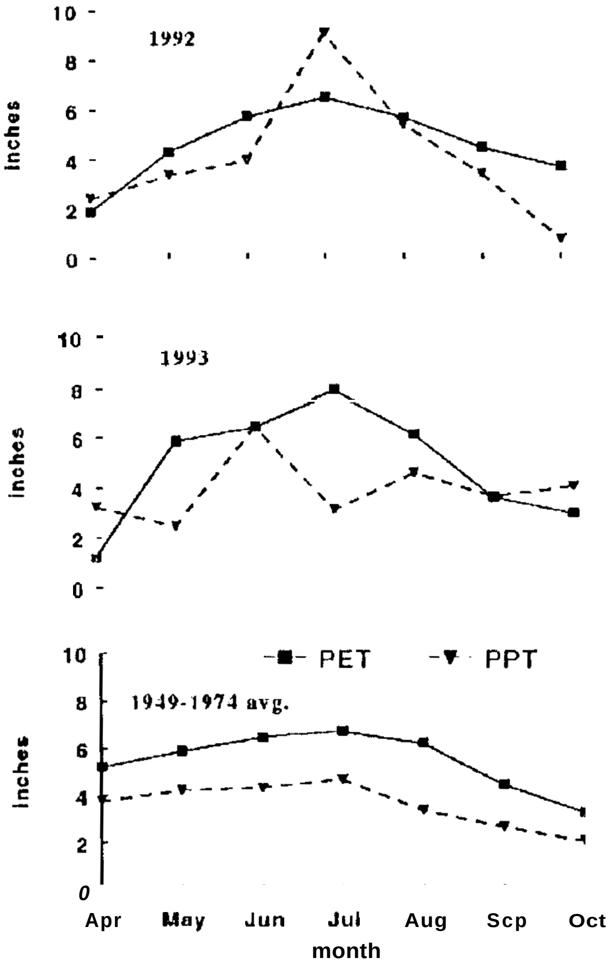

Figure 1. Average, 1992, and 1993 open pan potential evapotranspiration (PET,) and precipitation (PPT) for the Kentucky Agricultural Experiment Farm, Lexington, KY.

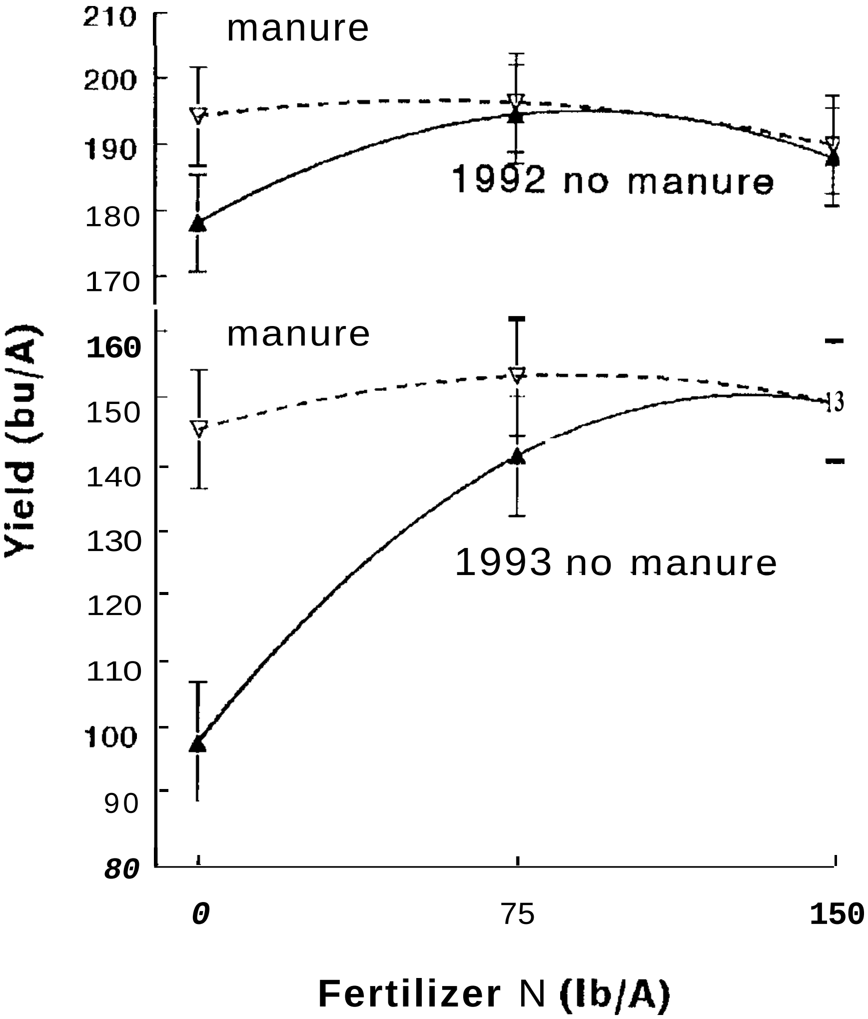

Figure 2. Corn grain yield response for manured and non-manured treatments. Error bars are ± one standard error.

Table 3. Regression equations for corn grain yield (y) as a function of fertilizer N rate (X) for manured and non-manured treatments for each year.

Year	Manure	Equation	R	CV[1] (for y)
1992	none	$y = 178.2 + 0.38x - 0.002x^2$	0.52^*	6.5
	yes	$y = 194.3 + 0.09x - 0.001x^2$	0.22	5.5
1993	none	$y = 98.4 + 0.83x - 0.003x^2$	0.80^{**}	14.2
	yes	$y = 145.6 + 0.22x - 0.001x^2$	0.28	9.7

*,** Significant at *0.05* and 0.01 probability levels, respectively.
1. CV = coefficient of variation.

Table 4. Maximum yields and N fertilizer levels calculated to achieve optimum economic returns.

		Max yld[1]	N rate[2]	PI[3]	Max N[4]	Savings[5]
Year	treatment	bu A^{-1}	lb A^{-1}	Py/Px	lb A^{-1}	\$ A^{-1}
1992	manure	196	45	0.10	0	15.48
1992	none	196	95	0.10	70	
1993	manure	158	110	0.10	60	13.64
1993	none	155	138	0.10	122	

1. Maximum yields calculated from regression equations.
2. Pounds of N per acre needed to achieve maximum yields.
3. PI = price index. Py = $2.20 per bushel and Px = cost of urea fertilizer at $199 per ton ($ 0.221 per lb N). ***Source:*** Ky ***Ag.*** *Stats.,* 1992.
4. Pounds of N per acre needed to achieve maximum economic yields.
5. Savings per acre from using manure based on maximum economic yields and urea as the N source. Does not include hauling and spreading costs.

To determine the fertilizer N rate to achieve maximum economic yields, a price index was calculated by dividing the cost of N (per pound) by the selling price of corn (per bushel) and setting this index equal to the first derivative of the regression equations for manured and non-manured plots:

$$Py/Px = B + 2Cx$$

where B and C are constants in the regression equation ($Y = A + Bx + Cx^2$), Py is \$0.221 lb^{-1} using urea as the N source. and Px is \$2.20 bu^{-1} of corn (KY Ag Stats., 1992). Urea was used for the price of N in the fertilizer (as opposed to the ammonium nitrate used in this study) because urea is the most common N fertilizer used on corn in the state of Kentucky. The 1992 price index was also used for 1993 because this is the most recent data available. The fertilizer rates calculated to achieve maximum economic returns are presented in Table 4. The amount of N fertilizer needed to achieve maximum economic yields was substantially reduced in the manured plots. Nitrogen fertilizer was not needed in 1992, probably due to the optimal growing season and abundant N mineralization that may have occurred. By reducing rates of fertilizer N to compensate for inputs from the manure, the average nitrogen equivalent value from manure was \$15.48 A^{-1} in 1992, and \$13.64 A^{-1} in 1993.

CONCLUSIONS

This experiment was conducted to observe the effects of tillage, nitrogen fertilizer, and timing of manure application had on continuous corn yields. No differences were found between no-tillage and chisel/disk tillage treatments in either year. Application of manure resulted in significantly greater yields in both years, but the timing of manure application had no significant effect. There was a tendency, however, for spring manure treatments to have higher yields, especially on chisel/disked plots. The lack of response to tillage method and manure timing may be partly explained by the fact that 1992 was the first year of the study and enough sod mineralization occurred, along with abundant precipitation, to mask treatment effects.

Nitrogen fertilizer inputs resulted in significant yield increases up to the 75 **lb** A^{-1} rate in unmanured plots in both years. However, in manured plots there was little response to N rate. Based on regression equations for corn yields as a function of fertilizer N rate and using urea as the fertilizer N source, manure's monetary contribution was calculated to average \$14.56 per acre. The results from this study show that manure does significantly increase yields in conservation tillage systems while allowing for a reduction in the fertilizer N required. The results also suggest that spring is a better time to apply manure than in the fall.

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SURFACE RESIDUE COVER IN NO-TILL COTTON

Paul Denton[1] and Don D. Tyler[2]

Acreage in no-till cotton is expanding rapidly in western Tennessee. No-till is increasingly seen as the most cost-effective way to meet Conservation Compliance requirements for program participation as well as meet farmer goals for erosion reduction.

The soils on uplands in western Tennessee are derived from loess. They are very silty and very susceptible to erosion. Erosion rates in excess of 20 tons per acre per year have often been observed in continuous cotton production with conventional tillage. Almost all upland fields meet the Farm Bill definition of highly erodible land. In addition, most of the upland soils have fragipans which restrict root penetration. Thus loss of soil by erosion leads to a shallower rooting zone and loss of productivity due to more frequent water stress.

The effectiveness of no-till in reducing erosion depends on maintenance of a cover of crop residue over the soil surface. Most western Tennessee cotton fields are in continuous cotton. Cotton is a low residue crop, and may not always provide enough residue to adequately protect the soil by itself. As a practical matter, a cover of at least 30 percent is needed to meet Conservation Compliance requirements. Cover crops can increase the residue cover, but they are costly and difficult to establish early enough in the fall to contribute greatly to winter cover. The purpose of this work is to determine what residue levels are actually being achieved in no-till cotton fields under different soil, landscape and management conditions, with and without cover crops, and to determine the conditions under which the residue cover will fall below 30 percent.

METHODS

Measurements of residue cover soon after planting were made in 23 fields in 6 western Tennessee counties (Crockett, Shelby, Fayette, Lauderdale, Haywood and Tipton) in May, 1993. Within each field, areas of differing slope and/or soil type were chosen for measurement. Within each area, residue cover was determined by the line transect method along three transects of 50 feet. Along each transect, 100 points spaced 6 inches apart were counted. The three transects were then averaged to give one observation. Measurements were made in two to seven areas in each field, for a total of 95 observations and 285 transects. All the fields were in no-till cotton in 1993, except for one field which was in no-till grain sorghum planted in cotton residue from 1992. The length of time in no-till varied from one to six years. In most cases, the fields had been in cotton for two or more years prior to 1993, but one field had been planted in corn in 1992 and another in corn in 1991. Five of the fields had a wheat cover crop established by overseeding in standing stalks in the late fall of 1992. When residue measurements were made, separate counts were made of old crop residue and residue from winter weeds or cover crops. These counts were combined to give total residue cover. If a point overlay both crop residue and winter weed residue, it was counted as crop residue.

For purposes of evaluating the effects of soils and landscapes, observations were divided into three classes: bottoms (0 to 1 percent slope), uplands of 1 to 4 percent slope and uplands of 5 percent slope or more. The steepest slopes ranged up to 9 percent. All the observations on uplands were on highly erodible land as defined by the 1985 farm bill.

Soils in the bottoms were in the Adler (coarse-silty, mixed, nonacid, thermic Aquic Udifluents) or Collins (coarse-silty, mixed, acid, thermic, Aquic Udifluents) series. Most soils on uplands were in the Grenada (fine-silty, mixed, thermic Glossic Fragiudalfs) or Loring (fine-silty, mixed, thermic Typic Fraguidalfs) series. A few observations were on Calloway (fine-silty, mixed, thermic Glossaquic Fragiudalfs), Center (fine-silty, mixed, thermic Aquic Hapludalfs). Henry (coarse-silty, mixed, thermic Typic Fragiudalfs) or Memphis (fine-silty, mixed, thermic Typic Hapludalfs) soils.

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Table. 1 Numbers of Observations Exceeding 30 and 45 Percent Residue Cover

Residue Cover	Observations Number	Observations Percent
%		
0-29	22	22%
3044	34	34%
45+	44	44%

RESULTS

The average surface residue cover across all observations was 44 percent. Most areas measured exceeded the 30 percent residue requirement after planting. Including crop residue, winter weeds, and residue from cover crops, 78 percent of the areas were above the minimum level (Table 1).

Although most areas had more than 30 percent cover overall, residue cover varied considerably by landscape position and slope (Table 2). Bottoms had the highest average percent surface cover, averaging 59 percent without cover crops. All observations on bottoms had more than 30 percent residue cover, with 9 of 11 exceeding 45 percent (Table 3). On the gently sloping uplands of 1 to 4 percent slope, surface residue cover averaged 44 percent without cover crops (Table 2). with 81 percent of all observations exceeding 30 percent cover (Table 3). However, on the most erosive uplands of 5 percent slope or more, residue cover without cover crops averaged only 27 percent (Table 2). and 9 of 14 observations, or 64 percent, did not meet the 30 percent cover criteria (Table 3).

Cover crops increased residue cover by an average of 9 percent on the upland areas of 5 percent slope or more (Table 2). The number of observations was limited, but with cover crops all observation on the 14 percent slope areas and two-thirds of those on the areas of 5 percent slope or more met the 30 percent cover criteria (Table 4).

Within landscape and slope classes, residue cover was affected by the number of years in no-till. the presence of cover crops, and use of corn in the rotation (Table 5).

With continuous cotton without a cover crop, surface residue tended to be higher in fields which had been in no-till for one or more years prior to 1993 (Table 5). However, the effect varied by landscape position. On bottoms, fields previously no-tilled had 66 percent residue cover versus 48 percent on fields in their first year of no-till, a difference of 18 percent. On uplands of 1 to 4 percent slope, the difference was similar at 14 percent. Unfortunately, on the most erosive sites of 5 percent slope or more, there was little difference in residue cover between first year and longer term no-till.

The lower residue cover on the steeper (5% +) slopes and the lack of accumulation through time was very obvious in the field. Where there was no cover crop, rill erosion was quite often visible in these areas, especially if the rows were oriented up and down the slope. The reasons for the low

Table 2. Average Residue Cover by Landscape Position With and Without a Cover Crop

Position	Cover Crop Observations	Cover Crop Residue Cover	No Cover Crop Observations	No Cover Crop Residue Cover
	N	%	N	%
Upland				
1 to 4% slope	12	49	52	44
≥5% slope	6	36	14	27
Bottoms	11	59	---	---

Table 3. Number of Observations Exceeding 30 and 45 Percent Residue Cover by Landscape Position Without a Cover Crop

			Uplands			
Cover	Number	%	Number	%	Number	%
0-29%	0	0	10	19	9	64
30-44%	2	18	17	33	5	36
45+%	9	82	25	48	0	0

Table 4. Number of Observations Exceeding 30 and 45 Percent Residue Cover By Landscape Position With a Wheat Cover Crop

Cover	Number	%	Number	%

Table 5. Average Residue Cover by Cropping System Within Landscape Positions

Position and Cropping System	Number of Observations	Residue Cover		
		Mean	Std. Dev.	Range
		----------------	%	----------------
Uplands, 1-4% Slopes				
No Cover Crop, 1st Year No-till	22	35	13	20-68
No Cover Crop, 2nd + Year No-till	25	49	13	28-59
No Cover Crop, 1992 or 1991 Corn	5	64	14	48-76
Cover Crop	12	49	17	31-77
Uplands, ≥ 5% Slopes				
No Cover, 1st Year No-till	5	25	9	18-33
No Cover Crop, 2nd + Year No-till	8	28	10	17-43
No Cover Crop, 1991 Corn	1	30	--	--
Cover Crop	6	36	16	21-59
Bottoms				
No Cover Crop, 1st Year No-till	4	48	13	35-62
No Cover Crop, 2nd + Year No-till	7	66	12	50-77

residue level are the lower productivity of cotton on these sites, the lower population of winter annual weeds compared to bottoms and less sloping uplands (Table 6) and possibly downslope washing of residue. There has been considerable discussion about the importance of winter annuals in providing surface cover in low residue crops. In this study, winter annuals contributed considerably to the total residue cover on bottoms and less-sloping uplands, particularly in fields which had been no-tilled in previous years. However, on steeper uplands where extra residue cover was most needed, winter annual weeds contributed very little. This is attributed to lower fertility on these sites, especially lower nitrogen, and greater carryover of herbicides. Both of these effects are due to the lower soil organic matter content on these sites, which are generally severely eroded.

The increase in residue cover on the bottoms and 1 to 4 percent slope uplands in fields in longer term no-till was due to increases in both crop residue and winter annual weeds (Table 6). On the steeper slopes, there was little or no increase in either compared to the first year in no-till.

The effect of cover crops varied considerably by slope. On the uplands of 1 to 4 percent slope, use of a cover crop did not increase the average residue cover after planting when compared to fields in no-till for more than one year. Cover crops did increase residue cover compared to areas without cover crops in the first year of no-till. On the steeper areas, cover crops increased residue cover by about 10 percent on average, and were necessary in most cases to raise residue cover levels above the 30 percent level.

One notable aspect was the wide range in residue cover observed between and within fields with similar soils and cropping systems (Table 5). This was particularly evident with cover crops. In all cases, the cover crop was wheat overseeded in standing stalks. It was evident in the field that this could lead to a significant increase in cover or little or no increase depending on time of seeding, seeding rate, seed quality, care taken to get even distribution, timing relative to defoliation or stalk shredding, and weather conditions. Where proper attention to detail had been given to establishing the cover crop, residue cover was enhanced considerably. Where the cover had been established with minimal input and attention to meet program requirements, the value was much more limited.

It appears that to establish and maintain an acceptable level of residue cover in no-till cotton following conventional cotton, on the less sloping uplands the best way is to seed a cover crop prior to the first year in no-till. After the first year, it appears that adequate residue can be maintained in most cases without a cover crop. On the areas of 5 percent or greater slope in western Tennessee,

Table 6. Residue Cover From Cotton and Winter Weeds by Landscape Position and Years in No-till [No Cover Crop)

Position and Years In No-Till	Observations	Residue Cover Total	 Cotton	 Winter Weeds
		---------------%	---------------	
Uplands, 1-4% Slopes				
1st Year No-till	22	35	29	6
2nd + Year No-till	25	49	39	10
Uplands, ≥ 5% Slopes				
1st Year No-till	5	25	21	4
2nd + Year No-till	8	28	26	2
Bottoms				
1st Year No-till	4	48	38	10
2nd + Year No-till	7	66	49	17

well-managed cover crops appear to be necessary to maintain residue levels of 30 percent or more at planting, even in continuous no-till. Even with cover crops, residue levels are sometimes inadequate for good erosion control in these areas.

As noted earlier, most fields in this study were in continuous cotton. However, in two fields corn had been grown either the season before or two seasons before. Based on these limited observations, it appeared that having corn in the rotation increased the surface residue as effectively as cover crops, if not more so (Table 5). Based on the two fields examined, the effect of corn declined considerably in the second year of cotton, but more fields need to be examined for a more definitive answer.

In summary, in most situations in no-till cotton in west Tennessee, surface residue levels of 30 percent or more at planting are being maintained. The residue is a combination of old crop residue, cover crops and winter weeds. Unfortunately, the residue levels drop as slope increases, productivity declines and erosion potential increases. On slopes of 5 percent or more, it appears that either well-managed cover crops or rotation with higher residue crops will be needed to maintain adequate cover for erosion control.

Observations on the steeper slopes and in fields rotated with higher residue crops were limited in number. More information is needed for these situations. This study is continuing in 1994.

INFLUENCE OF RELAY INTERCROPPING ON WHEAT AND SOYBEAN YIELD COMPONENTS

S.U. Wallace, M. Bacanamwo, J.H. Palmer, and S.A. Hull[1]

INTRODUCTION

Relay intercropping of wheat (Triticum aestivum L.) and soybean [Glvcine max (L.) Merr.1 is an alternative to conventional sequential doublecropping in which soybean is planted after wheat harvest. The relay intercropping system developed at Clemson University (Hood et al., 1991) involves planting soybean between wheat rows prior to wheat harvest. Both crops are planted with the Clemson Interseeder drill; the most widely used planting pattern places wheat in 13-in. rows with 24-in. traffic lanes between the 3rd and 4th. and between the 8th and 9th. wheat rows in each 11-row planter pass (Fig. 1).

Wheat yields in this planting pattern have been similar to drilled wheat at locations in the SC Coastal Plain and lower Piedmont (Khalilian et al., 1991: Hood et al.. 1991). but 15 to 20% yield reductions have been seen for intercropped wheat at Pendleton, SC, and Griffin, GA (Hood et al., 1991: W. Hargrove, pers. comm.) The objective of this work was to compare growth, yield, and yield components for 3 wheat cultivars followed by one soybean cultivar in both cropping systems.

MATERIALS AND METHODS

Wheat cultivars NK Coker 9766, Pioneer 2555, and Williams were planted on 2 Nov. 1990 and 13 Nov. 1991 at the Simpson Research and Educational Center near Pendleton, SC, in a split-plot design with cultivar as the main plot and cropping system as the subplot. The relay intercropped subplots were planted with the Clemson Interseeder (Fig. 1) whereas the doublecropped subplots were planted with a conventional grain drill in 7-in.-wide rows. Measurements including light interception by the wheat canopy were taken during the season (Bacanamwo, 1992). Wheat was harvested on 3 June 1991 and 16 June 1992 with a combine. Prior to wheat harvest, samples were taken for yield component analysis. In the relay intercropped subplots, separate samples were taken from interior rows and from rows bordering the traffic lanes (Fig. 1).

Intercropped 'Thomas' soybean was planted with the Clemson Interseeder (Fig. 1) on 15 May 1991 and 20 May 1992 (prior to wheat harvest). Doublecropped Thomas soybean was planted in 38-in.-wide rows without tillage on the same day as wheat harvest. Samples for yield component analysis and measurement of other growth parameters (Bacanamwo, 1992) were taken at maturity; separate samples were taken from interior rows and rows bordering traffic lanes in the relay intercropped subplots (Fig. 1). The four (intercroppedl or two (doublecropped) interior rows were harvested with a small plot combine on 7 Nov. 1991 and 18 Nov. 1992 for yield determination.

RESULTS AND DISCUSSION

Wheat yields (Table 11 and test weights (Bacanamwo, 1992) were low in both years of this study, especially in 1991 when Septoria and other diseases were observed in the wheat. Averaged over cultivars and years, intercropping reduced wheat yield by 18% as compared with doublecropped wheat (Table 1).

The reduction in intercropped wheat yield was associated with a reduction in light interception by the intercropped wheat canopy, particularly for the wheat rows bordering the traffic lanes (Bacanamwo, 19921. Number of spikes per area was the yield component most adversely affected by intercropping, with the largest reduction in this yield component in the traffic lane rows (Table 2). Plants bordering the traffic lanes apparently failed to tiller sufficiently to compensate for the additional space available. This may be related to the wide-row planting pattern, but it may also be due to a lower wheat population (plants per area, measured at stand establishment) for the intercropped wheat. The reduced population in the intercropped subplots occurred even though similar seeding rates (about 100 lb/ac) were used in both

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Table 1. Influence of wheat cultivar and cropping system on wheat yields and lodging scores

Wheat Cultivar	Cropping System†	1991	1992	
		Yield -bu/ac-	Yield -bu/ac-	Lodg.‡
NK Coker 9766	I	24.3	45.4	2.2
	D	32.4	56.4	3.0
Pioneer 2555	I	29.4	46.5	1.0
	D	37.1	52.2	1.5
Williams	I	20.2	42.2	1.0
	D	21.9	53.2	1.7
S. V. (from ANOVA)				
Wheat Cultivar		**	NS	**
Cropping System		**	**	**
Cult. x Syst.		**	NS	NS

† I = relay intercropped; D = sequentially doublecropped

‡ Lodging was scored on a scale of 1 [none) to 5 (severe). Wheat lodging scores were not taken in 1991.

**,*,(0.1) = significant at $p < 0.01$, $p < 0.05$ or $p < 0.10$, respectively; NS = not significant ($p < 0.10$)

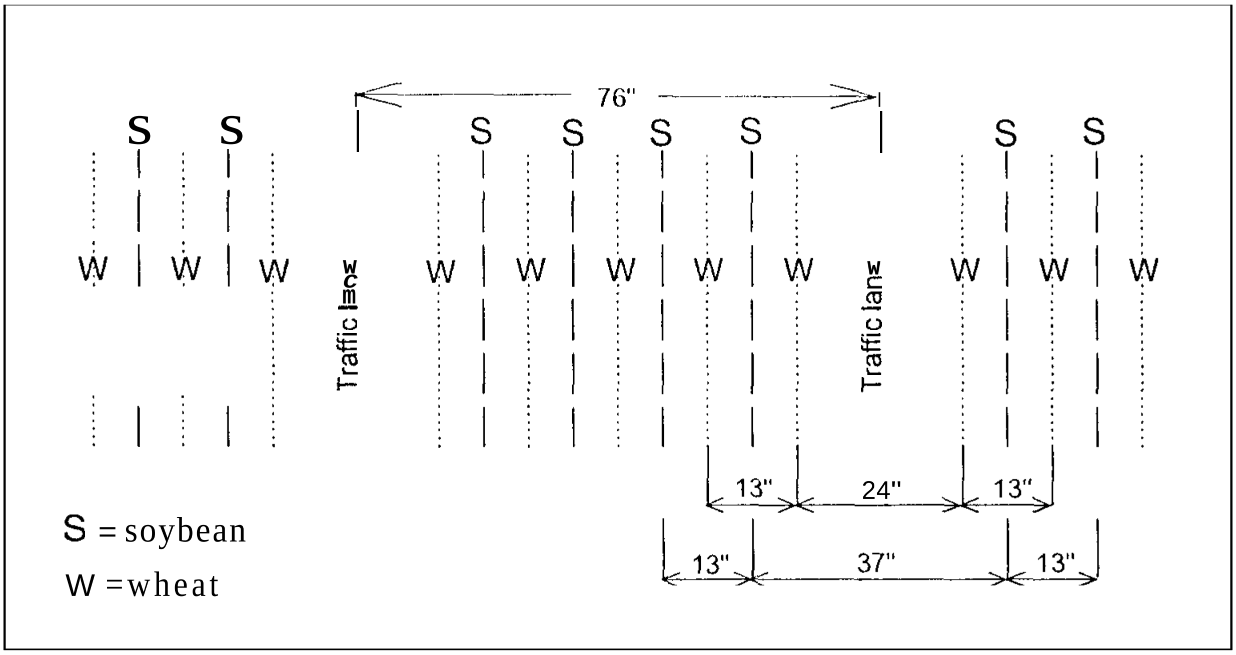

Figure 1. Planting pattern for relay intercropped wheat and soybean.

Table 2. Influence of wheat cultivar and row type on wheat yield components

Year	Wheat Cultivar	Row Type	spikes / m^2	grains / spike	ma / grain
1991	NK Coker 9766	I[1]	687	17.3	19.1
		T	542	17.5	19.4
		D	867	16.1	19.0
	Pioneer 2555	I	501	23.8	23.0
		T	417	23.0	20.8
		D	633	23.8	20.9
	Williams	I	494	20.8	18.3
		T	374	20.8	17.2
		D	593	22.1	18.7
S. V. (from ANOVA)					
Cultivar			**	**	**
Row Type			**	NS	*
Cultivar x Row			*	NS	*
1992	NK Coker 9766	I	650	25.6	28.6
		T	516	27.2	29.3
		D	839	23.2	27.5
	Pioneer 2555	I	502	24.2	33.8
		T	400	29.0	34.2
		D	626	24.6	31.5
	Williams	I	455	30.9	29.8
		T	402	32.7	29.9
		D	638	28.0	28.3
S. V. (from ANOVA)					
Cultivar			**	**	**
Row Type			**	**	**
Cultivar x Row			NS	**	NS

[1] I = intercropped interior row; T = intercropped row bordering traffic lane; D = doublecropped row
**,* = significant at $p < 0.01$ or $p < 0.05$, respectively; NS = not significant ($p > 0.10$)

systems (Bacanamwo, 1992) and may have been caused by deeper seed placement as compared with the conventionally planted wheat.

In 1991, average weight per grain was somewhat higher for intercropped than doublecropped plants (Table 2), and in 1992, the intercropped treatment had increases in grains per spike and weight per grain. Nonetheless, the small increases in these yield components were not enough to compensate for the reduction in spikes per area (Table 2).

Wheat cultivar and the cultivar by cropping system interaction significantly influenced wheat yield in 1991 but not in 1992 (Table 1). Williams had the lowest yield in both cropping systems in 1991 but also had less yield reduction in the intercropping planting pattern. The poor performance of Williams in 1991 was associated with disease (e.g., Septoria) problems. Lodging scores (taken in 1992 only) showed more wheat lodging in the doublecropped planting pattern, and lodging scores were higher for NK Coker 9766 than for the other cultivars (Table 1).

In 1991. 18 days elapsed between intercropped soybean planting and wheat harvest. In 1992, cool weather slowed wheat development and rain further delayed wheat harvest, so that the period between intercropped soybean planting and wheat harvest was 27 days. This is a longer period of overlap between the two crops than has been suggested (Palmer et al.. 1993). yet intercropped plants did not appear to suffer any major harm from the lengthy shading period, as evidenced by plant growth' characteristics (Bacanamwo, 1992) and yield (Table 3). However, soybean emergence and growth were slow in late May and early June of 1992 because of cool temperatures, and slower growth may have allowed the intercropped plants to avoid some problems, such as excessive soybean height at wheat harvest, which might be expected if too much time elapses between soybean planting and wheat harvest in most years.

Intercropped and doublecropped soybean yields were not detectably different either year (Table 3) although the yield component analysis suggested a potential advantage for intercropping (Table 4). In particular, plants in the interior rows of the intercropping planting pattern had more pods per ground area than those in the intercropped rows bordering the traffic lanes or the doublecropped rows (Table 4). indicating an advantage of the narrow row spacing (Fig. 1). Yield was higher ($P<0.10$) for soybean following Williams wheat than for soybean following Pioneer 2555 in 1992, whereas in 1991 soybean following Williams lodged less ($P<0.10$) than soybean following NK Coker 9766 (Table 3). but in general previous wheat cultivar had little influence on soybean growth or performance (Bacanamwo. 1992; Tables 3 and 4).

Intercropping resulted in increases in lower internode lengths (Bacanamwo, 1992) as a result of shading of the young soybean seedlings by the wheat canopy. This characteristic of intercropped soybean, which has been reported previously (Wallace et al., 1992). may result in increased lodging as seen in both years of this study (Table 3).

In summary, as compared with a conventional sequential doublecropping system, relay intercropping reduced wheat yield in both years, whereas soybean yield was similar for the two systems. The intercropped wheat yield reduction was associated with reduction in number of spikes per ground area, especially in intercropped rows bordering traffic lanes (Fig. 1). Previous wheat cultivar had an effect (significant at $P<0.10$) on soybean yield only in 1992. Lodging scores were higher for intercropped than for doublecropped soybean; this may be related to increased elongation of lower internodes formed when intercropped soybeans were developing under the wheat canopy before wheat harvest.

Table 3. Influence of wheat cultivar and cropping system on soybean (cv. Thomas) yields and lodging scores

Wheat Cultivar	Cropping System[†]	1991 Yield	1991 Lodg.[‡]	1992 Yield	1992 Lodg.
		-bu/ac-		-bu/ac-	
NK Coker 9766	I	59.6	2.7	42.8	2.0
	D	42.9	2.2	42.3	1.6
Pioneer 2555	I	53.1	2.8	43.2	2.2
	D	43.7	1.8	39.7	1.6
Williams	I	53.1	1.8	44.5	1.9
	D	42.7	1.5	45.6	1.7
S. V. (from ANOVA)					
Wheat Cultivar		NS	(0.1)	(0.1)	NS
Cropping System		NS	*	NS	**
Cult. x Syst.		NS	(0.1)	NS	(0.1)

[†] I = relay intercropped; D = sequentially doublecropped

[‡] Lodging was scored on a scale of 1 (none) to 5 (severe).

**,*,(0. 1) = significant at $p < 0.01$, $p < 0.05$ or $p < 0.10$, respectively; NS = not significant ($p > 0.10$)

Table 4. Influence of wheat cultivar and row type on soybean (cv. Thomas) yield components

Year	Wheat Cultivar	Row Type	pods m2	seeds pod	mg seed
1991	NK Coker 9766	I[1]	1909	2.07	137
		T	1303	1.63	190
		D	1124	1.89	139
	Pioneer 2555	I	1690	1.91	148
		T	1096	1.63	179
		D	1195	2.02	125
	Williams	I	1775	1.87	144
		T	1149	1.75	152
		D	1129	1.83	143
S. V. (from ANOVA)					
Cultivar			NS	NS	NS
Row Type			**	*	*
Cultivar x Row			NS	NS	NS
1992	NK Coker 9766	I	1821	1.73	149
		T	1054	1.68	149
		D	1132	1.77	153
	Pioneer 2555	I	1563	1.69	155
		T	956	1.64	145
		D	1094	1.80	148
	Williams	I	1640	1.71	158
		T	1090	1.68	151
		D	985	1.76	150
S. V. (from ANOVA)					
Cultivar			NS	NS	NS
Row Type			**	**	**
Cultivar x Row			NS	NS	*

[1] I = intercropped interior row; T = intercropped row bordering traffic lane: D = doublecropped row

**,* = significant at $p < 0.01$ or $p < 0.05$. respectively; NS = not significant ($p > 0.10$)

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INFLUENCE OF TILLAGE AND WINTER COVER CROPS ON NITROGEN STATUS OF COTTON

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INTRODUCTION

In fields where moderate to high yields of cotton can be obtained, the profit potential of cotton is often greater than that of alternative crops. It is not surprising, then, that many producers throughout the Cotton Belt elect to maintain productive acreage in continuous cotton until pressure from pests suggests the necessity of rotation with another crop. During the past several years, research in Louisiana has emphasized the use of conservation tillage systems and winter cover crops to ensure the continued productivity of land used in intensive cotton production (Boquet and Hutchinson, 1992; Hutchinson et al., 1993).

Reduced tillage systems minimize the potential for soil erosion and offer the additional advantage of permitting more timely early season field operations in the humid mid-south (Boquet and Coco. 1991; Crawford, 1992). Management systems that combine reduced tillage systems with winter cover crops can offset the depletion of soil organic matter that results from continuous cotton production (Boquet and Hutchinson, 1992). Most soils used for cotton production in the mid-South contain low amounts of organic matter. Increasing soil organic matter tends to improve soil aeration. drainage, water infiltration and retention, and the ability of soil to retain and supply nutrients to crops.

When legumes are used as winter covers, appreciable amounts of biologically fixed N can accumulate (Oyer and Touchton, 1988). Legume cover crops can supply all or a substantial portion of the N required by a cotton crop and reduce the need for purchased inorganic N fertilizers (Touchton and Reeves, 1988; Millhollon et al., 1991). Covers of wheat and other non-legume crops may also enhance the N fertility of cotton soils by immobilizing residual soil N into organic forms. Immobilization prevents accumulation of residual N as nitrate (NO_3^-), a form of N easily lost by leaching and denitrification during winter and spring rains.

Recent field studies in Louisiana indicate that cotton production systems that employed both reduced tillage and legume cover crops to produce cotton on Sharkey clay soils resulted in yields that exceeded those obtainable using conventional production practices regardless of the amount of fertilizer N applied (Boquet et al., 1994). It is well known that an adequate supply of soil N during the growing season is essential to high cotton yields. It is difficult to determine from yield responses alone whether the beneficial effect of reduced tillage and legume covers result from improved N availability, from other beneficial effects of conservation practices on the soil environment, or from a combination of these factors.

Monitoring the N status of cotton grown under different management regimes can provide additional information regarding the influence of tillage practices and cover crops on the ability of soils to supply cotton crops with N. Petiole NO_3 concentrations during fruiting have been used successfully to assess the N status of cotton (Maples et al. 1977). Because petiole NO_3 concentrations are influenced by rainfall and other climatic factors, concentrations are more variable in the humid lower Mississippi River Valley where their ability to reflect the N status of cotton is less than in arid and semiarid regions (Phillips et al., 1987).

The N status of developing cotton plants has also been assessed by determining the total N content of upper leaves (Sabbe et al., 1972). When N uptake by plant roots is not sufficient to adequately supply developing tissue with N, a portion of *N* in older vegetative tissue can be mobilized and transported to allow continued growth. Recent studies indicate that the average N contents of leaf blades collected from uppermost fully expanded leaves during the maturation of cotton are not greatly affected by environmental

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influences and provide a reliable indicator of N status of cotton (Breitenbeck et al., 1994).

The principal objective of this work was to monitor N status of cotton during boll development to determine whether the beneficial effects of reduced tillage and legume cover crops on cotton yields are due primarily to improved N nutrition or to other advantageous changes caused by these practices.

MATERIALS AND METHODS

Tissue samples were collected from field experiments located in Winnsboro, LA. This experiment was established in 1991 on a Gigger silt loam to compare the effects of tillage (conventional and no-till). cover crops (fallow. hairy vetch and wheat) and various annual rates of N fertilization (0, 35, 70, 105, and 140 lbs N/ac) with three replications. Nitrogen fertilizer was applied as 32% N urea-ammonium nitrate solution (UAN) 17-21 days after planting. The liquid fertilizer was applied approximately 10 inches from the drill. In 1991 a surface dribble band was applied and immediately incorporated with a conservation-tillage cultivator. In 1992 and 1993, N fertilizer was knifed-in behind a coulter at a depth of 3 inches. The design and management of this experiment are described in detail by Hutchinson et al. (1994).

Petioles were collected from the most recent fully expanded leaves of 10 plants from each replicate plot in 1991, 1992 and 1993 beginning at first bloom and at weekly intervals for 5 additional weeks. The affixed leaf blades were also collected from these leaves. Nitrate concentrations of petioles were determined in hot H_2O extracts using a Wescan Ammonium Analyzer (Wescan Instruments, Inc., Deerfield, IL) fitted with a Zn column to reduce NO; to NH_4^+. Total N content of leaf blades was determined by a dry combustion technique using a Heraeus CHN Rapid Analyzer (UIC, Inc., Joliet, IL).

Before termination of winter cover crops by tillage (conventional-till) or herbicide application (no-till), samples of wheat or vetch biomass were harvested from each plot by clipping at the soil surface all plant material contained within a square frame 40" on each side. Samples were dried (65°C), weighed and finely ground for determination of N content by dry combustion. Total N contained in the aboveground biomass of each cover crop plot was calculated by multiplying plant biomass by N concentration.

Immediately prior to fertilization in 1991, 1992 and 1993, composite soil samples consisting of replicate soil cores (1.5" dia.) were collected at depths of 0-6", 6-12" and 12-24" from each plot. Soils were air-dried, crushed to pass a 2-mm sieve, and the amounts of NH_4^+ and NO_3 determined in 10:1 1 N KCl:soil extracts.

Table 1. Average N content of cotton leaf blades collected at weekly intervals from the uppermost fully expanded leaves between first bloom and end of effective blooming in 1991, 1992 and 1993.

	Conventional-till'				No-till'			
N rate	Native	Vetch	Wheat	Ava.	Native	Vetch	Wheat	Avg.
	% N							
0	2.96	3.78	2.92	3.22	3.19	3.59	3.08	3.29
35	3.27	4.11	2.86	3.41	3.35	3.98	3.22	3.52
70	3.75	4.23	3.61	3.86	3.89	4.28	3.76	3.98
105	4.16	4.47	4.00	4.21	4.21	4.35	4.04	4.20
140	4.21	4.30	4.18	4.23	4.28	4.25	4.29	4.27
Avg.	3.67	4.18	3.52	3.79	3.79	4.09	3.68	3.85

[†] Values in bold correspond to the lowest N treatments resulting in optimum seedcotton yield for each combination of tillage and cover crop. LSD (0.05) to compare values for tillage x cover crop x N rate combinations, 0.26 %N; LSD (0.05) to compare values for tillage x N rates averaged across cover crops, 0.15 %N; LSD (0.05) to compare values for tillage x cover crops averaged across N rates, 0.11 %N.

RESULTS AND DISCUSSION

Average leaf blade N contents during maturation of cotton indicated that the N status of unfertilized cotton following vetch was similar to that obtained by applying 70 lbs N/Ac to cotton in plots where native vegetation was permitted to grow without a planted cover crop (Table 1). Volunteer native species consisted primarily of annual bluegrass and sibara. Petiole NO_3 concentrations during fruiting confirm that the use of a vetch cover was equivalent to applying approximately 70 lbs N/Ac (Fig. 1). The profile of petiole NO_3 in unfertilized cotton following vetch was remarkably similar to those of cotton receiving 70 lbs N/Ac after native vegetation or wheat. These findings are consistent with 3-yr average seedcotton yields indicating that 0 and 70 lbs of fertilizer N were adequate to produce maximum yields following vetch and native vegetation, respectively (Hutchinson et al., 1994). It is noteworthy that when 70 lbs N/Ac was applied to cotton following vetch, N uptake increased substantially but an increase in cotton yield was not obtained. This supports the conclusion of Boquet et al. (1993) that the ability of N to increase the yield potential of cotton is limited. Excessive N availability, whether caused by application of inorganic fertilizers or a combination of fertilizer and N derived from legume covers, can delay crop maturity and adversely affect harvestability.

The N status of cotton after a wheat cover as indicated by leaf blade N content was consistently less than that of cotton grown after native vegetation receiving an equivalent amount of fertilizer N (Table 1). It is not clear from these data, however, that the slight differences evident in N status adequately account for that fact that cotton after wheat required approximately 35 lbs/Ac more N than cotton after native vegetation to obtain similar seedcotton yields (Hutchinson, 1994). Petiole NO_3 concentrations during fruiting indicate that N availability to cotton after wheat was similar to that of cotton after native vegetation (Fig. 1). It appears that additional N is needed to offset other changes in the soil environment caused by a wheat cover. Early season growth was exceptionally vigorous in cotton after wheat, and additional N may have been required to compensate for damaged early bolls. In these experiments, cotton was irrigated and therefore it is not likely that depletion of subsurface soil moisture by wheat accounts for the need for additional fertilizer N at the soil surface.

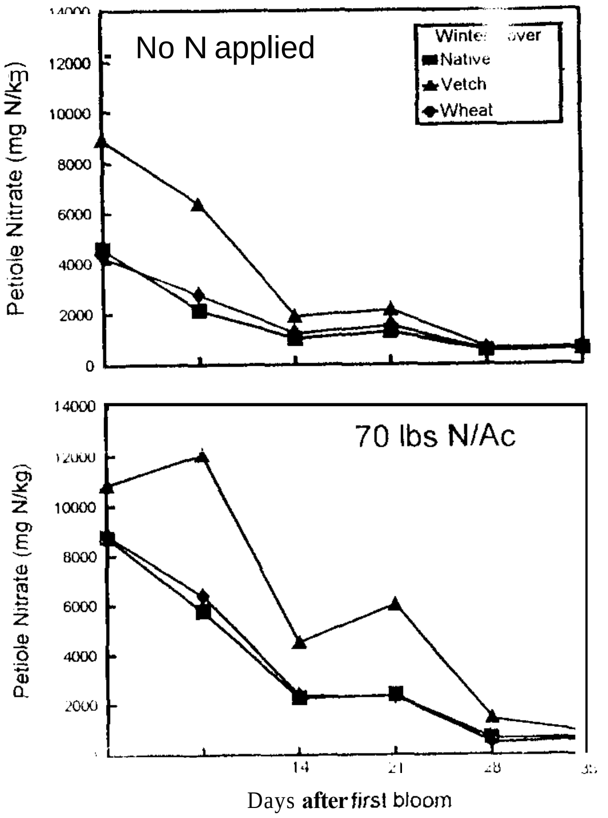

Fig. 1. Effects of cover crops on petiole nitrate concentrations between first bloom and end of effective blooming of cotton receiving 0 or 70 lbs N/Ac.

The contribution of vetch to the N nutrition of the subsequent cotton crop was somewhat greater under conventional tillage than under no-till, presumably because conventional tillage caused more rapid or complete mineralization of N in vetch residues. Averaged over all fertilizer treatments, vetch plots under conventional tillage contained about 50 lbs N/Ac more soil NO_3 before fertilization than did no-till plots (Fig. 2). No-till also reduced the concentration of soil NO_3 following native vegetation in both surface and subsurface horizons. This reduction in the amount of NO_3 accumulated before fertilization, however, did not adversely affect seasonal availability of soil N to the cotton crop. After native or wheat cover, the N status of cotton during maturation was consistently greater

Table 2. Average amount of N contained in aboveground cover crop biomass prior to tillage Iconventional-till) or herbicide application (no-till) in 1992 and 1993.

	Conventional-till[†]			No-till[†]		
Nrate	Vetch	Wheat	Difference	Vetch	Wheat	Difference
	lbs N/Ac					
0	103.0	33.4	69.5	99.4	27.0	72.4
35	101.3	16.6	84.7	108.0	17.6	90.4
70	108.8	25.6	83.2	130.2	26.4	103.8
105	103.7	41.4	62.3	124.6	32.4	92.2
140	120.9	51.5	69.4	103.8	53.2	50.5
avg	107.5	33.7	73.8	111.2	31.3	79.9

[†] LSD (0.05) to compare values for various tillage x cover crop x **N** rate combinations, 33.7 Ibs N/Ac,; LSD (0.05) to compare values for tillage x cover crops averaged across N rates, 15.1 lbs N/Ac.

under no-till than under conventional tillage (Table 1).

Soil NO_3 accumulations before fertilization of cotton were significantly lower after a wheat cover than after native vegetation or vetch under both tillage systems. Whether the observed reduction in preplant soil NO_3 after wheat was due to greater immobilization of N into organic forms or to greater denitrification losses induced by large quantities of carbon substrate available to soil microorganisms during heavy spring rains merits further study. Clearly, a wheat cover contributes substantially to soil organic matter. Wheat covers not only provided an average of 3550 lbs/Ac in aboveground plant biomass, but contributed an additional unknown quantity of organic matter upon decay of their pervasive root systems.

Wheat covers contained 17-53 Ibs N/Ac prior to termination (Table 2). The N contents of the aboveground biomass of wheat covers were similar under no-till and conventional management but tended to increase as the amount of N fertilizers previously applied to cotton increased, demonstrating the potential of wheat covers to recover residual soil N. The low amount of soil NO_3 present after wheat illustrates the value of this cover crop for preventing contamination of surface and ground water by NO_3 in run-off and leachate from cotton fields during winter and spring rains.

The amount of biologically fixed N contributed by a vetch cover crop generally exceeded the amount of N removed by the subsequent cotton crop. Conservatively estimating the amount of biologically fixed N as the difference between N contents of vetch and wheat covers (Table 2), the annual contributions of a vetch cover to soil N reserves averaged 73.8 lbs N/Ac under conventional tillage and 79.9 Ibs N/Ac under no-till. Maximum cotton yields resulted in removal of about 63 Ibs N/Ac in harvested seedcotton (Fig. 3). If N losses from this soil are minimal, our findings indicate that the use of a vetch cover can provide sufficient N for optimum yields without depleting soil N reserves in fields used for continuous cotton production.

Summary

No-till management enhanced N status of cotton grown on Gigger silt loam after a winter cover of wheat or volunteer native vegetation, but led to a slight reduction in N status following a vetch cover crop. Regardless of the tillage system employed, N availability following a vetch cover was sufficient to produce maximum cotton yields without the addition of supplemental inorganic N fertilizers. Assuming losses of N from this soil are not great, the biologically fixed N contributed by the vetch cover crop is adequate to sustain soil N reserves under continuous cotton production. Wheat cover crops were highly effective in recovering residual soil N and in preventing its accumulation as NO_3 during early spring. The influence of wheat covers on N availability to the subsequent cotton crop does not adequately account for the need for greater amounts of inorganic N fertilizers to obtain maximum yields of cotton grown after a wheat cover than after a fallow of native vegetation.

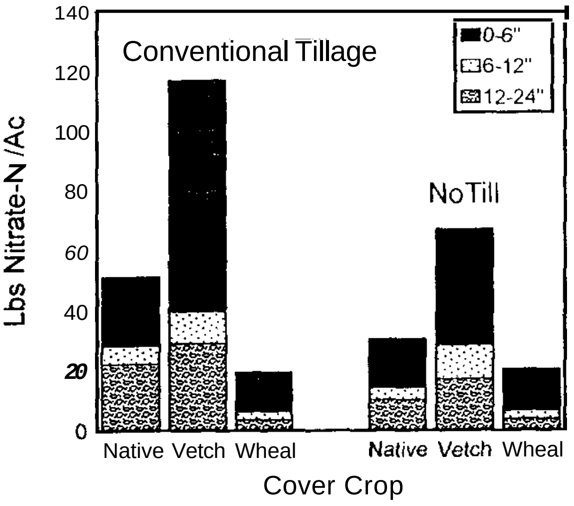

Fig. 2. Effects of tillage and winter cover crops on the average amounts of soil nitrate present in the surface 0-24" prior to planting cotton in 1991, 1992 and 1993.

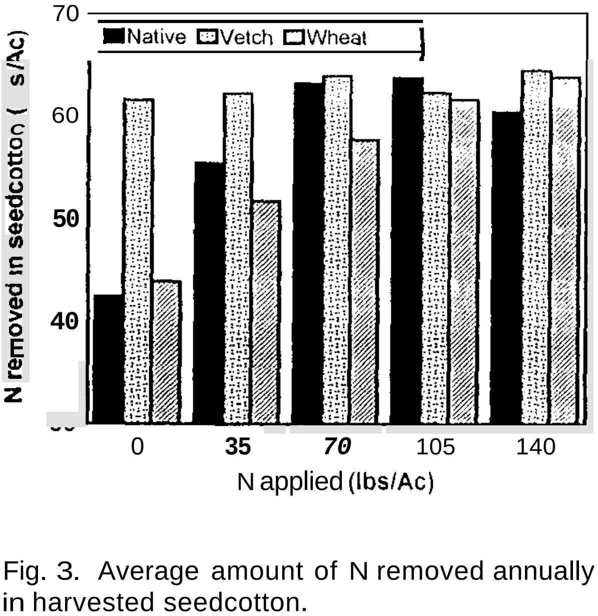

Fig. 3. Average amount of N removed annually in harvested seedcotton.

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SOYBEAN RESPONSE TO STARTER FERTILIZER IN CONSERVATION TILLAGE SYSTEMS

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ABSTRACT

A three-year study (1991-931 of tillage and N, P and K liquid starter fertilizer in selected combinations indicated that tillage and N, P and K fertilizer combinations had no effect on soybean [Glycine max (L.) Merr] yield, seed test weight, and percent leaf N, P and K. Orthogonal statistical analysis (averaged over years), however, indicated that no-tillage produced higher yield than reduced and conventional tillage. No-tillage plants were taller than reduced tillage and conventional tillage treatments. Seed mass showed differences only in 1992 but did not relate to yield. Plant populations were statistically different in 1992 and 1993. However, plant populations were above 82,000 plantslac, adequate for maximum yield. Soil temperature data at the one-inch depth during emergence showed no difference in temperature between no-tillage and conventional tillage in 1991 and 1992. In 1993, however, the no-tillage temperatures often were sightly higher than conventional tillage during the emergence period.

In conclusion, late maturity group IV soybean produced acceptable yield planted in April with either no-tillage, reduced tillage, or conventional tillage. The results are in agreement with other research (Mengel et al., 1987) which indicate no response to P and K fertilizer when soil test levels of both P and K were in the medium to medium-high range.

INTRODUCTION

Mississippi soybean producers are interested in moving a part of their acreage to highly productive Group IV maturity varieties which will allow them to reduce the number of irrigations and have greater opportunity for fall tillage and more flexibility in a rotation with wheat or other fall planted crops while maintaining acceptable yields. However, early planting is subject to heavy rainfalls during planting and high humidity during harvest increasing the chances for phomposis seed decay. Caviness and Mayhew (1994) showed that these environmental effects may be reduced by breeding varieties resistant to phomposis seed decay. Accelerating the early growth of Group IV maturity through varieties resistant to phomposis seed decay and proper tillage methods may expand the window of opportunity for early planted Maturity Group IV soybeans.

Limited research information (Kamprath, 1989, and Touchton and Rickerl, 1986) is available on early planted soybean response to starter fertilizer in conservation tillage systems. On sandy Coastal Plain soils, Kamprath (1989) reported that soybeans do not response to fertilization when P soil test values were greater than 80 lb/ac on poorly drained soils (typical soil characteristic of northeast Mississippi). Nor, did they respond to fertilization when K soil test values were greater than 140 lb/ac (Kamprath, 1989). However, starter fertilizers can increase plant growth when the root growth is restricted or when temperatures remain cool. Touchton and Rickerl, (1986) reported that N-P-K starter fertilizers did increase yield, plant root growth and top weights in soils with high test **P,** K values, but had a greater effect when residual P, K, or both are low. However, Nitrogen fertilization during planting and flowering has shown to increase soybean yield (Reese and Buss, 1992).

April planted Group IV soybean (Riverside 499). response to starter fertilizer was evaluated in 3 tillage environments. The effect of tillage and N, P, and K applied as a starter fertilizer alone and in selected combinations on soybean grain yield, seed mass, seed test weight, leaf N, P and **K,** and plant height at maturity was evaluated.

MATERIALS AND METHODS

The study was conducted in 1991-93 at the Mississippi State University, Northeast Branch of the Mississippi Agriculture and Forestry Experiment Station, Verona, MS. The study was located on the same site for the duration of the study and soil test results indicated medium to high in both P and K. The experimental design was a randomized complete block with 5 replications and plots were 15 ft wide x 30 ft long.

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Table 1. Liquid fertilizer solution mixtures and sources.

N-P_2O_5-K_2O lb/ac	Sources Description
15-30-0	Mixture of N-Sol-32 (liquid N solution) and 10-34-0
0-30-0	Mixing reagent grade phosphoric acid with water
0-0-30	Commercial liquid fertilizer K solution
15-30-30	3-18-18 commercial liquid fertilizer was mixed with Urea to bring the N-P-K ratio to 1:2:2
15-0-0	N-Sol-32

Table 2. Soybean yield response to tillage and N, P. and K fertilizer rate applied as a surface band application on a Leeper silty clay soil in 1991-1993 at the MAFES Northeast Mississippi Branch Station, Verona, MS.

Tillage Fertilizer/ N-P_2O_5-K_2O lb/ac*	1991	1992	1993	mean
	bu/ac			
No-Tillage				
1. 15-30-30	37.5	52.9	41.3	43.9
2. 15-30-0	33.2	48.4	39.5	40.4
3. 0-30-0	32.4	48.6	38.3	39.8
4. 15-0-0	37.8	50.7	38.5	42.3
5. 0-0-30	29.8	51.3	36.2	39.1
6. 0-0-0	34.5	48.1	37.2	40.0
B. Reduced Tillage				
7. 15-30-30	32.2	41.9	39.1	37.7
8. 15-30-0	29.1	48.7	37.6	38.5
9. 0-30-0	29.5	49.4	39.6	39.5
10. 15-0-0	30.6	48.4	36.4	39.1
11. 0-0-30	33.8	48.2	36.7	39.6
12. 0-0-0	31.2	49.4	37.5	39.4
C. Conventional Tillage				
13. 15-30-30	33.0	19.1	35.7	39.3
14. 0-0-0	29.7	46.5	34.3	36.8
LSD 0.05	NS	NS	NS	3.7
CV %	15.9	12.5	9.2	12.9

*All N-P-K fertilizer applied as a 4-in wide surface band over the planted row, Due to excessive rainfall and wet soil conditions experienced during April and May of 1991, which delayed planting until early June, a decision was made to put all the tillage treatments (in the fall of 1991) on beds or ridges in the following manner: no-till (bedding); reduced tillage lone-pass with field cultivator 3 inches deep plus bedding followed by a doalled before planting); and conventional tillage [field cultivated (5 to 6 inches deep), disked twice plus bedding and doalled before planting]. No-till plots were not tilled in the fall of 1992. The reduced tillage and conventional tillage treatments were repeated in the fall of 1992.

No-tillage plots, only in 1993, received an application of 2.4-D at 0.75 lb a/lac on 2/10/93. Each year Gramoxone (paraquat) + surfactant at 0.62 lb ailac + 0.4 pt/ac was applied as a burndown application to the no-till and reduced tillage treatments five to ten days before planting. All reduced tillage and conventional tillage plots were smoothed with a row conditioner before planting. Gramoxone + Prowl (pendimethalin) + Scepter (imazaquin) + surfactant were applied preemergence at 0.25 + 0.8 + 0.06 lb ailac + 0.4 pt/ac over no-tillage and reduced tillage plots . Prowl + Scepter at 0.8 + 0.06 lb ailac was applied preemergence to conventional tillage plots in both study. No postemergence herbicides were required during the growing seasons. One application of dimethoate was applied 5/02/92 for bean leaf beetle control.

Maturity Group IV soybean variety, Riverside 499, was planted on 6/05/91. 4/09/92. and 4/28/93, with a CASE-IH 900 Early Riser planter at 9 seed/ft in 30-inch rows. All starter fertilizer solutions were applied as a surface band (4-inch wide) during the planting operation (Table 1). The N, P and K liquid fertilizer solution mixtures were made by mixing different N, P and K sources to obtain the appropriate solutions. All fertilizer IN-P-K) solutions (Table 2) were applied as a surface band using a fan nozzle (8002-VS) mounted behind the planter press wheel.

Data collected were plant population, early bloom leaf N, P and K content, seed yield, plant height at maturity, seed test weight, and 1000 seed weight (gm/1000 seed). Soil temperatures at 1-inch depth in the no-tillage and conventional tillage plots were measured for the first 3 wk after planting in 1991, 1992, and 1993. A data logger with soil thermocouples placed at the 1-inch depth was used to record soil temperatures every minute. Ten mature trifoliate leaves from the upper most part of the plant in the center two rows of each plot were collected at early bloom for N, P and K analyses. The leaf samples were dried at 75° C for 48 hr and analyzed for N, P and K by appropriate chemical analysis.

The center two rows of each plot were harvested each year in late September or early October with a plot combine. Plot seed yield were weighed and adjusted to bushels per acre utilizing *'yield cal'* a basic computer program. Plot seed test weight and moisture were determined by a GAC II Dickey John Seed Analyzer. Random seed samples of 1000 seed from each harvested plot were weighed. Plant population data was collected from four 3-ft samples of row selected at random in the center 2 rows of each 6-row plot. Plant height at maturity was obtained by measuring the height Ifrom the soil surface to the upper most growing point) of 5 consecutive plants from a randomly selected point in both of the center 2 rows of each plot. All data was subjected to statistical analysis (SAS, Cary, N.C.) and means were separated by Least Significant Differences (LSD) at the 0.05 probability level.

RESULTS AND DISCUSSION

Soil temperatures for 3 wk after planting in 1991 and 1992 (data not shown) showed no difference between no-tillage and conventional tillage. In 1992 the conventional tillage soil temperature ranged from a low of 46° F on April 29 to a high of 90 F on April 17. Seven of 14 days, April 17 to 30, the minimum soil temperature was below 60 F. Four of these 7 days, however, occurred April 27 to April 30. On the contrary, soil temperature in 1993 showed differences between no-tillage (Figure 1) and conventional tillage and generally the no-tillage had slightly higher temperature than conventional tillage. This difference may be due to conventional tillage having greater water infiltration than no-tillage (more water in the soil profile) thereby requiring more energy to warm the soil. The conventional tillage also may have had a rougher surface and, therefore, receive less direct sunlight. Nine of 21 days (May 1 to May 21) in 1993, the minimum soil temperature was below 60°F. Soil temperature from May 1 to May 21 ranged from a low of 53°F to a high of 92 F in no-tillage.

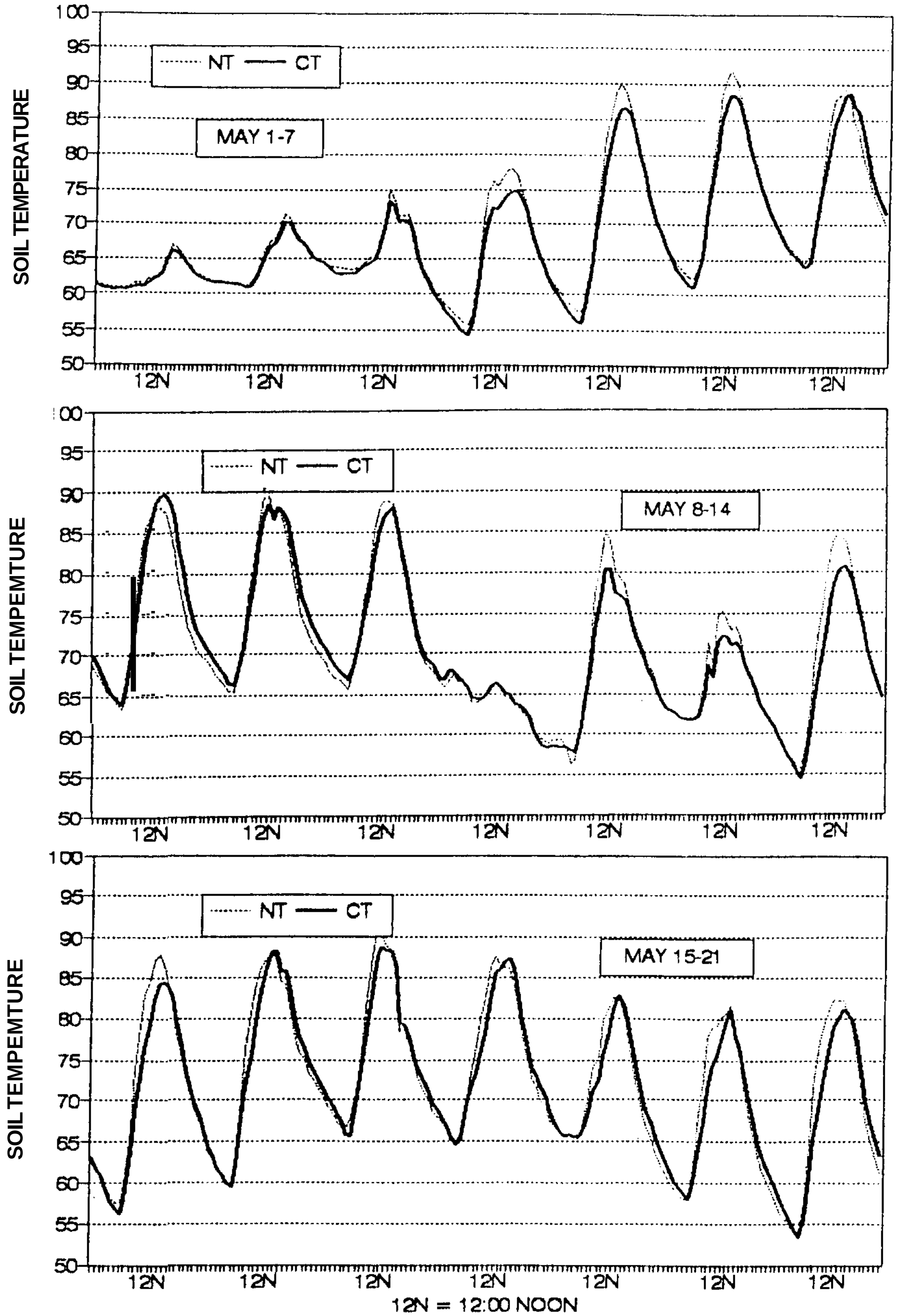

Figure 1. Soil temperatures at 1 inch depth for May 1-21, 1993, Northeast Mississippi Research and extension Center.

Table 3. Soybean plant height and yield. averaged over years 11991-93) and fertilizer rate, response to tillage systems at the MAFES Northeast Mississippi Branch Station, Verona, MS.

Tillage System	Yield bu/ac	Plant Ht(in)
No-tillage	41.0a*	41.2a
Reduced-tillage	38.9b	39.5b
Conventional tillage	38.1b	40.2b

* Numbers in a column with the same lower case letters is not significantly different according to DNMRT at the 5% probability level.

Table 4. Soybean seed weight response to tillage and starter fertilizer applied as a surface band application on a Leeper siltv clav soil (1991-93) at the MAFES Northeast Mississippi Branch Station, Verona, MS.

Tillage Fertilized N-P_2O_5-K_2O lb/ac*	1000 Seed weight 1991	 1992	 1993	 mean
			-gm-	
A. No-Tillage				
1. 15-30-30	124.7	141.8	133.9	133.5
2. 15-30-0	125.1	135.7	134.2	131.7
3. 0-30-0	129.1	138.2	130.5	132.6
4. 15-0-0	122.4	140.0	132.3	131.6
5. 0-0-30	124.6	136.5	129.7	130.3
6. 0-0-0	124.3	137.3	132.8	131.5
B. Reduced Tillane				
7. 15-30-30	125.5	142.8	131.8	133.4
8. 15-30-0	124.8	135.6	133.9	131.4
9. 0-30-0	124.6	139.4	137.6	133.9
10. 15-0-0	120.6	133.6	133.3	129.2
11. 0-0-30	120.8	135.1	131.6	129.2
12. 0-0-0	123.9	133.1	131.8	129.6
C. Conventional Tillage				
13. 15-30-30	120.4	132.9	132.8	128.7
14. 0-0-0	123.0	135.8	131.9	130.2
LSD 0.05	NS	9.3	NS	3.7
CV %	3.3	5.8	4.8	1.7

* All N-P-K fertilizer solutions applied as a 4-in wide surface band over the planted row.

Tillage and fertilizer combinations had no effect on yield all three years of the study (Table 2). The 3 yr (1991- 93) average , however, indicated that the 15-30-30, (N-P_2O_6-K_2O) lb/ac rate with no-tillage produced higher yield than all tillage checks (no fertilizer). 0-30-0, 0-0-30 no-tillage treatments and all conventional and reduce tillage treatments. Orthogonal statistical analysis indicated that averaged over years and fertilizer treatments, no-tillage produced higher yield than reduced tillage and conventional tillage (Table 3).

Seed mass data (Table 4) indicated that 2 of 3 years neither fertilizer nor tillage combinations had any effect on seed mass. However, the 15-30-30 reduced tillage and no-tillage treatments had higher seed mass in 1992 than the 15-30-30 conventional tillage. The 3-yr average data indicated that 15-30-30 in no-tillage and reduced tillage had higher seed mass than conventional tillage, and the reduced tillage check, 0-0-30 and 15-0-0 treatments.

Seed test weight showed difference in 2 of 3 years (Table 5). The 15-30-0 no-tillage and reduced tillage treatments had the highest test weight but was only different from the 0-30-0 reduced tillage treatment in 1992. The 15-30-30 reduced tillage treatment in 1993 had the highest test weight but was different from 0-0-30 and 15-30-0 reduced tillage treatments, 0-0-0, 0-0-30 and 0-30-0 no-tillage and 0-0-0 conventional tillage treatments. The 3-year mean seed test weight, however, showed no response to fertilizer and tillage. Plant height at maturity (Table 6) indicated that in 1991 the no-tillage 15-30-30 was taller than all reduced tillage and conventional treatments, There was no difference in plant height in 1992 and 1993. Orthogonal analysis indicated that averaged over years and fertilizer, no-tillage was taller than conventional and reduced tillage (Table 3). There was no difference between reduced tillage and conventional tillage.

Plant populations showed differences between fertilizer and tillage treatment in 1992 and 1993 (Table 7). The 3-year mean, however. showed no difference in plant population in all treatments. Populations all three years, however, were above 80,000 plants/ac for all treatments, more than sufficient for maximum yield (Doss and Thurton, 1974 and Ramseur et al.. 1984). Soybean leaf tissue analyses, averaged over years, for N, P and K at early bloom, indicated no differences between tillage and fertilizer treatments (Table 8).

The results indicated that late maturity group IV soybeans produced acceptable yield planted in April with either no-tillage, reduced tillage, or conventional tillage. The results are in agreement with other reported research (Mengel et al., 1987) that starter fertilizer is not necessary when soil test levels of both P and K are in the medium to medium-high range.

Table 5. **Soybean seed test weight response to tillage and starter fertilizer applied as a surface band application on a Leeper silty clay soil (1991-93) at the MAFES Northeast Mississippi Branch Station, Verona, MS.**

Tillage Fertilizer/ $N\text{-}P_2O_5\text{-}K_2O$ lb/ac*	Seed test weight 1991	1992	1993	mean
	lb/bu			
A. No-Tillage				
1. 15-30-30	55.2	54.1	54.5	54.6
2. 15-30-0	55.0	54.7	55.4	55.0
3. 0-30-0	54.7	54.2	55.2	54.7
4. 15-0-0	55.3	54.5	54.8	54.9
5. 0-0-30	54.9	54.4	54.2	54.5
6. 0-0-0	55.0	54.3	55.0	54.8
B. Reduced Tillage				
7. 15-30-30	54.3	54.4	56.2	55.0
8. 15-30-0	55.3	54.6	55.2	55.0
9. 0-30-0	55.3	52.9	55.3	54.5
10. 15-0-0	55.1	54.4	55.4	55.0
11. 0-0-30	54.6	54.6	55.1	54.8
12. 0-0-0	55.4	54.1	55.5	55.0
C. Conventional Tillage				
13. 15-30-30	55.8	54.7	55.3	55.3
14. 0-0-0	54.9	54.6	55.2	54.9
LSD 0.05	NS	1.3	0.9	NS
CV %	2.0	2.0	1.2	0.8

*** All N-P-K fertilizer solutions applied as a 4-in wide surface band over the planted row.**

Table 6. Soybean plant height at maturity response to tillage and starter fertilizer 11991-93) on a Leeper silty clay soil at the MAFES Northeast Mississippi Branch Station. Verona, MS.

Tillage/Fertilizer N-P$_2$O$_5$-K$_2$O lb/ac	Plant Height 1991	 1992	 1993	 mean
A. No-Tillage		inches		
1. 15-30-30	31.0	50.7	46.9	42.9
2. 15-30-0	29.8	48.9	45.9	41.5
3. 0-30-0	29.2	49.1	43.4	40.6
4. 15-0-0	30.2	50.2	44.4	41.6
5. 0-0-30	29.4	48.9	43.4	40.6
6. 0-0-0	30.0	47.6	43.5	40.4
8. Reduced Tillage				
7. 15-30-30	27.6	48.8	42.1	39.5
8. 15-30-0	28.0	48.0	43.4	39.8
9. 0-30-0	28.0	46.6	42.3	38.9
10. 15-0-0	27.6	48.1	39.8	38.5
11. 0-0-30	27.6	47.6	44.9	40.0
12. 0-0-0	28.4	48.7	42.7	39.9
C. Conventional Tillage				
13. 15-30-30	28.4	49.6	43.8	40.6
14. 0-0-0	27.4	41.3	44.5	39.7
LSD.05	1.8	NS	NS	1.8
CV %	5.0	4.1	7.6	6.2

Table 7. Soybean plant population for tillage and starter fertilizer (1991-93) on a Laeper silty clay soil at the MAFES Northeast Mississippi Branch Station. Verona. MS.

Tillage/fertilizer N-P$_2$O$_5$-K$_2$O lb/ac	1991	1992	1993	mean
A. No-Tillage		Plant Population/ac X 1000		
1. 15-30-30	129.2	85.6	106.2	107.0
2. 15-30-0	122.4	90.6	114.0	109.0
3. 0-30-0	122.4	90.8	100.6	104.6
4. 15-0-0	115.2	94.6	118.6	109.5
5. 0-0-30	125.8	98.8	114.0	112.9
6. 0-0-0	101.2	99.8	116.6	105.9
B. Reduced Tillage				
7. 15-30-30	118.6	98.6	86.6	101.3
8. 15-30-0	115.2	97.6	97.8	103.5
9. 0-30-0	118.8	95.6	105.8	106.7
10. 15-0-0	115.4	95.4	97.4	102.7
11. 0-0-30	115.2	96.4	110.0	107.2
12. 0-0-0	112.0	95.2	97.4	101.5
C. Conventional Tillage				
13. 15-30-30	129.2	106.0	95.8	110.3
14. 0-0-0	111.8	82.4	104.0	99.4
LSD.05	NS	12.0	18.5	NS
CV %	14.4	9.9	13.9	13.6

Table 8. Three year (1991-93) average soybean leaf percent nitrogen. potassium, and phosphorus at early bloom as influenced by tillage and starter fertilizer rate applied as a surface band application on a Leeper silty clay soil at the MAFES Northeast Mississippi Branch Station, Verona, MS.

Tillage Systems/ N-P_2O_5-K_2O lb/ac*	3 yr average % N	 % P	 % K
A. No-Tillage			
1. 15-30-30	4.6	0.46	1.7
2. 15-30-0	4.8	0.46	1.6
3. 0-30-0	4.9	0.48	1.5
4. 15-0-0	4.6	0.48	1.5
5. 0-0-30	4.9	0.49	1.6
6. 0-0-0	4.7	0.46	1.5
B. Reduced Tiilaae			
7. 15-30-30	4.9	0.46	1.6
8. 15-30-0	4.6	0.48	1.4
9. 0-30-0	4.7	0.46	1.5
10. 15-0-0	4.5	0.47	1.6
11. 0-0-30	5.0	0.47	1.6
12. 0-0-0	4.8	0.48	1.6
C. Conventional Tillage			
13. 15-30-30	4.9	0.47	1.6
14. 0-0-0	5.0	0.47	1.4
LSD 0.05	NS	NS	NS
CV %			

* All N-P-K fertilizer solutions applied as a 4-in wide surface band over the planted row.

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A COMPARISON OF WATER-SEEDED RICE MANAGEMENT SYSTEMS: POTENTIAL IMPROVEMENTS IN WATER QUALITY.

P.K. Bollich[1] and S.E. Feagley[2]

ABSTRACT

Rice fields in southwest Louisiana are generally tilled under flooded conditions, a cultural practice referred to as 'mudding in.' This practice is very effective in controlling or suppressing red rice, a noxious rice biotype. A consequence of mudding in is the release of significant amounts of solids and nutrients once the field is drained after planting. These discharges have been associated with water quality degradation in surface waters that receive rice field effluent. A study was initiated in 1993 to compare the practice of mudding in with three alternative management practices: 1l no-till planting (into previous residue], 2) mudding in with floodwater retention (floodwater retained for 2 weeks to allow for settling), and 3) clear water planting (dry seedbed preparation). The three management practices were very effective in reducing levels of total suspended solids, total solids, and some dissolved elements during the initial drain. Five-day biological oxygen demand was significantly reduced in the no-till planting. Total dissolved solids were significantly reduced in the clear water and no-till plantings. Levels of suspended solids and most dissolved elements in the floodwater decreased over time. Stand density and grain yield were significantly reduced in the no-till planting, and maturity was delayed 5 to 7 days when compared with other planting methods. This study indicates the potential of alternative rice planting practices to mitigate problems associated with degradation of surface waters that receive rice field effluent. Stand establishment in no-till rice plantings appears to be the limiting factor in widespread adoption of this practice. Since evaluation of red rice in this study was limited to visual observation, the potential for these alternative management practices to control red rice needs further study.

INTRODUCTION

Water seeding is the most popular rice planting practice in Louisiana, especially in the southwest area. Rice fields are generally tilled under flooded conditions, a cultural practice referred to as 'mudding in.' This practice is very effective in controlling or suppressing red rice, a noxious rice biotype, and preparing a smooth and weedfree seedbed. Various types of mechanical operations are employed when fields are prepared in this manner. These puddling operations result in the release of significant amounts of solids and nutrients once the field is drained after planting, and rice field discharges have been associated with water quality degradation in receiving streams in the Mermentau River Basin (Cormier et al., 1990). These problems resulted in Bayou Queue de Tortue being selected for the United States Department of Agriculture Water Quality Initiative and the Louisiana Department of Environmental Quality Nonpoint Source Program.

A study conducted by Feagley, et al. (19921, compared mudding in with a number of rice management practices (MPs) developed by the Agricultural Stabilization and Conservation Service (ASCS), Soil Conservation Service ISCS), and research and extension personnel of the LSU Agricultural Center. These MPs were also offered to farmers in the Bayou Queue de Tortue drainage basin on a cost-share basis while being evaluated in cooperating farmers' fields and at the Rice Research Station in Crowley, LA.

Data in this study was collected from large, non-replicated plots in both the farmers' fields and at the Rice Research Station. All of the alternative MPs showed significant improvement in rice field effluent when compared with mudding in. Yield data were collected from the demonstration plots in farmers' fields only. There was also no evaluation made to determine the effectiveness of the alternative MPs in controlling or suppressing red rice. The objectives of this study were to 1) characterize rice field effluents from the various MPs, 2) compare stand establishment, grain yields, and other agronomic characteristics among MPs,

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and 31 assess the potential for controlling red rice in each MP.

MATERIALS AND METHODS

The experiment was conducted at the Rice Research Station in Crowley, Louisiana, on a Crowley silt loam (fine, montmorillonitic, thermic, Typic Albaqualfl. The test area was infested with red rice in 1991 and 1992 and allowed to reseed to establish a native population for this study.

Each MP was individually leveed, replicated three times, and arranged in a randomized complete block. Plots were 43 x 298 ft^2 (0.28 A) and were individually flooded and drained for water sample collection. Roundup (glyphosate) was applied to the no-till seedbed (MP1) at the rate of 1.0 lb ai/A 5 days prior to flooding. No soil-disturbing activities occurred after levee construction. The mudding in with water retention practice (MP2) was plowed dry, flooded, vibra-shanked, and smoothed with a drag. Rice field effluent was not released for 14 days to allow for settling. The clear water planting practice (MP3) consisted of dry seedbed preparation with no soil-disturbing activities occurring after flooding. The traditional mudding in practice (MP4) was prepared as described in MP2 and was drained 7 days after seedbed preparation. A 75-45-45 (N-P-K) fertilizer was preplant incorporated in MP3 at the time of dry seedbed preparation. Fertilizer was applied to the other MPs approximately 3 weeks after planting, All MPs received an application of 69 lb NIA at midseason.

The test area was aerially seeded with presprouted rice (cv Maybelle) at a rate of 150 lb/A. All MPs were drained 3 days after seeding to encourage seedling anchorage. The study was reflooded 7 days later. Water samples were collected from each plot during the drainage procedure and immediately refrigerated. Total N was determined with a Wescan Ammonia Analyzer. Anions were analyzed with an ion chromatograph. Metals were analyzed by inductively coupled plasma spectroscopy. Water pH was determined on a filtered sample in the laboratory (Page, 1982). Electrical conductivity (EC) was determined using an EC bridge (Page, 1982). Total suspended solids (TSS) (non- filterable residue) and total dissolved solids (TDS) (filterable residue) were determined gravimetrically (EPA, 1983). The biological O, demand at 5 days (BOD5) was determined using EPA method 405.1 and DO was measured with an Orion portable O, meter.

Water quality parameters were determined at the initial drain, once at midseason, and at harvest drain. The BOD5 was not determined at midseason. Stand density was measured 3 weeks after planting. Plant height, days to 50% heading, grain yield, and milling quality were determined. Due to non-uniform establishment of red rice, only visual observations were noted.

Table 1. Influence of management practices on agronomic performance of water-seeded Maybelle rice. Rice Research Station, South Unit, Crowley, LA. 1993.

Management Practice'	Stand density	Days to 50% heading	Plant height	Grain yield at 12% moisture	% Milling yield
	-(ft^2)-		(in)	-(lb/A)-	(head-total1
MP1	9	76	37	4376	56-67
MP2	35	71	39	5449	57-69
MP3	41	69	37	5594	54-69
MP4	41	70	35	5243	51-69
C.V., %	22.35	1.06	5.52	5.43	3.3-1.4
LSD (0.05)	14	1	ns	560	4-ns

[1] MP1 = No till; MP2 = mudding in with floodwater retention; MP3 = clear water planting; MP4 = traditional mudding in.

Table 2. Influence of management practices on water quality of rice field floodwater (initial drain) from water-seeded rice. Rice Research Station, South Unit, Crowley, LA. 1993.[1,2]

Parameter	MP1	MP2	MP3	MP4	LSD (0.05)
BOD5 (mg/L)	7.3	18.6	18.1	14.0	4.4
pH	7.8	7.7	8.2	7.4	0.4
EC (dS/m)	0.55	0.38	0.48	0.35	0.05
TSS (mg/L)	7	100	74	300	14
TDS (mg/L)	436	2000	325	3887	2036
TS (mg/L)	453	4207	520	8800	2776
Fe (mg/L)	0.05	1.35	0.02	11.31	7.08
Mn (mg/L)	0.001	0.009	0.001	0.021	ns
Ni (mg/L)	0.03	0.03	0.03	0.04	ns
Al (mg/L)	0.03	3.51	0.06	28.68	18.0
Cd (mg/L)	0.002	0.002	0.002	0.003	ns
Cu (mg/L)	0.004	0.005	0.003	0.010	0.005
As (mg/L)	0.020	0.033	0.023	0.070	ns
B (mg/L)	0.087	0.050	0.100	0.070	ns
Cr (mg/L)	0.004	0.004	0.004	0.023	ns
Si (mg/L)	15.5	13.5	7.7	55.2	30.5
P (mg/L)	0.28	0.17	0.15	0.41	ns
Pb (mg/L)	0.050	0.050	0.050	0.053	ns
Zn (mg/L)	0.018	0.015	0.010	0.052	.027
Mg (mg/L)	24.8	14.2	22.5	10.4	6.4
K (mg/L)	8.2	4.6	5.7	5.5	1.3
S (mg/L)	0.94	2.28	1.09	2.75	0.64
Na (mg/L)	80.2	61.5	95.6	67.6	ns
Ca (mg/L)	40.9	23.4	31.7	13.9	11.4
F^- (mg/L)	0.56	0.72	0.74	0.70	ns
Cl^- (mg/L)	42.0	40.8	50.1	48.3	ns
Br^- (mg/L)	0.07	0.15	0.13	0.20	ns
NO_2^- (mg/L)	<0.10	<0.10	<0.10	<0.10	ns
NO_3^- (mg/L)	0.28	0.53	0.25	0.90	ns
PO_4^{3-} (mg/L)	<0.2	<0.2	<0.2	<0.2	ns
SO_4^{2-} (mg/L)	1.10	4.43	1.81	5.98	1.64

[1] MP1 = No till; MP2 = mudding in with floodwater retention; MP3 = clear water planting; MP4 = traditional mudding in.

[2] < may indicate no measured amount at the detection limits for that particular variable.

RESULTS AND DISCUSSION

Agronomic characteristics of the MPs are shown in Table 1. Maybelle emerged 5 to 6 days after planting in MP2, MP3. and MP4 (water-seeded rice is considered emerged when 75% of the seedlings have a shoot 3/4 of an inch in length). Emergence in MP1 occurred 7 days later. Loss of seedlings and poor rooting were observed in this MP. These problems appeared to have been associated with poor floodwater quality that resulted from decomposition of terminated vegetation. Stand establishment in water-seeded, no-till rice has been a problem in previous studies (Bollich, 1992) and also in commercial fields. As a result, stand density was significantly reduced in MP1. Stand densities were similar for the other MPs.

Table 3. Influence of management practices on water quality of rice field floodwater (midseason drain) from water-seeded rice. Rice Research Station, South Unit, Crowley, LA. 1993.[1,2]

Parameter	MP1	MP2	MP3	MP4	LSD (0.05)
BOD5 (mg/L)[3]					
pH	7.8	7.8	7.8	7.7	ns
EC (dS/m)	221	167	185	160	13
TSS (mg/L)	8.67	4.33	5.67	7.67	ns
TDS (mg/L)	156	127	144	117	19
TS (mg/L)	158	114	125	113	15
Fe (mg/L)	0.57	0.94	1.21	1.40	ns
Mn (mg/L)	<0.001	<0.001	0.001	0.002	.001
Ni (mg/L)	0.001	0.004	0.004	0.000	ns
Al (mg/L)	0.017	0.047	0.033	0.043	ns
Cd (mg/L)	<0.002	<0.002	<0.002	<0.002	ns
Cu (mg/L)	0.003	0.003	0.004	0.002	ns
As (mg/L)	0.028	0.044	0.037	0.039	ns
B (mg/L)	0.037	0.033	0.033	0.033	ns
Cr (mg/L)	0.000	0.004	0.000	0.000	ns
Si (mg/L)	3.53	3.03	2.97	2.93	.29
P (mg/L)	0.30	0.28	0.19	0.24	ns
Pb (mg/L)	0.087	0.117	0.090	0.083	ns
Zn (mg/L)	0.002	0.012	0.005	0.005	ns
Mg (mg/L)	7.99	6.25	6.89	6.10	0.55
K (mg/L)	1.01	1.23	1.41	1.56	ns
S (mg/L)	0.44	0.38	0.35	0.37	0.05
Na (mg/L)	21.6	16.9	18.7	16.5	1.9
Ca (mg/L)	21.7	14.1	15.8	12.8	1.4
F^- (mg/L)	0.21	0.20	0.18	0.19	0.02
Cl^- (mg/L)	11.3	8.6	9.3	8.4	ns
Br (mg/L)	0.056	0.058	0.051	0.054	ns
NO; (mg/L)	<0.10	<0.10	0.10	0.432	0.230
NO, (mg/L)	1.29	0.48	0.34	0.05	0.35
PO_4^{3-} (mg/L)	<0.2	<0.2	<0.2	<0.2	ns
SO_4^{2-} (mg/L)	0.40	0.38	0.36	0.39	ns

[1] MP1 = No till; MP2 = mudding in with floodwater retention; MP3 = clear water planting; MP4 = traditional mudding in.

[2] < may indicate no measured amount at the detection limits for that particular variable.

[3] BOD5 was not determined on the midseason drain samples.

Stand establishment difficulty in MP1 also delayed maturity. Time to 50% heading was increased 5 to 7 days in MP1 when compared with the other MPs. Earliness is an important consideration in southwest Louisiana where ratoon cropping is practiced extensively, and delayed maturity of the main crop is a serious disadvantage. Plant height was similar in each MP.

Grain yield was significantly reduced in MP1. When compared with MP2, MP3, and MP4, yield of MP1 was reduced 20, 22, and 16%. respectively.

Table 4. Influence of management practices on water quality of rice field floodwater (harvest drain) from water-seeded rice. Rice Research Station, South Unit, Crowley, LA. 1993.[1,2]

Parameter	MP1	MP2	MP3	MP4	LSD (0.05)
BOD5 (mg/L)	2.6	3.6	5.3	2.4	ns
pH	8.0	8.0	7.9	7.9	0.1
EC (dS/m)	282	292	283	277	ns
TSS (mg/L)	2.0	7.3	9.0	10.7	3.1
TDS (mg/L)	197	202	207	204	ns
TS (mg/L)	200	218	208	212	ns
Fe (mg/L)	1.0	0.1	1.2	1.2	0.7
Mn (mg/L)	<0.001	<0.001	<0.001	<0.001	ns
Ni (mg/L)	0.020	0.017	0.021	0.023	ns
Al (mg/L)	0.027	0.020	0.013	0.003	ns
Cd (mg/L)	0.003	0.002	<0.002	<0.002	ns
Cu (mg/L)	0.003	0.002	0.002	0.001	ns
As (mg/L)	0.034	0.012	0.016	0.023	ns
B (mg/L)	0.080	0.080	0.067	0.073	ns
Cr (mg/L)	0.009	0.003	0.003	0.002	0.005
Si (mg/L)	7.2	9.1	11.2	8.2	1.5
P (mg/L)	0.117	0.100	0.070	0.087	ns
Pb (mg/L)	0.063	<0.05	<0.05	<0.05	ns
Zn (mg/L)	0.001	0.001	0.002	0.003	ns
Mg (mg/L)	12.0	12.4	12.2	11.8	ns
K (mg/L)	3.1	6.2	7.8	6.3	1.5
S (mg/L)	0.34	0.39	1.23	0.46	ns
Na (mg/L)	30.8	32.9	30.5	30.6	ns
Ca (mg/L)	23.1	19.6	20.0	17.5	3.7
F (mg/L)	0.24	0.25	0.22	0.26	0.01
Cl^- (mg/L)	22.2	28.0	28.7	29.8	4.5
Br^- (mg/L)	0.15	0.25	0.24	0.23	0.02
NO_3^- (mg/L)	<0.10	0.38	0.77	0.51	ns
NO_2^- (mg/L)	<0.05	<0.05	<0.05	<0.05	ns
PO_4^{3-} (mg/L)	0.053	0.122	0.144	0.081	ns
SO_4^{2-} (mg/L)	0.18	0.37	0.43	0.40	0.11

[1] MP1 = No till; MP2 = mudding in with floodwater retention; MP3 = clear water planting; MP4 = traditional mudding in.

[2] < may indicate no measured amount at the detection limits for that particular variable.

The yield reduction was associated with inadequate stand density. Red rice stand density was not determined because of very nonuniform establishment in the test area. By visual estimation, the amount of red rice established among treatments was in the following order: clear water < mudding in = mudding in with floodwater retention < no-till. Grain samples were collected at harvest in each treatment to determine whether milling, grade, or quality was affected by red rice. Head rice (whole grain) yield was significantly lower in MP4 but was due to severe lodging rather than red rice. Head rice was similar for the other MPs, and the total (whole grains + brokens) was unaffected.

The BOD5 was significantly lower in MP1 during the initial drain (Table 2). Values were similar in the other MPs. In MP2, BOD5 was significantly higher than in MP4. The pH was highest in MP3 and lowest in MP4. Both MP2 and MP4 were similar in EC, while EC was significantly higher in MP1 and MP3. Levels of TSS were significantly lower in MPI, followed by MP3, MP2, and MP4. Levels of TDS and TS were similar for MP1 and MP3. There was no difference in TDS between MP2 and MP4, but TS was significantly lower when the floodwater was retained for 2 weeks in MP2.

There were no differences among MPs in concentration of most of the nutrients. metals, and anions. Concentrations of Fe, Al, Cu, Si, Zn, Mg, S, Ca, and SO_4^{2-} were similar for MP1 and MP3, and in most instances, lower than levels found in MP2 and MP4. A higher concentration of K was released from MPI. Levels of most dissolved elements were similar for MP2 and MP4, with the exception of Fe, Al, Cu, and Si. These elements were decreased in MP2.

At midseason, EC increased in all MPs (Table 3). This parameter was similar in MP2 and MP4, and significantly higher in MP1 and MP3. This is due to evaporation and additions of water to maintain flood depth. There were no differences in TSS among MPs, and although there were differences in TDS and TS, levels in all MPs were much lower than during the initial drain, indicating that sediment had settled overtime.

Concentrations of Si, Mg, S, Na, Ca, NO_3^{2-}, and PO_4^{3-} were significantly higher in MPI. Level of NO; was highest in MP4 with none being detected in MP1 or MP2.

With the exception of EC, Na, and Cl^-, values for most parameters were further reduced at harvest drain (Table 4). The increase in EC is most likely resulting from the increase in Na and Cl^-. Concentrations of most dissolved elements and metals, BOD5, EC, TDS, TS, NO; NO; and PO_4^{3-} were similar for all MPs. The TSS was significantly lower in MP1 but overall values were quite low. Concentrations of Fe and Cr were lowest and highest, respectively, in MP1. Concentration of Si was highest in MP2 and MP3, while K, Br^-, Cl^-, and SO_4^{2-} were lowest in MP1.

Rice planting practices do have a significant impact on effluent parameters when floodwater is released, especially during the initial drain. The quality of most effluent parameters improves over time, and while differences among MPs are detected at midseason and during harvest drain, most of the problems associated with degraded water in receiving streams occur during the initial drain. These alternative MPs have all been shown to be effective in improving rice field effluent. Stand establishment in MP1 is a serious concern, especially when grain yield is reduced to the extent measured in this study. Rice variety suitability, preplant vegetation manipulation, and floodwater management need to be addressed in order to minimize stand problems to make no-till planting more attractive to widespread commercial application. Greater emphasis also needs to be placed on red rice control, since red rice is the primary reason for culturing rice in the traditional mudding in system.

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EFFECTS OF TILLAGE SYSTEMS AND COVER CROPS ON NITROGEN FERTILIZER REQUIREMENTS OF COTTON

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INTRODUCTION

Conservation tillage systems and winter cover crops can reduce soil erosion on highly erodible cotton fields. Estimates of soil erosion on loess soils in northeast Louisiana indicate that these practices may reduce soil erosion by over 85% compared to conventional tillage practices (Hutchinson et al., 1991). Research conducted in Louisiana from 1987-1992 has shown that cotton yields in conservation tillage systems are usually equal to conventional tillage (Hutchinson, et al., 1991; Hutchinson, et al., 1993). In most instances performance of cotton in no-till (NT) and ridge-till (RT) systems was significantly improved with winter cover crops (Hutchinson, et al., 1993). Several studies in other states have demonstrated similar yield improvements when cotton followed winter cover crops in conservation tillage systems (Brown, et al., 1985; Keeling, et al., 1989) while others, showed no benefits from winter cover crops (Stevens, et al., 1992). Cover crop mulches are very effective for conserving soil moisture. Thus, yield benefits from winter cover crops are more likely to occur under non-irrigated conditions on drought-prone soils where moisture stress is a limiting factor on yields.

Several researchers have studied the use of legume cover crops as a N source for cotton in conservation tillage systems (Brown et al., 1985; Dumas, 1980; Touchton et al., 1984). In some instances the legume cover crops provided adequate N for optimum yields while in others additional N was needed. Results from these studies indicate that N fertilizer responses of cotton following legumes may be quite variable due to differences in biomass production of the cover crop, and due to soil and environmental factors that influence decomposition and mineralization rates and leaching of N below the cotton rooting zone. Information on N fertilization of conservation-tillage cotton following small grain cover crops is limited, however, several researchers have found that conservation-till cotton following small grain cover crops requires higher N fertilizer rates than cotton following winter fallow (Brown et al., 1985; Touchton and Reeves, 1988).

This study was initiated to develop N fertilization guidelines for NT and conventional-till (CT) cotton following selected winter cover crops on a loessial soil of the Macon Ridge region of northeast Louisiana. Results of these studies are needed to optimize yields and reduce the environmental risks associated with over fertilization of cotton in CT and NT production systems.

MATERIALS AND METHODS

A field experiment was conducted from 1991-93 on a Gigger silt loam soil (fine-silty, mixed, thermic Typic Fragiudalf) at the Macon Ridge Branch Research Station at Winnsboro, Louisiana to study the effects of tillage systems and winter cover crops on N fertilizer requirements of cotton. Winter cover crops were native winter vegetation, hairy vetch, or winter wheat. Tillage systems included NT and CT. Nitrogen fertilization rates ranged from 0 to 140 pounds/acre in 35 pound/acre increments. All treatments were maintained in the same location each year of the study.

Hairy vetch and winter wheat (cultivar 'Florida 302') cover crops were NT planted with a grain drill after cotton harvest each year. Seeding rates for vetch and wheat were 25 and 90 pounds/acre. respectively. Planting dates were October 23, 1990; November 5, 1991; and October 19, 1992. A rotary stalk cutter was used to shred the cotton stalks immediately after the cover crops were planted each year.

Hairy vetch and wheat cover crops were terminated either with herbicides (NT treatments) or tillage (CT treatments) on April 24, 1991 and on April 10 in 1992 and 1993. Plots were retreated with herbicides or tillage 11 to 14 days later. The hairy vetch cover crops were adequately controlled with two applications of paraquat (0.5 lb ai/acre). The wheat cover crop received two applications of

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Table 1. Effects of tillage systems on seedcotton yield averaged across cover crops and N rates.

	Seedcotton		
Tillage System	1991	1992	1993
	lb/acre		
Conventional-till	2671	2626	2806
No-till	2687	2688	2731
LSD (0.051	NS	NS	NS

Table 2. Effects of winter cover crops and N rates on seedcotton yield averaged across tillage systems.

Cover Crop	Cotton N Fertilizer Rate	Seedcotton Yield		
		1991	1992	1993
	lb/a	lb/a		
Native	0	2261	1993	1674
Native	35	2687	2490	2483
Native	70	2775	2941	3025
Native	105	2801	2920	3093
Native	140	2627	2747	2982
Vetch	0	2769	2802	2949
Vetch	35	2666	2848	3092
Vetch	70	2757	2939	3145
Vetch	105	2801	2738	3080
Vetch	140	2807	2938	3173
Wheat	0	2398	1891	1796
Wheat	35	2473	2399	2287
Wheat	70	2661	2643	2678
Wheat	105	2772	2774	2984
Wheat	140	2936	2796	3094
Cover Crop Means Across N Rates				
Native		2630	2618	2651
Vetch		2760	2853	3087
Wheat		2648	2500	2568
N Fertilization means across cover crops				
	0	2476	2229	2139
	35	2608	2579	2620
	70	2731	2841	2949
	105	2791	2811	3052
	140	2790	2827	3083
LSD 10.05) To compare N rates within cover crop species		246	257	299
LSD (0.05) Cover crops averaged across N Rates		110	138	134
LSD (0.051 N rates averaged across cover crops		142	178	173

glyphosate 1.0 lb ai/acre) in 1991 and 1992. In 1993 paraquat (0.5 lb ai/acre) was substituted for the second application. Native winter vegetation in NT plots received an application of glyphosate (1.0 lb ai/acre) on April 24 and May 7 in 1991. In 1992 these plots received paraquat 10.5 lb ai/acre) on March 3 and glyphosate 1.0 lb/acre) on May 5. In 1993 glyphosate (1.0 lb ai/acre) was applied on April 10 followed by paraquat (0.5 lb ai/acre) on April 21.

All CT plots were disked twice on April 24, 1991 and on April 10 in 1992 and 1993. The CT plots were disked twice again 11 to 14 days later and bedded with disk hippers. A reel and harrow bed conditioner was used for seedbed preparation in CT treatments.

The experimental design was a split plot in a randomized complete block design with four replications in 1991 and three replications in 1992 and 1993. Main plots were tillage systems. Subplots were a factorial arrangement of cover crop and N rate combinations. Plots were eight rows wide 140-inch spacing) and 45 feet in length.

Stoneville 453 cotton was planted with a John Deere 7100 planter in 1991 and 1992 and with a John Deere 7300 planter in 1993. The seeding rate for all treatments was approximately six seed per foot of row. Ripple coulters were mounted ahead of each planter unit for planting the NT treatments. Dates of planting were June 4, 1991; May 4, 1992; and May 7, 1993. In-furrow granular pesticide applicators mounted on each planter unit were used to apply aldicarb 10.5 lb ai/acre) plus Ridomil PC (10 lb product/acre) at planting.

Soil samples taken from each plot (0-6 inches) in the spring of 1991 indicated medium to high levels of P, K, Ca, and Mg. The soil pH was 6.3 and organic matter was 1.2%.

Nitrogen fertilizer was applied as 32% N urea-ammonium nitrate solution (UAN) on June 21, 1991; May 22, 1992; and May 28, 1993. Thus, applications were made from 17 to 21 days after planting. The liquid fertilizer was applied approximately 10 inches from the drill. In 1991 a surface dribble band was applied and immediately incorporated with a conservation-tillage cultivator. In 1992 and 1993 the N fertilizer was knifed-in behind a coulter at a depth of 3 inches.

The entire test was irrigated on an as-needed basis according to neutron soil moisture probe readings and visual inspection of soil cores. Total amounts of water applied in 1991, 1992, and 1993 were 6.25, 9.0, and 9.1 inches, respectively.

Preemergence weed control in all treatments consisted of broadcast applications of fluometuron (1.2 lb ai/acre) plus metolachlor (1.5 lb ai/acre) in 1991 and 1992. Fluometuron (1.2 lb ai/acre) plus pendimethalin (1.0 lb ai/acre) was used in 1993. Postemergence weed control was accomplished with two mechanical cultivations with a conservation-tillage cultivator and post-directed applications 120-inch band) of fluometuron (0.6 lb ai/acre) plus MSMA (1.0 lb ai/acre) and prometryn 0.3 lb ai/acre) plus MSMA (1.0 lb ai/acre).

The entire test area was scouted at least twice each week for insects. Recommended insecticides were used to keep all pests below economic thresholds.

All plots were defoliated on October 4, 1991; September 10, 1992; and September 17, 1993. The center four rows of each plot were harvested for seedcotton yield with a spindle picker on October 11 and 22 in 1991; September 18 and 25 in 1992; and September 24 and October 4 in 1993.

RESULTS

Cotton Yield

Seedcotton yields of NT and CT cotton averaged across cover crops and N rates were similar in 1991, 1992, and 1993 (Table 1). Furthermore, we found no significant interactions between tillage and cover crops or tillage and N rates.

Significant cover crop x N rate interactions were noted each year of the study. In 1991 cotton yield following native vegetation was increased significantly as the N rate was increased from 0 to 35 lb/acre (Table 2). No further yield increase was observed with higher N rates. In 1992 and 1993 optimum cotton yield following native vegetation was obtained with 70 lb N/acre. Each year cotton yield following native vegetation with 140 lb/acre was numerically less than the 105 lb/acre N rate.

Table 3. Effects of tillage systems on cotton maturity averaged across cover crops and N rates.

Tillage System	First Harvest 1991	1992	1993
		%	
Conventional-till	82.7	81.2	91.4
No-till	82.3	76.9	92.0
LSD (0.05)	NS	2.2	NS

Table 4. Effects of winter cover crops and N rates on cotton maturity averaged across tillage systems.

Cover Crop	Cotton N Fertilizer Rate	First Harvest 1991	1992	1993
	lb/a		%	
Native	0	80.0	84.3	93.3
Native	35	84.9	84.7	93.3
Native	70	82.6	80.3	91.2
Native	105	83.6	80.5	89.8
Native	140	80.1	80.5	90.5
Vetch	0	85.1	80.7	91.5
Vetch	35	84.2	79.7	90.3
Vetch	70	82.2	75.2	89.8
Vetch	105	81.4	77.7	90.7
Vetch	140	82.4	78.1	91.7
Wheat	0	83.1	81.0	94.3
Wheat	35	82.1	84.8	94.5
Wheat	70	81.9	17.3	92.3
Wheat	105	83.0	73.1	91.5
Wheat	140	81.0	67.2	91.0
Cover Crop Means Across N Rates				
Native		82.2	82.1	91.6
Vetch		83.1	78.4	90.8
Wheat		82.2	76.8	92.7
N Fertilization means across cover crops				
	0	82.8	82.0	93.1
	35	83.8	83.1	92.7
	70	82.3	77.6	91.1
	105	82.7	77.3	90.7
	140	81.2	75.4	91.1
LSD (0.05) To compare N rates within cover crop species		3.3	6.0	NS
LSD (0.05) Cover crops averaged across N Rates		NS	2.7	1.0
LSD (0.05) N rates averaged across cover crops		NS	3.5	1.3

Cotton following hairy vetch cover crops did not require fertilizer N in 1991, 1992, or 1993 (Table 2). These data indicate that adequate N was mineralized from the vetch residue to produce optimum yields without additional N fertilizer. Furthermore, yields of cotton following hairy vetch with 0 N were equal to yields of cotton following native vegetation or wheat cover crops with optimum levels of fertilizer N. It is interesting to note that yields of cotton following hairy vetch did not decline even with highest rates of fertilizer N. The N contribution of above ground vetch residue averaged 93, 99, and 124 lb N/acre in 1991, 1992, and 1993, respectively (Breitenbeck and Hutchinson, 1994).

In 1991 and 1993, cotton following wheat cover crops required at least 105 lb/acre of fertilizer N to produce optimum yields (Table 2). In 1992 yields of the 70, 105, and 140 lb/acre N rates were not significantly different, however, yield tended to increase numerically with increases in N rates. These data suggest that cotton following wheat cover crops may require approximately 35 lb/acre more N to produce optimum yields than cotton following native vegetation.

Maturity

Maturity of cotton was not influenced significantly by tillage systems in 1991 or 1993 (Table 3). In 1992, however, CT cotton was significantly earlier than NT; however, this difference was probably less than three or four days. Cover crop and N rate effects on earliness varied from year to year (Table 41. In most instances N fertilization rates that provided optimum yield resulted in slightly later maturity than lower N rates. Increasing N rates above the level needed to produce optimum yield usually resulted in a significant delay in maturity with no increase in yield. Although the delays in maturity measured as percent first harvest were generally quite small, considerable visual differences were apparent between N deficient, sufficient, and excessively fertilized plants. N deficient plants showed varying degrees of chlorosis as early as the first week of bloom. This was especially severe with cotton following wheat and receiving 0 N. Sufficiently N fertilized cotton following native vegetation or wheat, and cotton following vetch with 0 N fertilizer began to exhibit significant leaf chlorosis approximately 40 to 45 days after first bloom. Excessively fertilized plants remained dark green up to the time of defoliation.

Plant Height

Mature plant height of cotton was significantly greater in NT plots than CT in 1991 and 1992 (Table 5). Plant heights for both tillage regimes were similar in 1993. Cotton vegetative growth was strongly influenced by cover crops and N fertilization each year. In addition, the cover crop x N rate interaction was significant each year (Table 6). Averaged over N rates, cotton following vetch was consistently taller than cotton following native vegetation and was usually taller than cotton following wheat. This was due largely to the fact that cotton following vetch produced maximum or near maximum plant height even at 0 and 35 lb/acre of N while cotton following wheat and native vegetation produced short plants at the lowest N rates. In most instances cotton following native vegetation reached maximum plant height with either 70 or 105 lb N/acre. Cotton following wheat usually required 105 to 140 lb/acre for maximum plant growth. It is interesting to note that cotton plant height rarely exceeded 48 inches regardless of the treatment. Thus, rank vegetative growth caused by excessive N fertilization was not observed in this study as has been reported in many cotton fertilization studies where above-optimum N rates were applied. This was probably a result of several factors including the selection of a short-statured, fast fruiting cultivar and excellent insect control throughout the growing season, which allowed maximum retention of early fruiting forms.

SUMMARY

Yields of CT and NT cotton were similar each year of the study. Furthermore, interactions between tillage and cover crops and between tillage and N rates were not significant. Cotton following hairy vetch did not require any N fertilizer to produce optimum yields in this study in any of the three years. Cotton following native winter vegetation produced optimum yields with 70 to 105 lb N/acre. Cotton following wheat cover crops required approximately 35 lb/acre more N to produce optimum yield than cotton following native vegetation.

Maturity of CT and NT cotton was usually similar. In one year out of three, NT was

Table 5. Effects of tillage systems on mature plant height of cotton averaged across cover crops and N rates.

Tillage System	Mature Plant Height 1991	1992	1993
		inches	
Conventional-till	42.4	36.2	42.4
No-till	45.3	40.2	43.8
LSD (0.05)	1.2	1.6	NS

Tabla 6. Effects of winter cover crops and N rates on mature plant height of cotton averaged across tillage systems.

Cover Crop	Cotton N Fertilizer Rate	Mature Plant Height 1991	1992	1993
	-----lb/a-----		inches	
Native	0	39.9	27.2	27.7
Native	35	42.4	34.3	38.2
Native	70	43.4	38.9	44.7
Native	105	44.4	39.9	48.7
Native	140	42.1	36.8	46.3
Vetch	0	45.3	40.1	43.4
Vetch	35	43.7	40.5	47.1
Vetch	70	44.9	42.9	48.9
Vetch	105	47.0	43.6	50.1
Vetch	140	42.4	39.3	48.5
Wheat	0	41.4	27.8	27.6
Wheat	35	43.2	34.9	36.6
Wheat	70	44.9	40.8	42.9
Wheat	105	46.2	42.8	45.8
Wheat	140	46.7	43.6	49.2
Cover Crop Means Across N Rates				
Native		42.5	35.4	41.1
Vetch		44.6	41.3	47.6
Wheat		44.5	38.0	40.4
N Fertilization means across cover crops				
	0	42.2	31.7	32.9
	35	43.1	36.6	40.7
	70	44.4	40.9	45.5
	105	45.9	42.1	48.2
	140	43.7	39.9	48.0
LSD (0.05) To compare N rates within cover crop species		3.2	4.3	4.8
LSD (0.05) Cover crops averaged across N Rates		1.4	1.9	2.2
LSD (0.05) N rates averaged across cover crops		1.8	2.5	2.8

significantly later than CT. In most instances N fertilization resulted in some delay in maturity compared to no fertilization. Application of higher than optimum rates of N usually resulted in additional delays in maturity compared to optimum fertilization. Although late-season insect control was excellent in this study, it is probable that the excessively fertilized plants remained more attractive to late-season insect pests than plants with optimum or deficient N. Thus, management of N fertilizer rates to produce optimum yields and maturity may also be beneficial for minimizing late-season insect control costs and boll damage some years.

No-till cotton often produced taller plants than CT in this study. At optimum N fertilization rates, plant heights of cotton following native vegetation, vetch, and wheat were usually similar. Fertilizer N rates above those necessary to produce optimum yields did not result in excessive vegetative growth, lodging, or boll rot in this study, although, past research has demonstrated that the potential for these problems does exist.

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CROP SEQUENCE EFFECTS ON THE PRODUCTIVITY AND ORGANIC MATTER CONTENT OF MISSISSIPPI RIVER ALLUVIAL SOILS

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INTRODUCTION

Continuous monocropping has been, and still remains, the primary cropping system used by cotton and soybean farmers in the Mississippi River Valley during most of this century. Long-time continuous monocropping of cotton has had adverse effects on soil and crop productivity. According to Waddle (1984). crop rotation is a beneficial cost-effective soil management practice that has not been used extensively by cotton growers because it complicates production and is an extra challenge to management. This is true, but reluctance to implement alternative cropping systems is also related to the difficulty of demonstrating to producers that continuous monocropping does, in fact, result in decreased productivity over the long term.

The influence of crop sequences grown for two or more years can have positive, neutral or negative influences on crop yields. Increased yield of cotton grown in two- and three-year cropping sequences with corn and grain sorghum compared with continuous cotton has been attributed to nematode suppression and beneficial changes in some soil properties [Barnett et al., 1961; Brage et al., 1950; Kirkpatrick and Sasser, 1984; Page and Willard, 1947; Sturkie, 1966; Vhland, 19491. A soybean crop preoeding cotton can increase yield and also reduce the fertilizer N required by cotton [Boquet et al., 1987; Gordon et al., 1986; Melville, 1961-72; Waddle, 1984). Not all studies have demonstrated beneficial effects from crop rotation. Spurgeon and Grisson (1965) reported yield decreases for cotton following other crops because the rotations improved conditions for cotton growth to the extent that lodging and insect infestation became more of a problem. Hinkle and Fulton (1963) found that crop rotations had no beneficial effect on cotton yield unless soils were infested with Verticillium wilt.

The use of soybean in multi-crop systems has largely been done to provide benefits of residual fertility to non-leguminous crops such as corn, cotton, and grain sorghum. In many instances the response of these crops to a preceding soybean crop has been immediate and obvious (Dabney et al., 1986; Kinlock and Hewitt, 1984). On the other hand, the benefits of alternate crops on soybean yield have been less obvious, and in some cases, lacking entirely (Boquet et al., 1987, 1993; Dick and Van Doren, 1985; Griffin et al., 1985; Hutchinson, et al., 1990; Rabb et al., 1985). Exceptions occur where diseases and nematodes are present, in which case, benefits to soybean productivity are likely.

The objectives of these studies were to: i) determine the effects of selected crop sequences on soybean, cotton and wheat yields and, ii) determine the effects of these crop sequences on soil organic matter content.

MATERIALS AND METHODS

In 1982, two cropping systems studies were initiated at the Northeast Research Station near St. Joseph, Louisiana. One of the studies, with 13 different cropping sequences, was on Commerce silt loam [fine-silty, mixed, nonacid, thermic Aeric Fluvaquentl. In this study, cotton was included in most crop sequences except the continuous corn, soybean and grain sorghum treatments [Table 11. A second cropping system study with eight crop sequences was located on Sharkey clay (very fine montmorillonitic, thermic, nonacid, vertic Haplaqueptl [Table 2). Both studies were conducted in a randomized complete block design with four blocks. Plots in the silt loam study were 16 rows 140-inch spacing) wide and 50 feet in length. Plots in the clay study were 16 rows (20-inch spacing) wide and 120 feet in length. Each year, each crop except for doublecrop soybean was planted at optimal dates and was grown using labeled pesticides for control of weeds and insects. Optimal management and fertilization practices were used for each crop to maximize yields. In

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Table 1. Cropping sequences under evaluation on Commerce silt loam soil at the Northeast Research Station, St. Joseph, Louisiana.

	Year					
Treatment	1982	1983	1984	1985	1986	1987
number	1988	1989	1990	1991	1992	1993
1	C	C	C	C	C	C
2	S	S	S	S	S	S
3	CRN	CRN	CRN	CRN	CRN	CRN
4	GS	GS	GS	GS	GS	GS
5	CRN	C	CRN	C	CRN	C
6	CRN	S	CRN	S	CRN	S
7	C	S	C	S	C	S
8	GS	C	GS	C	GS	C
9	GS	S	GS	S	GS	S
10	C	CRN	S	C	CRN	S
11	C	GS	S	C	GS	S
12	C	C	S	C	C	S
13	C	C	CRN	C	C	CRN

C, cotton; S, soybean; CRN, corn; GS, grain sorghum.

spring 1990, soil samples were taken from the 0- to 6-inch depth from each plot to determine, after nine years, the effect of each crop sequence on soil organic matter content. Analyses for soil organic matter were done at the Louisiana Agricultural Center Agronomy Department Soils Lab using the Walkley-Black procedure (Nelson and Sommers, 1982).

Cotton yields were determined by mechanically picking four rows from each 16-row plot. Soybean yields were determined by combine harvesting four rows from each 16-row plot in both the Commerce silt loam and Sharkey clay experiments. Wheat yields were determined by harvesting a 6.5 by 50 foot strip from each plot. Cotton yields are reported as seedcotton yields per acre. Soybean, corn and wheat yields are reported as grain

Table 2. Cropping sequences under evaluation on Sharkey clay at the Northeast Research Station, St. Joseph, Louisiana.

	Year					
Treatment	1982	1983	1984	1985	1986	1987
number	1988	1989	1990	1991	1992	1993
1	S	S	S	S	S	S
2	GS	GS	GS	GS	GS	GS
3	S	GS	S	GS	S	GS
4	GS	S	GS	S	GS	S
5	S-W	S-W	S-W	S-W	S-W	S-W
6	S-W	GS-W	S-W	GS-W	S-W	GS-W
7	GS-V	GS-V	GS-V	GS-V	GS-V	GS-V
8	SF	S-W	SF	S-W	SF	S-W

S, soybean; **GS,** grain sorghum; **W,** wheat; **V,** hairy vetch; **SF,** summer fallow.

Table 3. Crop yields and soil organic matter content in selected crop sequences of a long-term crop rotation experiment on Commerce silt loam, Northeast Research Station. St. Joseph, Louisiana.

Crop sequence	Seedcotton or grain yield						Soil organic matter†
	1988	1989	1990	1991	1992	1993	
	lb or bu per acre						-%-
Continuous cotton	2100	2512	3800	3092	2587	2633	0.84
Continuous soybean	47	36	51	49	---‡	50	0.84
Continuous corn	115	151	174	136	123	99	0.85
Continuous sorghum4	---	---	---	---	---	---	0.87
1 yr cotton - 1 yr corn	119	3100	175	3190	162	2910	0.74
1 yr cotton - 1 yr soybean	1845	55	4190	61	3080	61	0.77
1 yr sorghum§ - 1 yr cotton	---	3200	---	3330	---	3040	0.80
1 yr cotton-1 yr corn-1 yr soybean	2210	174	65	3170	159	65	0.70
1 yr cotton-1 yr sorghum-1 yr soybean	2270	---	66	3370	62	61	0.70
2 yr cotton - 1 yr soybean	2285	2900	63	3610	2820	62	0.80
2 yr cotton - 1 yr corn	1780	3060	180	3320	2770	133	0.77
1 yr corn - 1 yr soybean	117	54	180	58	161	67	0.66
1 yr sorghum§ - 1 yr soybean	---	59	---	58	---	65	0.86
LSD(0.05) cotton	370	360	248	377	180	242	
LSD(0.05) soybean		10	9	6		6	0.18
LSD(0.05) corn	10	22	16		26	16	

† Soil organic matter after 9 years of each crop sequence.

‡ Soybean plot weight not recorded in 1992.

§ Sorghum yields not reported because bird depredation reduced yields 30 to 100%.

yield in bushels per acre. Grain moisture content was adjusted to 13% for soybean and wheat and to 15.5% for corn. Yield data were analyzed by analysis of variance and the LSD P=0.05 was calculated for mean separations.

RESULTS AND DISCUSSION

Yield

Silt loam. On Commerce silt loam, the 12th year of the study was completed in 1993. Continuous cotton yields have varied from a low of 1980 pounds of seedcotton per acre in 1985 to a high of 4048 pounds of seedcotton per acre in 1987. On a year to year basis there has been no consistent trend in the yield of the continuous cotton treatment as the lowest yield was produced in the 4th year of the study and the highest yield was produced in the 9th year of the study. When yields were grouped into 3-year intervals, however, a trend did emerge. The initial 3-yr yield average was 3360 pounds of seedcotton per acre, the second 3-yr interval yield average was 3020 pounds, the third 3-yr interval yield average was 2800 pounds, and the fourth 3-year interval yield average was 2770 pounds of seedcotton per acre. Thus, it appears that the yield trend for continuous cotton has been downward since the inception of the study in 1982.

Although year to year variations in the yield of continuous cotton have been large, rotations have increased yield in most years. Two-year rotations of cotton with corn, sorghum or soybean increased cotton yield compared with continuous cotton (Table 3). The only exception was 1988. In 1988, rainfall between planting (April 25) and maturity (August 101was only 2.5 inches, which limited the yield of cotton in all treatments. Cotton following two years of alternate crops, either soybean-corn or soybean-sorghum was also higher yielding than

Table 4. Yield of soybean and wheat and soil organic matter content in selected crop sequences of a long-term cropping system study on Sharkey clay.

Crop sequence	Grain yield 1989	1990	1991	1992	1993	Soil organic matter[†]
	bu per acre					-%-
Continuous soybean	**29**	**21**	**43**	**42**	**25**	1.82
Continuous sorghum[§]	---	---	---	---	---	2.03
1 yr soybean - 1 yr sorghum[†][§]	**32**	**28**	**49**	**42**	**34**	1.92
Continuous doublecrop	18	25	44	27	19	2.16
soybean/(wheat)	(22)	(0)	(33)	(60)	(10)	
1 yr doublecrop soybean/(wheat)	**14**	---	**41**	---	**20**	
1 yr doublecrop sorghum[‡]/(wheat)	**(21)**	**(0)**	**(34)**	**(56)**	**(14)**	1.97
1 yr soybean/wheat - 1 yr	20	SF	50	SF	16	
summer fallow	(37)	--	(42)	--	(37)	1.89
Continuous sorghum/vetch[‡]	---	---	---	---	---	2.40
LSD(0.05) soybean	4	5	6	7	5	
LSD(0.05) wheat	4		6	6	6	0.14

[†] Soil organic matter content after 9 years of each crop sequence.

[‡] Sorghum yield not reported because of bird depredation.

[§] Includes Treatments 3 and 4 for soybean yield, which alternate crop years.

continuous cotton. Planting two years of an alternate crop was not better than one year of alternate crop in increasing cotton yield. Second-year cotton following one year of soybean or corn experienced increased yields but the yields tended to be lower than first-year cotton following an alternate crop.

As with cotton, there has been large year to year variation in the yield of the continuous soybean treatment. The lowest yield of 36 bushels per acre was produced in 1989 and the highest yield of 51 bushels per acre was produced in 1991. Rotation of soybean with corn, cotton, or sorghum increased soybean yield each year compared with continuous monocrop yields (Table 3). The response of soybean to crop rotation was generally greater than the response of cotton. Whereas cotton yields were increased an average of 15% by rotation, soybean yield was increased by an much as 60%. Cotton, corn and grain sorghum increased soybean yield about the same amount with two and three-year crop sequences being equally effective.

Yields of continuous corn initially increased for several years, but were reduced in the latter stages of the study, especially in 1993. The lowest corn yield was produced in 1993 and the highest was produced in 1990 (Table 3). Corn has shown a less consistent response to rotation than cotton or soybean. Corn yields were increased by rotation in 1989, 1992 and 1993 but not in 1988 or 1990. Corn yields in 1988 were limited by dry weather, as were the yields in 1993. In 1988, corn following cotton produced yield similar to 7th year continuous corn, whereas, in 1993, corn yield following cotton was higher than yield of 12th year continuous corn.

Sharkey clay. The yield of both continuous monocrop and rotational soybean varied substantially from year to year in response to growing conditions. When a poor growing season occurred, such as the drier-than-normal summers in 1990 and 1993, continuous soybean yields were low and were impacted more than rotational soybean (Table 4). In three of the last four years, a 2-yr rotation of soybean and sorghum has increased soybean yield an average of 7 bushels per acre. In 1991, soybean following wheat/summer fallow produced yields equivalent to the soybean-sorghum rotations. Thus, both of these alternatives to continuous monocropping of soybean increased soil productivity. Crop rotations are preferable over fallow in most farm enterprises, however, because economic returns are needed each year and the cost of maintaining fallowed land can be high.

Soybean in the continuous soybean/wheat doublecrop system has yielded, on average, 4 bushels less than continuous monocrop soybean and 8 bushels per acre less than soybean rotated with sorghum. This crop sequence consistently produced excellent wheat yields in the early years of the study, but the yields of continuous doublecrop wheat have declined in recent years, probably because of disease buildup in the plots. The crop sequence in which wheat has been planted every other year (1989, 1991, 1993) has yielded an average of 18 bushels per acre higher than plots in which continuous wheat has been planted since 1983 (Table 4).

Soil organic matter

Silt loam. The organic matter content of the silt loam soil in this study is very low but is representative of this soil type after many years of continuous row cropping. After nine years, soil organic matter content among the 13 crop sequences did not differ significantly (Table 3). It appears that, on silt loam soil in the lower Mississippi River Valley, crop rotations alone cannot increase organic matter content of row-cropped land.

Sharkey clay. The organic matter of clay soil was much higher than silt loam and was affected by the different crop sequences. After nine years, the lowest soil organic matter was in the plots with continuous monocrop soybean (Table 4). Continuous monocrop sorghum increased organic matter 12% compared with continuous soybean. The doublecrop soybean/wheat treatment had organic matter levels 19% higher than continuous soybean plots. The highest organic matter was in plots continuously cropped to sorghum/vetch, which had soil organic matter content 32% higher than continuous soybean plots. These data contrast with the silt loam results in that some row crop sequences did increase organic matter content. However, the best crop sequences for improving soil organic matter were those that also included a winter crop of wheat or vetch and thus sustained a crop on the soil year round.

SUMMARY

Compared with continuous monocrop cotton, rotations of cotton on silt loam soil in 2- and 3-year cycles with soybean, corn or sorghum increased cotton yield by an average 15%. Rotation of soybean with corn, cotton or sorghum increased soybean yields by as much as 60%. On Sharkey clay, soybean yields increased an average of 16% when grown in rotation with sorghum. Soil organic matter content of silt loam was not affected by various crop sequences that included cotton, soybean, corn and grain sorghum. On Sharkey clay, soil organic matter was increased 12 to 32% by rotational crop sequences compared with monocrop soybean.

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CROP ROTATION AND TILLAGE SYSTEMS FOR CONSERVATION COMPLIANCE FOR BLACKLAND PRAIRIE

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INTRODUCTION

The Blackbelt Prairie soils (about 2 million acres) are predominately heavy, expanding clays and are highly erosive when pulverized. Topography ranges from level to sloping and is classified as highly erodible by federal law in the 1985 Food Security Act. The Prairie soils are underlined by soft limestone or chalk as the main soil-forming material. This formation causes this land resource region to be one of the nation's most susceptible to productivity losses from soil erosion (USDA 1989, U.S. Corp of Engineers and USDA, SCS, 1990). Previous research (Hairston et al., 1984; Hairston et al., 1987) in the Blackbelt Prairie has shown that a positive correlation existed for higher soybean yield on soils with a greater soil-to-chalk depth. When topsoil is lost to erosion, the unproductive chalk subsoil will render the region unsuited for row crops.

Limited information is available on the rotational influence no-tillage and ridge-tillage corn in rotation with fall tillage wheat followed by double cropped no-till soybean and monocrop soybeans in no-tillage and ridge-tillage systems. The appropriate use of ridge-tillage, no-tillage, cover crop, and rotation systems have potential to be effective practices in minimizing production costs, enhancing productivity, and meeting conservation compliance.

The objectives of this study are to evaluate soybean yield response and residue ground cover and vegetative canopy development by selected tillage and crop rotationItillage systems in the Blackland Prairie Region.

MATERIALS AND METHODS

The experiment was initiated in 1992 at the Prairie Research Unit in Prairie, Mississippi on a Vaiden silty clay (very-fine,montmorillonitic, thermic, Vertic Hapludalfsl with a 1 to 2% slope. The previous crop history on this site was native grass hay meadow.

A randomized complete block design with 14 tillage treatments were evaluated in four replications. Plot size was 20 ft x 70 ft long. P_2O_5 and K_2O fertilizer were applied according to soil test recommendations. Fertilizer was applied broadcast to all plots, prior to establishing tillage sequence. Additional fertilizer will be surface applied broadcast each year according to soil test. Tillage treatments and description of grain crop sequence are presented in Table 1.

The herbicide 2.4-D was applied as an early (mid Feb - mid March) weed control method on all monocrop and wheat-double crop soybean treatments except CT. Two weeks prior to planting soybeans, Gramoxone Extra (0.47 lb ai/ac) was applied to all soybean plots, except RP planted soybean, as a burndown. Soybean plots were planted in 30-inch rows with 9 seedlft of row length. Preemergence application of Dual (1.5 lb ailac) + Canopy (0.28 lb ai/ac) was applied to all soybean plots. All soybean plots received an application of Poast Plus (0.375 lb ailac) over the top to control broadleaf signalgrass grass.

Corn plots were planted in 30-inch rows with 1.5 seedlft of row length. Preemergence Atrazine (2.0 lb ai/ac) + Dual (2.0 lb ailac) + Gramoxone Extra (0.62 lb ailac) + surfactant (0.25% v/v) was applied to all corn plots. Linuron (1.0 lb ai/ac) was applied post-directed to NT and RT corn plots. Nitrogen was applied broadcast over the top to corn plots at the rate of 160 N/ac when corn was approximately 12 to 15 inches tall.

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Table 1. Tillage/Grain Crop Sequence Treatments, MAFES Prairie Research Unit, Prairie, MS.

Sequence Description

1 Continuous crops

A. **Corn**
  1. No-Tillage (NT)
  2. Ridge-Tillage (RT)
  3. Conventional Tillage (CT), Fall Chisel and Bed
  4. Turf Aerator (TA)

B. Soybean
  5. NT
  6. RT
  7. CT
  8. TA

II. Two Year Rotation/Tillage

A. Corn/Soybean Rotation
  9. RT Corn (92,94,96); Followed by (Fb) RT Beans (93,95,97)
  10. RT Beans (92,94,96); Fb RT Corn (93,95,97)

B. Corn-Wheat-Double Cropped Soybean Rotation
  11. **NT** Corn (92,94,96);Fb Fall Disk + Do-all (MT) Wheat and NT Double-Crop Beans (93,95,97).
  12. MT Wheat and NT Double-Crop Beans (92,94,96); Fb NT Corn (93,95,97).
  13. MT Wheat (92,94,96) and Relay Planted (RP) NT Beans (92,94,96); Fall (F) Bed and NT Corn (93,95,97).
  14. F Bed and **NT** Corn (93,94,96); Fb MT Wheat and RP NT Beans (93,95,97).

Wheat plots were planted in 7.5 inch rows, at 20 seedlft row. Relay planted wheat plots were planted in 7.5 inch rows with 15 inch skips for tractor wheel tracks (2/20 ft planter swath) and every 30 inches for soybean row. Nitrogen was applied broadcast to wheat plots in the spring at 120 N/ac. Harmony-Extra (0.38 lb ai/ac) was applied in mid February for weed control in the wheat.

A 100 pin cam line was used to measure ground residue cover (GRC) and vegetative canopy (VC). This line was drawn diagonal across each plot, approximately in the same location when measurements were made. The pin spacings on the cam line were 8 inches apart. Vegetative and residue counts were made under each pin marking. Measurements were taken periodically during the fall, winter, spring and early summer and after planting each crop. from 3 replications.

Entire wheat plots were harvested for grain yield. The center two rows of corn and soybean plots were harvested for grain yield. Grain yield from each plot was weighed and adjusted to

Table 2. Tillage and grain crop sequence effect on corn plant population and yield, on a silty clay soil in 1993, at the Prairie Research Unit, Prairie, MS.

Crop Sequence/ Tillage System	Pl/ac X 1000	Yield bu/ac
I. Continuous crops		
A. **Corn**		
1. NT	**20.8**	**72**
2. RT	**20.3**	**100**
3. CT	**24.7**	**93**
4. TA	**17.5**	**62**
B. Soybean		
5. NT	----	---
6. RT	----	---
7. CT	----	---
8. TA	----	---
II. Two Year Rotation/Tillage		
A. Corn/Soybean Rotation (2 yr)		
9. RT Corn; Fb RT Beans ('93)	----	---
10. RT Soybeans; Fb RT Corn ('93)	**22.4**	**109**
B. Fall MT Wheat-NT Beans Fb Corn Rotation (2 yr)		
11. NT Corn; Fb MT Wheat-NT Beans ('93)	----	---
12. MT Wheat-NT Beans; Fb NT Corn ('93)	**15.9**	**56**
13. MT Wheat-RP Beans; Fb F Bed NT Corn ('93)	**22.9**	**88**
14. F Bed NT Corn; Fb MT Wheat-RP Beans ('93)	----	---
LSD 0.05	4.1	18
% CV	15.2	14

bushels per acre. Data was subjected to statistical analysis (SAS, Cary, N.C.) and means were separated by Least Significant Differences (LSD) at the 0.05 probability level.

DISCUSSION

This is the second year of a five year study at the Prairie Research Unit. Data for 1992 is not presented since this was the establishment year of tillage/cropping sequence. The study area had to be smoothed with a disk before tillage treatments were imposed in 1992. Measurements of ground residue cover (GRC) and vegetative canopy (VC) were initiated in the fall of 1992 after harvest of corn and soybeans.

Grain yields in 1993 ranged from 56 to 109 bu/ac (Table 2). Continuous conventional tillage (CT) and ridge tillage (RT) corn, RT corn following RT soybeans and fall bed with NT corn following minimum tillage (MT) wheat with RP soybeans showed no difference in yield. No-tillage (NT) corn following MT wheat and NT double cropped soybeans, continuous NT corn and continuous corn with turf aerator tillage (TA), however, showed

Table 3. Tillage and grain crop sequence effect on wheat and soybean yield, on a silty clay soil in 1993, at the Prairie Research Unit, Prairie, MS.

Crop Sequence/ Tillage System	---------bu/ac---------- Wheat	 Beans
I. Continuous crops		
A. Corn		
1. NT	--	--
2. RT	--	--
3. CT	--	--
4. TA	--	--
B. Soybean		
5. NT	--	41
6. RT	--	29
7. CT	--	41
8. TA	--	41
II. Two Year Rotation/Tillage		
A. Corn-Soybean Rotation (2 yr)		
9. RT Corn; Fb RT Beans ('93)	--	41
10. RT Beans; Fb RT Corn ('93)	--	--
B. Fall MT Wheat-NT Beans Fb Corn Rotation (2 yr)		
11. NT Corn; Fb Wheat-NT Beans ('93)	26	43
12. MT Wheat-NT Beans; Fb NT Corn ('93)	--	--
13. MT Wheat-RP Beans; Fb F Bed NT Corn('93)	--	--
14. F Bed NT Corn Fb; FB MT Wheat-RP Beans ('93)	25	35
LSD 0.05	13	7
% CV	22	12

lower yield than continuous CT corn, continuous RT-corn, RT corn following RT soybeans, fall bed with NT corn following doublecropped soybeans. This yield difference is attributed to the significantly lower corn populations on flat plots as opposed to raised bed treatments (Table **2).**

Soybean yields for continuous CT, continuous NT, RT soybeans following RT corn, and NT doublecropped soybeans were not different (Table 3). This is in contrast to previous soybean work on Prairie soils (Buehring et al., 1981; Buehring et al., 1988; Hairston et al., 1984; and Hairston et al., 1990) which showed that NT soybeans produced lower yield than CT. However, additional years of research are needed to determine whether NT yield will be equal or greater than CT. RT continuous and relay planted (RP) soybeans planted into standing wheat had lower yields than CT, NT, and NT doublecropped soybeans. The lower RT yields are attributed to observations of higher infestation levels of stem canker in the RT continuous soybean plots than in RT soybeans following corn, and continuous NT and CT soybeans.

Wheat yields were low in both doublecropping systems (Table **3).** due to a March freeze and wet, cloudy conditions. Doublecropped soybeans planted NT in 30-inch rows in wheat stubble in mid-June produced higher yields than soybeans

Table 4. Tillage and grain crop sequence effect on ground cover residue and canopy coverage on a silty clay soil in 1992 and 1993 at the Prairie Research Unit, Prairie, MS.

Crop Sequence/ Tillage System	11/25/92		4112/93		After Planting[3/]	
	GRC[1/]	VC[2/]	GRC	VC	GRC	VC
	----------	----------	----------	%	----------	----------
I. Continuous crops						
A. Corn						
1. NT	86	3	70	20	59	14
2. RT	78	6	56	25	55	16
3. CT	19	5	25	20	26	14
4. AT	88	5	60	5	56	5
B. Soybean						
5. NT	79	3	25	67	73	0
6. RT	77	6	17	29	76	1
7. CT	41	5	13	71	12	1
8. At	81	2	24	63	38	41
II. Two Year Rotation/Tillage						
A. Corn-Soybean Rotation (2 yr)						
9. RT Corn Fb RT Beans ('93)	86	3	53	39	54	40
10. RT Soybeans Fb RT Corn('93)	82	3	30	25	38	--
B. Fall Till Wheat-NT Beans Fb Corn Rotation (2 yr)						
11. Corn Fb Wheat-NT Beans ('93)	21	6	**6**	86	82	--
12. MT Wheat NT Beans Fb NT Corn ('93)	99	0	64	34	68	25
13. MT Wheat-RP Beans Fb Bd Corn ('93)	28	1	30	23	31	17
14. Bd Corn Fb; MT Wheat-RP Beans ('93)	31	1	25	86	78	12

[1/] GRC = ground residue cover

[21] VC = vegetative canopy

[3/] After planting of each crop. Corn planting date was 4-12-93, monocrop & RP soybean planting date was 5-31-93 and double cropped soybean planting date was 6-16-94.

relay planted in standing wheat in late May and was not different from continuous CT and NT soybeans. The good double cropped mid June planting yields are attributed to above normal rainfall in September of 1993.

Ground residue cover (GRC) and vegetative canopy IVC) data taken after harvest (November), in April, and after planting each crop are shown in Table 4. Residue decomposition during the fall and winter resulted in lower GRC percent in April. Continuous CT corn showed 26% after planting. All other corn tillage treatments had 31% or more GRC. The percent canopy coverage from 11-25-92 to 4-12-94 increased for all treatments except AT corn. The only corn treatments in which VC development was more than 30% was corn following soybean in a rotation, (MT wheat and NT soybeans Fb NT corn).

Soybean residue decomposition rate was greater than corn. April data for GRC residue for all treatments had 30% or less GRC, except the corn (92) Fb MT wheat-NT soybeans (93) treatment which had higher GRC due to corn residue. Percent VC was higher for soybean treatments than for corn treatments, which suggest that corn herbicide residue reduced canopy development more than soybean residue herbicides.

After planting, continuous CT corn had 26% GRC, and continuous NT and RT corn treatments had 55% or more GRC. RT corn following RT soybeans had 38% or more GRC. Continuous CT soybeans had 12% GRC in comparison to 70% or more GRC in continuous NT and RT soybeans. Soybeans planted NT into wheat stubble had 68% or more GRC in April.

CONCLUSION

This was the second year of a five year study to evaluate the tillagelcropping sequence effect on yield, ground residue and canopy development. Yields were low for wheat due to early frost and cool wet weather. Corn yields ranged from 56 to 109 bu/ac. CT, RT and MT (Bed) were not different in yield. NT, MT wheat-NT soybeans doublecropped, NT corn and TA corn yields were lower. These yield differences were a result of lower corn populations in the flat than raised bed systems. RT continuous and RP soybeans in standing wheat had lower yields than CT, NT, and NT doublecropped soybeans. Over the fall and winter GRC decreased with an increase in VC. Immediately after planting most treatments showed VC and GRC decreased. VC increased in all wheat plots. Immediately after planting the continuous CT corn and continuous CT soybeans had less than 30% GRC.

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DIFFERENTIAL SOYBEAN VARIETAL RESPONSE TO NO-TILL PLANTING IN WHEAT STRAW

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INTRODUCTION

Double-cropping soybeans and winter wheat grown for grain is a predominate cultural system in the Midsouth. In the last few years, equipment has become available to plant into the wheat stubble and obtain a stand consistently. The conservation compliance requirements of the farm bill has spurred many growers into adapting no-till planting practices for soybeans planted after wheat. Conservation compliance coupled with the recent increase in recommended varieties from about 30 (mostly public) to over 100 (mostly private) has resulted in much greater genetic diversity in commercial varieties. The "niche" to which varieties are best adapted has become smaller.

Genetic diversity among varieties to phytotoxic substances in wheat straw was demonstrated by Herrin et al. (1986). However, their field study was not related to their greenhouse derived indexes (Caviness and Collins, 1985). Boerma (19781has developed cultivars specifically adapted for double cropping. However, no documented grain yield reduction in the field from varieties planted in wheat straw has been reported. The objective of the study reported herein was to evaluate yield response of soybean varieties planted in standing wheat straw and to determine if their relative rank is the same as in a monocropping system.

MATERIALS AND METHODS

Experiments were initiated in 1992 in Mississippi and in 1993 in Arkansas. Specific cultural practices are given in Table 1. Fertilizer, preplant burndown and weed control followed recommended practices for each location and was tailored to the weed species and cultural practices. Weed control was maintained at a very high level.

Soybean varieties planted at Verona, MS were those entered in the conventional monocrop (MC) soybean variety trial. In Mississippi the MC conventional variety trial and the no-till double-cropped (DC) trial were adjacent to each other and on the same soil type. Trials were planted at the normal planting time and is listed in Table 1. The MC study was planted in a prepared seedbed and DC soybeans were planted no-till into wheat stubble after wheat harvest.

In Arkansas, varieties selected were those whose 3-year means were not measurably different in MC variety trials (ie. recommended varieties, Anon., 1993).

Each Maturity Group (MG) was analyzed separately at each location using analysis of variance procedure. Means were separated by least significant difference (LSD).

RESULTS AND DISCUSSION

In 1992 and 1993, the Mississippi yield range differences between varieties was about 20 bu/acre from low to high in MG V and VI in both years (Tables 2 and 3). In Mississippi, varieties responded differently planted in wheat stubble than planted in a monocrop system in both years. Overall means indicated that yields in double-cropped beans were about 25% or more less than monocrop beans. In addition, varieties which had the highest yield in monocrop were not the highest yield in double-cropped system. These data suggest that soybean varieties should be evaluated in both monocrop and double-cropped systems as one study to more fully evaluate as to whether varieties under both systems have the same yield potential.

In Arkansas, the yield differences ranged about 15 bu/acre and showed a difference in MG's (Table 4 and 5). MG VII was lower than MG's IV, V and VI. The data here are for varieties (excluding MG IV) that would normally be recommended as being equivalent for the location based on conventional variety trials. However, these data suggest that in the recommended varieties for MG V and VI, approximately ***50%*** are superior for

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planting no-till in wheat stubble. These studies should lead to a revision of our recommendations by eliminating those entries that do not maintain yield when no-tilled in wheat straw.

Table 1. Specific cultural practices and site characteristics of double-cropped soybean variety evaluation.

Location	Mississippi	Arkansas
Experimental Design	RCB with 4 reps	RCB with 2 reps
Plot Size	10 ft x 20 ft	7.9 ft x 25 ft
Soil Type	Leeper Silty Clay	Calloway Silt Loam
Wheat		
Land Prep. Wheat	Chisel, Disk, Do-all	Disk, Disk, Do-all
Variety	Coker 9835	Cardinal
Seeding Rate, Method (lb/acre)	80, Drilled	90, Drilled
Harvest Dates	6-21-92 6-10-93	6-31-93
Stubble Height (in.)	12	8
Soybean		
Planting Date		
Double-Crop (DC)	6-23-92 6-16-93	7-9-93
Monocrop (MC)	5-1-92 6-16-93	
Seeding Rate (seed/row-ft)	9	3 to 5
Row Spacing (in.)	30	19
Harvest Date		
Double-crop	10-26-92 11-8-93	11-8-93
Monocrop	10-4-92 10-21-93	

Table 2. Yield characteristics for 1992 for the Mississippi location. Maturity Group V and VI soybean variety yield response planted no-till in wheat stubble, Verona, MS.

Group V			Group VI		
Variety	D.C.	M.C.	Variety	D.C.	M.C.
	Bu/acre			Bu/acre	
Holliday	43.4	51.0	Deltapine DPX 3682	39.3	45.4
Capehart Stone	41.1	51.6	Pioneer 9641	37.8	43.8
Deltapine 415	39.8	52.4	North King S62-66	36.6	55.1
Hartz H5088	39.7	51.5	Young	35.8	48.0
Pioneer 9593	39.2	54.9	Sharkey	34.9	55.6
Agra Tech AT 575	38.6	48.9	Davis	34.6	43.9
Northrup King C485	38.4	54.8	Buckshot Bu 62	34.6	52.8
Asgrow A5885	37.9	52.3	Riverside Cajun	33.9	57.8
Riverside RVSL 9094	36.9	52.4	Hartz 6200	33.9	50.3
Forrest	36.8	39.8	Buckshot Bu 62	33.0	52.8
Hutcheson	36.0	57.2	Deltapine 3627	32.5	45.5
Rhodes	35.6	53.9	Hartz 6686	32.3	52.0
Asgrow ACT 9204	34.6	46.6	Hartz H6500	31.7	52.0
Hartz H5566	34.5	50.1	Leflore	31.4	47.0
Terra-Vig 515	34.2	43.7	TN6-90	29.5	47.7
Hartz H5810	34.1	42.9	D87-5870	29.1	55.1
Northrup King C6955	33.8	43.4	Northrup King S6423	29.1	42.0
Pioneer 9592	33.7	49.9	Riverside RVSL9185	28.9	27.0
Deltapine 105	33.5	46.0	Riverside RVSL9142	28.4	46.3
Agra Tech AT 2665	32.9	52.6	Tracy-M	28.1	51.0
Northrup King S5960	32.0	35.0	Bryan 66	28.0	44.0
Asgrow A5403	31.9	50.0	Buckshot 66	27.7	54.1
Terra-Vig 5452	31.8	48.6	Terra-Vig 6653	27.2	46.8
Riverside 577	31.5	46.8	Northrup King x9169	26.9	46.4
Hartz H5070	31.2	48.1	Riverside 699	25.8	52.4
Agra Tech AT 2555	30.7	41.1	Lamar	25.8	54.0
Terra-Vig 5693	30.3	39.0	Hornbeck HEK 65	25.1	45.2
Walters	29.8	37.3	Northrup King x9267	23.6	47.7
Asgrow A5560	29.4	51.3	Buckshot BU 68	22.5	53.5
Hartwig	29.4	33.0	Stoneville FFR 646	21.9	44.5
Asgrow ACT 9219	29.0	56.4	Terra-Vig x6670	18.7	42.9
Riverside AVSL 77	28.6	58.3			
Stoneville FFR38108	27.6	43.9	LSD_{10}	6.3	6.5
Epps	27.0	45.0			
Terra-Vig x6897	27.0	40.7			
North King x9256	27.0	47.0			
Underwood 509A	26.7	40.9			
Stoneville FFR 595	25.6	43.4			
Terra-Vig x5653	24.7	50.4			
Buckshot 55	24.6	54.0			
Pioneer 9551	24.5	43.3			
Buckshot 507	23.5	46.0			
LSD_{10}	7.3	7.3			

Table 3. Yield characteristics for 1993 for the Mississippi location. Maturity Group V and VI soybean variety yield response planted no-till in wheat stubble, Verona, MS.

Group V			Group VI		
Variety	D.C.	M.C.	Variety	D.C.	M.C.
	Bu/acre			Bu/acre	
Northrup King S5960	39.7	50.6	Sharkey	42.3	41.1
Delta King DK 5850	37.7	49.8	Davis	41.3	39.3
Pioneer 9584	36.9	43.9	Pioneer 9692	40.7	48.9
Asgrow ACT 14	36.6	47.6	Agra Tech ATX 2665	39.6	40.8
Buckshot 55	36.6	53.9	Asgrow XP 6711	38.8	50.0
Rhodes	36.1	47.3	Riverside 678	37.0	38.0
Deltapine 415	35.4	45.8	Young	36.6	37.2
Deltapine DP 3589	35.4	61.2	Lamar	36.4	42.7
Buckshot EK 58	33.7	43.5	Deltapine DP 3606	34.4	47.4
Northrup King C485	33.5	49.7	Hartz 6200	34.1	39.9
Pioneer 9592	33.5	50.8	Hartz H6500	34.0	40.7
Deltapine DPX 3553	33.1	47.2	Hartz 6686	33.7	38.9
Delta King DK 551	32.6	46.4	Lyon	32.9	39.5
Northrup King x9357	32.6	42.3	SC84-931	32.7	52.9
Northrup King C6955	32.1	37.8	Northrup King x9365	32.4	42.5
Terra-Vig 5555	31.8	45.6	Riverside Cajun	32.4	38.5
Buckshot 507	30.9	40.4	Northrup King S6266	31.1	45.1
N87-325	30.5	43.2	Northrup King x9366	30.4	42.5
Terra-Vig 5452	30.3	48.7	TN6-90	29.8	41.3
Asgrow XP 5843	30.1	50.7	Bogart Carl	29.1	32.2
Asgrow A5885	29.5	48.6	Pioneer 9641	28.9	39.6
Capehart Stone	29.4	43.3	Buckshot 66	28.6	41.1
Riverside RSVL 9094	28.2	47.9	Terra-Vig TVX 6565	28.1	40.6
Pioneer 9551	27.3	36.1	Vernal	27.6	36.6
Riverside RVSL 77	27.3	49.5	Terra-Vig 6792	25.6	38.0
Agra Tech AT 575	26.6	48.8	Riverside 699	24.1	42.2
Hutcheson	26.4	43.5	Terra-Vig 6253	21.4	46.1
Holliday	26.1	47.2	V86-815	18.0	34.2
Asgrow A 5560	26.0	47.3	Mean	32.4	41.0
Agra Tech AT 555	25.1	41.6	LSD$_{10}$	5.1	6.5
Asgrow A5979	25.0	46.9			
Agra Tech AT 520	24.7	42.9			
Forrest	24.3	30.9			
Pioneer 9593	22.4	44.9			
Riverside 577	20.9	40.3			
Hartwig	19.6	35.6			
KS 5292	17.1	36.8			
Mean	29.1	44.6			
LSD$_{10}$	5.8	6.3			

Table 4. Yield characteristics for 1993 for the Arkansas location using Maturity Group IV and V.

Group IV

Variety	Yield
	Bu/acre
Manokin	22.0
Pioneer 9442	19.9
Crawford	19.6
Northrup King S4884	18.3
Hartz H 4464	14.9
Northrup King RA452	13.7
RSV 499	13.7
Williams 82	9.9
TN 4-86	9.3
A 4715	8.0
LSD$_{06}$	9.4

Group V

Variety	Yield
	Bu/acre
Hartz H 5350	24.8
Hartz H 5088	24.8
Riverside 577	22.1
A 5560	22.1
Hartz 5164	21.7
Hutcheson	21.7
A 5403	20.2
Deltapine 415	20.2
Hartz H 5810	20.2
Northrup King C485	19.6
Terra-Vig 5555	18.9
Crowley	18.6
Deltapine 105	18.6
AT 555	18.6
AT 5885	18.0
Walters	17.7
Pioneer 9584	17.4
Northrup King C6955	16.4
Buckshot 55	16.4
Rhodes	15.2
Northrup King S5960	14.3
Hartz H 5566	12.7
Narow M	10.8
Terra-Vig 5452	9.6
LSD$_{06}$	9.7

Table 5. Yield characteristics for 1993 for the Arkansas location using Maturity Group VI and VII.

Group VI		Group VII	
Variety	Yield	Variety	Yield
	Bu/acre		Bu/acre
Pioneer 9641	25.9	Hartz H 7190	17.0
A 6961	23.9	Pioneer 9711	11.2
Brim	23.3	Stonewall	7.5
Young	23.0	Riverside 757	4.7
A 6785	22.4	LSD_{05}	10.3
Hartz 6200	21.7		
Riverside Cajun	19.9		
Sharkey	18.6		
Hartz 6686	18.3		
Terra-Vig 6253	17.4		
LLoyd	14.9		
Buckshot 66	14.0		
A 6297	13.7		
Davis	9.6		
LSD_{05}	**12.5**		

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WEED CONTROL WITH "LOW" AND "NORMAL" INPUT PRACTICES IN NO-TILL AND CONVENTIONAL-TILL COTTON.

H. R. Hurst[1]

Producers are always interested in producing a crop at the lowest cost while maintaining or increasing net returns. Input practices for weed control in cotton can often account for 15 to 20% of the total dollars spent. Increased interest is being shown in the adoption of reduced tillage practices by Mississippi Delta cotton farmers. This study was initiated to evaluate the long-term effects of reducing input practices for weed control with both no-till and conventional-till systems.

METHODS

The study was conducted on a silt loam soil site (28% sand, 56% silt, 16% clay, 5.9 pH, 0.8% organic matter) at the Delta Research and Extension Center at Stoneville, MS, during 1990-1993. No irrigation was used. Four treatments were used; a "low" and "normal" combination of mechanical and/or chemical weed control practices for no-till or conventional-till cotton. Mechanical practices are listed in Table 1 and herbicide applications are listed in Tables 2 and 3. Generally. it was the objective to apply herbicides on a 20-inch-wide band on the row with the "low" treatment in conventional-till and reduce the application rate by 21 to 33% from "normal." The conventional-till "normal" herbicide treatment was applied on a 20-inch-wide band also (except PPI Treflan + Zorial) at the recommended rate. Mechanical seedbed preparation and in-season cultivation with the "low" conventional-till treatment used 1 or 2 fewer operations per year when compared with the "normal" treatment. The no-till herbicide treatments were applied broadcast. The "low" herbicide treatment rates with no-till were 21 to 33% less than the "normal" (recommended) rate. All herbicides were applied with tractor-mounted spray equipment in a broadcast volume of 20 gallons per acre (except Roundup in 10 gallons per acre). A four-row boom sprayer was used for over-the-top applications and directed applications were made using a four-row Dickey cultivator with spray shields. Individual plots were four, 40-inch-wide rows 40 feet long. Treatments were established on the same area each year. The experimental design was a randomized complete block with four replications.

Johnsongrass counts were determined in mid-July of 1992 and 1993 from an area 20 inches by 40 feet centered on an inside row in no-till plots and from an area 12 inches by 40 feet centered on an inside row in conventional-till plots. Visual control estimates, where 0% = no control and 100% = complete control, were made during the winter and summer months for evaluation of weed response. Cotton stand was determined by counting the number of plants on an inside row in each plot and is presented in plants per acre in thousands. Seed-cotton yield was determined by mechanically harvesting the two center rows of each plot one time each fall. 'DES 119' cotton seed were planted on April 24, 1990; April 26, 1991; April 30, 1992; and May 6, 1993. The no-till area had to be replanted on May 7, 1990 and May 13, 1991 due to less than adequate stand. After replanting, the final 1991 stand was very good but was too low in 1990 for maximum yield with the "low" input treatments.

RESULTS

Cotton stand was not different between any treatment in 1991 or 1993 (Table 4). In 1992, the "normal" input conventional system stand was greater than the other systems but the stand with all systems was large enough for maximum yield without irrigation. In 1990, only the stands with the "normal" conventional-till and no-till systems were sufficient for maximum yield. The stands with the "low" conventional-till and no-till systems were only about 75% of that desired. This was due to early season weed competition, mainly broadleaves.

Seed cotton yield in 1990 with "low" and "normal" no-till was lower than "normal" conventional-till (Table 5). "Low" conventional-till yield was higher than "low" no-till. Yield was very good in 1991 with all treatments. The "normal" conventional-till yield was greater than the "low" no-till with the others intermediate. In 1992 and

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1993, yield with the "normal" conventional-till system was greater than the "low" conventional-till. In 1992, yield with this system was greater than the "low" no-till system, however this was not true in 1993. The very low yield in 1992 with the "low" input conventional-till system was caused by a very large population of horseweed which was not controlled at planting. Broadleaf weed control was very poor during the entire summer (Tables 8, 9). In 1993, yield with the "low" conventional-till treatment was less than with the "normal" conventional-till [Table 5). This was largely due to the lack of johnsongrass control in mid-and late-season (Table 10). Seed cotton yield with both input treatments in no-till was intermediate.

CONCLUSION

During 1990-1993, in this area where weed problems abounded, it was difficult to produce high yields without using weed control input practices that are considered to be "normal" (those currently recommended). Reducing herbicide rates on no-till cotton was not as detrimental as reducing herbicide rates and using reduced tillage for conventional-till cotton.

Table 1. Mechanical operations with conventional tillage.

	Input	
Operation	Low	Normal
	1990	
Subsoil	--	--
Disk	4/20	4/20
Hip	12/1/89, 4/20	1211/89, 4/20
Bed conditioner	--	--
Cultivate	5/17,5/30,6/8, 6/20	5/17.5/30,6/8, 6/20
	1991	
Subsoil	--	11/1/90
Disk	3/11	3/11, 3/13 (2X)*
Hip	11/7/90, 3/13	11/7/90, 3/13
Bed conditioner	4/25	4/25
Cultivate	5/31, 6/12, 6/20	5/31, 6/12, 6/20, 6/28
	1992	
Subsoil	--	10/10/91
Disk	--	--
Hip	11/13/91	11/13/91, 3/27,
Bed conditioner	4/29	3/17, 3/27, 4/29
Cultivate	5/12, 6/1, 6/22	5/12, 6/1, 6/22, 7/2
	1993	
Subsoil	--	11/9/92
Disk	11/16/92	11/16/92
Hip	2/1	2/1
Bed conditioner	3/10	3/10, 4/14
Cultivate	5/31, 6/30	5/31, 6/30

* Two times.

Table 2. Herbicide applications with conventional tillage (band-applied).

Herbicide	Date applied 1990	1991	1992	1993	Broadcast rate (lb ai/Acre) Low	Normal
Treflan + Zorial'	3/21	3/13	3/27	4/14	--	0.75 + 0.75
Cotoran + Zorial	4/24	4/26	4130	5/6	1.0 + 1.0	1.5 + 0.75
Fusilade (OT)	--	--	--	7/2	0.15	--
Caparol (DIR)	--	5/31	--	--	0.375	0.5
Caparol + Bueno (DIR)	6111	--	6/2	5/31	0.375 + 1.5	0.5 + 2.0
Bladex + Bueno (DIR)	6/21	6/12	--	--	0.45 + 1.5	0.6 + 2.0
Karmex (DIR)	716	711	7/9	7/9	--	1.0

* Broadcast.

Table 3. Herbicide applications with no tillage (broadcast applied).

Herbicide	Date applied 1990	1991	1992	1993	Broadcast rate (lb ai/Acre) Low	Normal
Gramoxone		--	4/30	4/22	0.5	0.94
Gramoxone + Karmex	2/14	--	--	--	0.5	0.94 + 0.5
Gramoxone + Bladex	--	4/23	--	4/22	--	0.94 + 1.0
Roundup D-Pak	--	2/28	3/2	2/22	0.5	0.67
Cotoran + Zorial	4/24	4/26	4/30	516	1.0 + 1.0	1.5' + 1.5
Fusilade (OT)	518	5/16	5/19	5/14. 7/2	0.15	0.188
Caparol (DIR)	--	5/31	--	--	0.375	0.5
Caparol + Bueno (DIR)	6/11	--	6/2	5/31	0.375 + 1.5	0.5 + 2.0
Bladex + Bueno (DIR)	6/21	6/12	--	--	0.45 + 1.5	0.6 + 2.0
Staple (OT)	--	--	6/22	5/14, 7/2	0.05	0.05
Karmex (DIR)	7/6	7/1	719	719	--	1.0

*Roundup 0.5 lb/A added in 90.

Table 4. Effect of weed control inputs on cotton stand.

Tillage	Input level	Plants/Acre*			
		1990	1991	1992	1993
		(1,000's)			
Conv.	Low	21.5 b	48.1 a	30.5 b	36.9 a
Conv.	Normal	34.4 a	50.6 a	46.3 a	48.4 a
None	Low	21.2 b	51.2 a	33.2 b	44.4 a
None	Normal	29.4 ab	54.2 a	33.2 b	47.2 a

* Values within the same column with the same letter are not different according to DMRT (P = 0.05).

Table 5. Effect of weed control inputs on yield.

Tillage	Input level	Seed cotton*			
		1990	1991	1992	1993
		(lb/A)			
Conv.	Low	2107 ab	3825 ab	1086 c	1397 b
Conv.	Normal	2491 a	3961 a	3295 a	2555 a
None	Low	817 c	2669 b	2044 b	2177 ab
None	Normal	1568 b	2937 ab	2527 ab	2269 ab

* Values within the same column with the same letter are not different according to DMRT (P = 0.05).

Table 6. Winter Weeds, % Control.*

		No-Till		Conventional	
Date	Weed	Low	Normal	Low	Normal
2/28/90	Eveningprimrose	52.5 b	85.0 a		
	Henbit	91.3 b	99.5 a		
	Horseweed	67.5 b	90.0 a		
	Venus Lookingglass	30.0 a	53.8 a		
4/12/90	Eveningprimrose	12.5 b	86.3 a		
	Henbit	92.5 a	98.0 a		
	Horseweed	45.0 b	86.3 a		
	Venus Lookingglass	22.5 a	70.0 a		
3/12/91	Grass	94.5 b	99.5 a	95.0 b	95.0 b
	Broadleaf	81.3 c	90.0 b	95.0 a	95.0 a
3126191	Grass	100.0 a	100.0 a	95.0 b	100.0 a
	Broadleaf	82.5 c	94.8 b	91.3 b	100.0 a
3/4/92	Grass + Broadleaf	63.8 a	75.0 a	53.8 a	80.0 a
3/24/93	Grass	98.0 ab	98.5 a	90.0 c	94.5 bc
	Broadleaf	68.8 c	75.0 bc	92.0 ab	98.5 b
417193	Grass	100.0 a	100.0 a	80.0 b	97.5 a
	Broadleaf	53.8 c	73.8 b	81.3 b	97.8 a

* Values in the same row with the same letter are not different according to DMRT (P = 0.05).

Table 7. Summer Annual Grass, % Control.*

	Conventional		No-Till	
Date	Low	Normal	Low	Normal
6/13/90	90.0 b	98.0 a	80.0 c	96.5 a
7/11/90	91.3 ab	98.0 a	46.3 c	81.3 b
7/30/90	80.0 b	96.5 a	53.8 c	92.5 a
5/28/91	68.8 b	97.3 a	97.3 a	98.0 a
6/19/91	76.3 b	98.0 a	94.5 a	98.0 a
7115/91	88.3 c	100.0 a	93.3 bc	96.5 ab
6/16/92	81.3 bc	95.8 a	68.8 c	87.5 ab
6/9/93	91.3 c	100.0 a	96.5 b	97.8 b
6123193	76.3 b	100.0 a	97.8 a	98.3 a
7/8/93	86.3 b	97.3 a	98.0 a	97.3 a

• Values in the same row with the same letter are not different according to DMRT (P = 0.05).

Table 8. Summer Annual Broadleaf, % Control.*

	Conventional		No-Till	
Date	Low	Normal	Low	Normal
6113/90	87.5 ab	98.0 a	40.0 c	62.5 bc
7111/90	83.3 ab	98.0 a	33.8 c	71.3 b
7/30/90	75.8 ab	97.3 a	35.0 c	61.3 bc
5128191	56.3 b	89.5 a	63.8 ab	63.8 ab
6/19/91	65.0 a	93.5 a	77.5 a	67.5 a
7/15/91	83.8 b	100.0 a	75.0 b	73.3 b
6/16/92	45.0 b	88.8 a	57.5 b	55.0 b
6/9/93	75.0 b	99.0 a	96.3 a	88.3 ab
6/23/93	52.5 a	95.0 a	85.8 a	77.5 a
718193	61.3 b	96.0 a	89.5 a	87.0 a

• Values in the same row with the same letter are not different according to DMRT (P = 0.05).

Table 9. Summer Annual Broadleaf + Grass, % Control.*

	Conventional		No-Till	
Date	Low	Normal	Low	Normal
6/25/90	88.8 a	98.3 a	42.5 b	61.3 b
5120192	50.0 b	95.3 a	26.3 b	48.8 b
7/1/92	33.8 c	94.5 a	66.3 b	61.3 b

* Values in the same row with the same letter are not different according to DMRT (P = 0.05).

Table 10. Johnsongrass, population and % control.

	Population*		Control*					
	7/13/92	7/15/93	6/13/90	6/19/91	7/15/91	3/30/92	5/31/93	7/14/93
	------------(Plants/133.3 ft^2)----------		---(%)---					
Conventional								
Low	144.3 a	23.4 a	0 b	15 b	99 a	51 b	100 a	61 b
Normal	21.8 b	9.0 ab	24 ab	0 b	100 a	97 a	100 a	100 a
No-Till								
Low	88.0 ab	0.8 b	61 a	80 a	53 b	91 a	86 b	95 a
Normal	58.5 ab	0.4 b	60 a	87 a	87 a	91 a	91 a	98 a

* Values within the same column with the same letter are not different according to DMRT (P = 0.05).

EFFECT OF TILLAGE METHOD, COVER CROP AND NITROGEN RATE ON YIELD OF KENAF

Carl H. Hovermale[1]

Kenaf is a potential alternative crop for the southeastern United States. Kenaf was planted using conventional and reduced tillage methods after two cover crops (crimson clover, ryegrass) and a fallow treatment for two years. Superimposed on tillage method and cover crop was nitrogen rates of 0, 34, 68, and 136 lb/A. Kenaf planted in a cover crop yielded more, was taller, and had thicker stems than when planted in fallow. There was no difference in yield or plant height attributable to tillage method. Conventionally planted kenaf had higher plant populations and thinner stems than when planted no-till. Application of 34 lb/A of nitrogen resulted in yields greater than 0 nitrogen but not different from as much as 136 lb/A. High nitrogen rates reduced stand and increased stem diameter but had no significant effect on plant height. There were no significant interactions with nitrogen rate and tillage method or cover crop. There was a significant interaction between tillage method and cover crop. Kenaf planted in conventionally tilled clover plots yielded more than kenaf planted no-till, this difference was not evident in the other cover crop treatments.

INTRODUCTION

Kenaf has the potential to become an important alternative crop in the southeastern United States. Existing newsprint factories in Mississippi have shown considerable interest in kenaf as an additative to wood pulp in their paper making process. With this in mind a kenaf cooperative has been formed in north Mississippi, to grow, conduct research, and promote the use of kenaf. Eight hundred hectares of kenaf have been planted for use in fiber separation. Plans are underway in South Carolina to build a fiber processing plant that will require 14,000 ha of kenaf. Basic information concerning tillage methods and fertility requirements must be developed for successful production and later industrialization of this new crop.

Kenaf is not a new crop in the United States but is experiencing a rebirth of interest. In the early 1970's this crop was introduced to south Mississippi but lack of effective storage methods made commercialization impossible (3). Solutions to this problem have been found, bringing commercialization a step closer. Current interest in kenaf production extends across the southeastern United States. In south Texas, the USDA-ARS and Rio Farms have been engaged in research for several years. Scientists from Texas to South Carolina are engaged in kenaf research including variety evaluation, weed control, planting date, disease, plant-parasitic nematodes, fertility, and storage experiments.

The recommended cultural practice for planting kenaf is a well prepared seedbed but as with most clean cultivated crops this increases the cost of land preparation and has the potential to increase soil erosion (1).

Limited information is available on the response of kenaf to nitrogen from legumes. Research in Florida and Georgia showed that fertilizer nitrogen rates above 103 kg ha^{-1} did not increase yields (4). In Kansas research has shown that nitrogen rates above 51.5 kg ha^{-1} did not increase yields (5). In Alabama, cotton planted after legume cover crops produced cotton lint yields comparable to cotton fertilized with rates up to 68 kg N h^{-1} (3).

MATERIALS AND METHODS

Kenaf was planted conventionally and no-till after two cover crops (crimson clover, and ryegrass) and fallow at a rate of 8 lb/A in 40 inch rows. Plot size was 14 X 20 feet. This experiment was a split-split plot design with cover crop as main plot. tillage as sub plot, and nitrogen rate as sub, sub plot with 4 replications. Cover crops were planted in October each year. Nitrogen fertilizer was applied to the ryegrass at planting at 68 lb/A. Potash and phosphorous were applied to maintain a high soil test level. Cover crops were killed with glyphosate in early April and kenaf planted 14 days later using a no-till planter equipped with rippled colters. Four nitrogen rates (0, 34, 68, and 136 lb/A) were applied to each cover crop x tillage treatment at

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Table 1. Effect of cover crop on height, stand, stem diameter, and yield of kenaf. MAFES South Mississippi Branch. a two year average 1992-1993.

Cover crop	Plant height	Plant stand	Stem diameter	Dry matter yield
	ft	plants/A	mm	lb/A
Crimson clover	13.0	16764	18.2	13036
Fallow	12.2	31200	14.0	10625
Ryegrass	12.6	16764	17.4	11696
AVE	12.6	22262	16.5	11786
LSD (0.05)	.6	4292	1.3	1517
CV %	7.3	25.2	16.7	20.6

Table 2. Effect of tillage method on height, stand, stem diameter, and yield of kenaf. MAFES South Mississippi Branch, a two year average 1992-1993.

Tillage method	Plant height	Plant stand	Stem diameter	Dry matter yield
	in	plants/A	mm	lb/A
Till	151	33123	15.8	12053
No-till	152	21258	17.3	11517
AVE	151	27190	16.5	11785
LSD (0.05)	NS	3539	1.0	NS
CV %	7.3	25.5	16.7	20.6

Table 3. Effect of nitrogen rate on height, stand, stem diameter, and yield of kenaf. MAFES South Mississippi Branch, a two Year average 1992-1993.

Nitrogen rate	Plant height	Plant stand	Stem diameter	Dry matter yield
lb/A	in	plants/A	mm	lb/A
0	149	24197	14.1	9821
38	153	21796	16.3	12232
76	151	23361	17.3	12518
152	152	19695	18.4	12616
AVE	151	22262	16.5	11803
LSD (0.05)	NS	2272	1.1	982
CV %	7.3	25.2	16.7	20.6

planting. Plant height was measured at harvest from the ground to the apical tip. Plants in 13 feet of row was counted at harvest in each plot to determine plant population. Eight stem diameters in each plot were measured 4 feet above the ground. Yield was determined by harvesting 13 feet of row and converted to lb dm/A.

RESULTS

Averaged over two years, kenaf planted in a clover cover crop was taller, had thicker stems, and yielded more than when planted in fallow (Table 1). Kenaf planted in the fallow treatment had a higher plant population than kenaf planted in either clover or ryegrass.

There was no difference in yield or plant height attributable to tillage method (Table 2). Conventionally planted kenaf had higher plant populations and thinner stems than when planted no-till.

Application of 34 lb/A of nitrogen resulted in yields greater than 0 nitrogen but not different from as much as 136 lb/A of nitrogen (Table 3). High nitrogen rates reduced stand and increased stem diameter but had no significant effect on plant height. There were no significant interactions with nitrogen rate. In clover plots kenaf planted in conventionally tilled plots yielded more than kenaf planted no-till, this difference was not evident in the other cover crop treatments.

DISCUSSION

These data indicate that kenaf can be grown after a ryegrass or clover cover crop using either conventional or no-till culture without a detrimental effect on dry matter yield. This not only reduces the cost of production by eliminating trips across the field but also gives farmers a method to reduce soil erosion. Nitrogen rates over 34 lb/A did not increase yields. This not only keeps the cost of production down by using small amounts of nitrogen but also reduces the chances of non-point source pollution.

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INTERSEEDING ALFALFA INTO BERMUDAGRASS SODS: WHAT WE HAVE LEARNED

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INTRODUCTION

Bermudagrass (BGI is a mainstay of pasture-livestock systems in much of the Southeast, particularly on sandy coastal plains regions. It is widely used as a hay crop, as well. As a tropical warm-season grass, it suffers from modest, or lower, forage quality, being relatively high in fiber and low in digestibility. The quality problem is most severe in mid- to late summer. Herbage quality in forage swards has traditionally been enhanced by adding a legume. Winter annual legumes have proven useful in adding high quality forage in the off season. Legumes for the BG growing season have suffered from severe competition from the grass sod.

Perennial legumes have been explored to a very limited degree as companions for bermudagrass. White clover and red clover (Montgomery et al., 1983). birdsfoot trefoil (Jutras, 1967) and alfalfa (Burton, 1978) have received passing attention as to their ability to contribute to the composition of warm season grass swards, but the literature is very limited as to practicality and management information.

In preliminary research we found that alfalfa established readily into "Coastal" BG sods. Indeed, when alfalfa was interseeded in 8-inch row spacing, it competed strongly with the established BG sod. These preliminary results caused us to embark on a line of investigation with the objective of learning how to manage to maintain both species in the mixture.

MATERIALS AND METHODS

Sods of "Tifton 44" BG at Clemson and Blackville, SC were subdivided into plots and interseeded with "Cimarron" alfalfa in 8-, 16-, and 24-inch row spacings. Other plots were left as pure BG. Interseeding was done in early October, after mowing the BG sod to a 2-inch stubble. Alfalfa was seeded at the rate of 17, 8.5 and 5.6 Ibs per acre for the 8, 16, and 24 inch row spacing treatments respectively. Each of these stand types was treated with 0. 100, 200. and 400 Ibs of N per acre. These experiments were harvested for two years for yield and botanical composition determination. For the sake of brevity, on the second year's data at each location is presented in this paper. Another area of Tifton 44 was interseeded with Cimarron alfalfa at 16- and 24-inch row spacings. Each of these stand types was harvested at 21- 28- and 35-day intervals and yield and botanical composition were determined.

RESULTS AND DISCUSSION

Nitrogen fertilization of pure BG swards resulted in linear increases in yield at both sites, for an average yield increase of almost 110% at the 400 lb rate over the zero N check. Nitrogen fertilization of interseeded treatments gave inconsistent results. In 24-inch row spacings, N increased total yield, but in 16-inch rows there was no effect. At Blackville, N increased yields in 8-inch rows. The average increase from N fertilization in 24-inch row interseeded plots was only 20%. Increasing the row spacing had no significant effect on herbage yield. However there was small downward trend in yield as row spacing increased. The N by row spacing interaction was not significant.

In terms of botanical composition, N had much less effect than was expected. Grass percentage in the mixtures was not affected by N fertilization up to 400 Ibs per acre, or in some cases was actually decreased slightly. Any yield increases in interseeded mixtures from N were not the result of increased BG contribution. Increasing row spacing resulted in small increases in percentage BG in the interseeded mixtures. Again, there was no significant N by row spacing interaction.

N fertilization had little impact on yields or composition of interseeded BG-alfalfa stands. Widening the row spacing did not influence yields, but did slightly increase the contribution of the BG component. The fact that BG, normally a very N-responsive species, did not respond to N

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Table 1. Total herbage yield of bermudagrass and alfalfa-bermudagrass mixtures (Blackville, 1988).

	Stand type				
		Alfalfa row spacing, in			
N rate	Grass alone	8	16	24	N Rate Means
lbs/ac.$^{-1}$			Mg ha^{-1}		
0	7.46	12.95	12.48	10.89	11.78
200	11.11	13.99	14.49	12.00	13.50
400	13.23	14.91	14.58	14.00	14.49
N effect	Lin.*	Lin.*	NS	Lin.*	Lin.*
Row Spacing Means	---	13.86	13.34	11.85	NS

• Significant at the 0.05 probability level. **NS** = not significant.

Table 2. Total herbage yield of bermudagrass and alfalfa-bermudagrass mixtures (Pendleton, 1989).

	Stand tvoe				
		Alfalfa row soacina. in.			
N rate	**Grass alone**	**8**	**16**	**24**	**N Rate**
kg ha^{-1}			**Mg ha^{-1}**		
0	8.45	17.29	15.81	14.58	15.88
100	13.35	17.20	15.45	14.60	15.76
200	16.47	15.09	15.96	16.05	15.70
400	20.45	17.50	16.38	16.80	16.90
N effect	Lin.*	Quad.'	NS	Lin.*	NS
Row Spacing Means	---	16.81	15.90	15.50	NS

* Significant at the 0.05 probability level. NS = not significant.

Table 3. Percentage bermudagrass in herbage of bermudagrass and alfalfa-bermudagrass mixtures (Blackville, 1988).

	Stand type				
		Alfalfa row soacina. in.			
N rate	**Grass alone**			**24**	**N Rate Means**
kg ha^{-1}			**% G**		
0	45	5	17	16	13
100	51	4	16	23	14
200	54	3	12	20	12
400	69	2	9	16	9
N effect	Lin *	Quad'	NS	NS	NS
Row Spacing Means	--	4	14	18	Lin*

* Significant at the 0.05 probability level. NS = not significant.

Table 4. Percentage bermudagrass in herbage of bermudagrass and alfalfa-bermudagrass mixtures (Pendleton, 1989).

	Stand type				
		Alfalfa row spacing, in.			
N rate	Grass alone	8	16	25	N Rate Means
kg ha^{-1}	----------	----------%	rass----------	----------	
0	81	3	8	20	10
100	81	2	8	18	9
200	85	2	7	16	8
400	86	2	7	16	8
N effect+	Lin.*, Cub."	NS	NS	Lin.'	NS
Row Spacing Means	---	2	7	17	Lin.'

* Significant at the 0.05 probability level. NS = not significant.

Table 5. Herbage yield (Mg ha^{-1}) of alfalfa-bermudagrass mixtures as affected by row spacing and clipping frequency.

	Year							
	1990			1991			1992	
Cutting Frequency	16 in	24 in	Mean	16 in	24 in	Mean	16 in	24 in
3 weeks	4.3	3.1	3.7b	8.4	6.7	7.5	--	--
4 weeks	5.0	4.9	4.9a	8.9	8.9	8.9	--	--
5 weeks	6.1	4.8	5.4a	11.6	11.0	11.3	8.85	7.90
Mean	5.2a' Quad.	4.2b Quad		9.7 Quad.	8.8 Lin.	Lin.		

'Means within main effects with same letter are NSD.

Interaction significant.

3- and 4-week treatments not harvested. No alfalfa.

Table 6. Percentage bermudagrass of alfalfa-bermudagrass mixtures as affected by row spacing and clipping frequency.

	Year							
	1990			1991			1992	
Cutting Frequency	16 in	24 in	Mean	16 in	24 in	Mean	16 in	24 in
3 weeks	38	49	43	58	61	60	---	---
4 weeks	31	38	34	47	54	50	---	---
5 weeks	26	33	30	21	36	28	7	21
Mean	42b	51a		42b	50a			

* Means within years followed by the same letter are not significantly different at the 0.05 probability level.

when interseeded with alfalfa suggests that another factor was controlling the fate of the BG. Ot is likely that the plant height advantage of alfalfa over BG was an important factor. The intolerance of BG for shade is well established (Burton et al., 1959). Under the cutting regime of this experiment (every 5 weeks), alfalfa towered over the companion BG at almost every harvest.

In a related experiment, we studied the effect of cutting frequency on yield and botanical composition. In the first harvest year, cutting more frequently than five weeks decreased total herbage yields (Table **1).** Yields were lower under the 24- than 16-inch row spacing. The effect of cutting frequency was similar under 16 and 24 inch row spacings. In the second harvest year, the cutting by row spacing interaction was significant. The decrease in yield from frequent cutting was smaller in 16- than **24-**inch rows. By the third cutting season, the **3-** and 4-week frequency plots were devoid of alfalfa. In terms of BG contribution, cutting more frequently increased the percentage BG in herbage. Increasing row spacing increased percentage BG. The yield effects of increased cutting frequency were related to the decreased occurrence of alfalfa in the mixtures. These findings suggest that defoliating more frequently than is normal for alfalfa hay production will aid in retaining the BG component in mixtures with alfalfa. row spacings of 24 inches or wider will also aid in BG persistence in competition with interseeded alfalfa.

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TILLAGE SYSTEMS FOR COTTON PRODUCTION ON LOESS SOILS IN CENTRAL MISSISSIPPI

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INTRODUCTION

The Brown Loam soil resource area of Mississippi is a narrow band (about 60 miles wide) of loessial soil that extends from about Natchez, MS almost to Memphis, TN. The region is classified as soil with high erosion capability and thus, conventional tillage row crop production is influenced by the 1985 and 1990 Food Security Act. Interest in reduced tillage cotton production systems has increased in central Mississippi because of the erosive capability of most soils in the region and government regulations restricting some tillage operations. Although each field is different with respect to meeting compliance requirements, generally, tillage operations are not allowed from the time of harvest until March 15-April 1, depending on soil type and slope (Dale Bullock, USDAISCS, Personal Communication). A minimum of 30% ground cover crop residue must be present at the time of planting if tillage system is the sole component for meeting conservation compliance. A cover crop must be planted to achieve the ground cover requirement if tillage is performed in the fall. Species of cover crop used (crimson clover, hairy vetch, wheat and native vegetation) did not significantly affect seedcotton yield in a three year study on Brown Loam soils in north Mississippi (Bloodworth and Johnson, 1992). In the same study, no-till cotton produced greater seedcotton yield than conventionally tilled cotton in two of the three years. Plant populations responded differently to the tillage treatments in each year of the study.

In Arkansas, in a two year study, conventionally tilled cotton grown in either 30- or 38-inch rows produced significantly greater lint yield per acre than no-till cotton (Keisling et al., 1994). However, plant stands per row foot were identical across row spacings and within tillage treatments resulting in greater plant population for 30-inch versus 38-inch row spacings.

Deep tillage (subsoiling) has been documented to increase conventional tillage seedcotton yield (Grissom et al., 1955) and no-till soybeans (Sharpe et al., 1988) doublecropped with wheat, when the deep tillage was performed on soils with a hardpan. Although soils in the Brown Loam region generally possess a fragipan, effects of subsoiling on cotton production have not been documented. This study was conducted to determine the influence of four tillage systems on cotton plant population and seedcotton yield on a loess silt loam soil in central Mississippi.

MATERIALS AND METHODS

The study was initiated in 1989 and continued through 1993 on a Calloway silt loam soil (fine-silty, mixed, thermic Glassaquic fragiudalfs) with 0-2% slopes and an initial pH of 6.5. The four tillage systems compared were: [1] Disk (conventional tillage consisting of disk, chisel, disk, hip, do-all, and plant); [2] Hip (rehip old seedbed in spring, do-all and plant); [3] Ro-Till'' (in-row subsoil to a depth of 14-16 inches preparing 14-inch-wide seedbed and plant); and [4] No-till (plant directly into standing cotton stubble after chemical burndown of winter vegetation). The experiment was set up as a split-plot in a randomized complete block design with four replications. Each plot consisted of eight rows, spaced 38-inches apart and 50 feet in length. Tillage treatments served as the main plot factor with all systems remaining in the same location for the duration of the study. Half of each plot (4 rows) was cultivated twice during each growing season with a Buffalo''' two-row cultivator to determine if cultivation (subplot factor) influenced population or yield. All tillage operations were performed in the spring.

Glyphosate was applied at 1.0 lb ai/acre 7 to 10 days prior to planting Ro-Till and no-till treatments. Cotton variety 'DES 119' was planted each year at 3-4 seed/ft of row with a no-till planter equipped with ripple coulters, double-disc openers and cast closure wheels. Aldicarb insecticide was applied in-furrow each year at 1.05 lb ai/acre at the time of planting. A tank mix of metolachlor and fluometuron each at

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Table 1. Planting and harvest dates for a five year tillage study. Raymond. MS.

Year	Planting Date	Harvest Date
1989	April 28	October 25
1990	May 9	October 11
1991	May 30	October 16
1992	May 4	October 19
1993	May 18	October 6

2.0 lb ai/acre was applied preemergence broadcast on all treatments each year. Fluaziflop (0.188 lb ai/acre) was applied as a spot treatment for rhizome johnsongrass control on an as needed basis. No other herbicide treatments were applied during the growing season. Lime, phosphorus, and potassium were applied to the whole study in the spring of each year according to soil test recommendations. Insecticides were applied as needed based on weekly scouting reports.

Plant populations were determined prior to harvest by counting the number of plants present in 3 linear feet of row in each of the two center rows of each subplot. Plots were defoliated when approximately 60% of bolls were open as determined by visual assessment. Seedcotton yield was determined by harvesting the two center rows in each subplot with a one row spindle picker modified for small plot cotton research. Plant height at harvest was determined in 1991, 1992 and 1993. Plant mapping data collected in 1993 included total number of nodes per plant, total number of fruiting nodes per plant, first fruiting node and length of the taproot. Stalks were shredded in the fall of each year to a height of approximately six inches.

RESULTS AND DISCUSSION

Planting and harvest dates are presented in Table 1. Planting dates ranged from late April to late May, depending on weather patterns. Rainfall by month for the cotton growing season (Table 2) indicates several abnormal rainfall events. In 1989, excess rainfall during the months of June and July occurred with extremely dry weather during August. In 1991, over seventeen inches of rainfall during April resulted in a late planting date. In 1992, less than one inch of rain fell in May and over eight inches in August along with cool temperatures slightly delayed maturity of the crop.

Table 2. Rainfall by month for the cotton growing season, Raymond, MS, 1989-1993.

	Year				
Month	1989	1990	1991	1992	1993
	Rainfall (in)				
April	2.14	2.96	17.54	1.83	4.96
May	5.81	7.25	5.67	0.96	3.26
June	10.37	5.01	1.08	8.19	3.44
July	10.72	1.81	2.97	2.53	5.19
August	0.88	2.37	3.72	8.81	3.94
September	5.23	4.73	4.82	3.14	1.02
October	0.16	1.13	2.02	2.22	4.87

Table 3. Influence of tillage system on plant population, Raymond, MS, 1989-1993.

Tillage System	Plant Population (plants/A in thous.)					
	1989	1990	1991	1992	1993	5-Yr. Average
Disk	42.3 a[z]	39.0 a	30.6 ab	45.6 b	38.8 a	39.3 a
Hip	52.2 a	13.0 b	23.3 c	43.4 b	43.7 a	35.1 a
Ro-Till	61.2 a	37.9 a	25.4 bc	51.9 a	36.1 a	42.5 a
No-till	56.2 a	34.9 a	33.1 a	27.6 c	25.4 b	35.5 a
Overall Mean	53.0	31.2	28.1	42.1	36.0	38.1
CV (%)	20.0	29.3	15.8	5.8	15.5	9.8
LSD (0.05)	NS	14.6	7.1	3.9	8.9	NS
Standard Error of Mean	5.3	4.5	2.2	1.2	2.8	1.9

[z] Means in a column followed by the same letter are not significantly different according to Fisher's Protected Least Significance Difference Test (P = 0.05).
NS = Not Significant.

With one exception in 1992, no significant interaction between cultivation and tillage occurred, thus, data were averaged over cultivation. No significant population differences occurred among the tillage systems in 1989 (Table 3). The hip system resulted in the lowest plant population among the treatments in 1990 and 1991. There was no significant difference in 1990 among the disk, hip and Ro-Till systems. In 1991 the no-till and disk treatments produced plant populations significantly greater than the hip treatment. The Ro-Till system resulted in significantly greater plant population than the other systems in 1992. The disk and hip systems followed, each with about 43-45,000 plants/acre. The no-till treatment resulted in significantly fewer plants per acre than the other systems in 1992 and 1993. There were no significant differences among the disk, hip and Ro-Till treatments in 1993. There were no significant differences in plant population among the tillage systems for the 5 year average. The trend was for the Ro-Till and disk systems to result in greater plant populations than the hip and no-till treatments.

Seedcotton yields for the tillage systems are presented in Table 4. There was no significant differences in seedcotton yield among the tillage systems in 1989. Ro-Till and disk tillage systems produced significantly greater yield than the hip treatment in 1990 and 1991. Low plant population in the hip treatment may have resulted in the lower yield (Bridge and Miller, 1989). No-till treatment in 1990 yielded similarly to the disk system but was significantly lower than the Ro-Till. Yield in the hip system (1,791 lb/acre) was higher in 1992 than 1991, but was not significantly different from the disk treatment (1,942 lb/acre). The no-till treatment produced the lowest seedcotton yield among the systems in 1992 and 1993. Plant populations in the no-till system were low in 1992 and 1993 and may have resulted in the low seedcotton yields. There was no significant difference in seedcotton yield

Table 4. Influence of tillage system on seedcotton yield, Raymond, MS, 1989-1993.

Tillage System	Seedcotton Yield (lb/A) 1989	1990	1991	1992	1993	5-Yr. Average
Disk	2,100 a[z]	1,331 ab	2,061 a	1,942 ab	1,685 a	1,823 a
Hip	2.383 a	796 c	1,555 c	1,791 b	1,428 a	1,591 b
Ro-Till	2,538 a	1,441 a	1,867 ab	2,185 a	1,470 a	1,900 a
No-till	2,524 a	1,142 b	1,649 bc	1,354 c	744 b	1,483 b
Overall Mean	2,386	1,177	1,783	1,818	1,331	1,699
CV (%)	20.2	21.5	14.5	14.4	27.3	7.9
LSD (0.05)	NS	216	266	269	374	215
Standard Error of Mean	241.1	126.5	129.2	130.8	181.4	67.1

[z] Means in a column followed by the same letter are not significantly different according to Fisher's Protected Least Significance Difference Test (P=0.05).
NS = Not Significant.

Table 5. Influence of tillage system on plant height at maturity, Raymond, MS, 1991-1993.

Tillage System	Plant Height (in) 1991	1992	1993	3-Yr. Average
Disk	29.1 a[z]	38.4 c	36.1 a	34.5 a
Hip	31.8 a	39.3 bc	33.9 a	35.0 a
Ro-Till	31.6 a	44.4 a	34.0 a	36.7 a
No-till	29.9 a	41.8 ab	35.4 a	35.7 a
Overall Mean	30.6	41.0	34.9	35.4
CV (%)	11.8	5.0	9.4	6.6
LSD (0.05)	NS	3.3	NS	NS
Standard Error of Mean	1.8	1.0	1.6	1.2

[z] Means in a column followed by the same letter are not significantly different according to Fisher's Protected Least Significance Test (P=0.05).
NS = Not Significant.

among the disk, hip and Ro-Till systems in 1993. The five-year average of seedcotton yield for the tillage systems suggests a trend for the Ro-Till and disk treatments to produce significantly greater seedcotton yields than the hip and no-till systems.

Significant differences in plant height among the treatments occurred only in 1992 (Table 5). Plants grown in the Ro-Till and no-till treatments were taller than those from the hip and disk systems. Extremely dry weather during May 1992 may have resulted in faster drying of the soil in the disk and hip treatments resulting in slower plant growth during this period. The Ro-Till and no-till treatments had ground cover present which may have conserved moisture from earlier rains.

Plant mapping data (not shown) collected during the 1993 growing season indicated no significant differences among the tillage systems for total nodes per plant, total fruiting nodes per plant, first fruiting node and length of the taproot. There was a trend for the Ro-Till and disk treatments to have slightly longer taproots. The subsoil begins about 7-8 inches deep and tillage from the Ro-Till and the chisel operation in the disk treatment may have fractured the upper layer of the subsoil resulting in less restriction for taproot growth in these treatments.

A significant (P $<$ 0.051 treatment x cultivation interaction (data not shown) occurred for both plant population and seedcotton yield in 1992. Fewer plants per acre were present in the cultivated plots of the disk, hip and Ro-Till systems as compared to the same plots not cultivated. About, 6,000 more plants per acre resulted in the cultivated no-till plot as compared to the no-till plot not cultivated. The result was greater seedcotton yield (about 200 lb/a) in the cultivated no-till plot when compared to the no-till plot not cultivated. Visual observation indicated more weeds were present at harvest in the no-till non-cultivated plot than the cultivated no-till plot. The result of cultivating no-till plots in this study most likely produced increased yield by controlling weeds. Plant populations have been shown to be variable from year to year in no-till experiments (Bloodworth and Johnson, 1992) and occasionally lower in cultivated versus not cultivated plots (Johnson et al., 1992).

SUMMARY

The Ro-Till and disk systems resulted in highest seedcotton yield in the 5 year study. The hip and no-till systems each resulted in the lowest plant populations in two out of five years of the study. There were no differences in plant populations among the four treatments for the 5 year average. Ro-Till and no-till systems produced taller plants in 1992. No significant differences were indicated for plant mapping parameters in 1993. Cultivation did not influence yield or plant population except in the no-till system in 1992 when cultivating resulted in slightly more plants per acre and increased yield.

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A COMPARISON OF SLIT TILLAGE AND SUBSOILING IN A SUBSURFACE HARDPAN SOIL

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ABSTRACT

Sorghum was grown for four years (1986 to 1989) on plots that were slit tilled, subsoiled, and no tilled. Corn was grown for three years (1990 to 1992) following the tillage to access its residual effects. Draft was measured for slit-till and subsoil implements the first year of the study. Pits were dug each year to assess root growth. Soil strength was measured the last three years. Draft requirements for the slit tillage implement was **75%** of that for a comparable subsoiler. The slit tillage implement disrupted the soil to the top of the pan and cut a eighth of an inch slit through the pan. The subsoiler disrupted the soil to the bottom of the subsoil pan. When the plots were tilled, slit tilled and subsoiled treatments both outyielded no tillage. Sorghum yields for slit tillage were slightly higher than subsoiling. After tillage ceased, subsoiled treatments outyielded no tillage. Yield for the slit tillage treatment was about the same as for no tillage. Soil strength readings showed that more of the profile was disrupted below the row for subsoiled treatments than for slit-tillage treatments. Few slits could be found in the pit walls after three years. With lower energy requirements than subsoiling and comparable yield, slit tillage has promise for this southeastern Coastal Plain soil as long as regularly scheduled tillage is required. Slit tillage management warrants further investigation.

INTRODUCTION

Reconsolidation of subsurface hardpans in southeastern Coastal Plain soils (Threadgill, 1982; Busscher, et al., 1986) forces producers to annually disrupt the profile to provide a zone of low strength for root growth. In-row subsoiling has been the norm for deep disruption for a number of years. Unlike deep chiseling, in-row subsoiling shatters only a portion of the profile. Thinner subsoil shanks disrupt smaller zones within the profile (Busscher *et al.,* 1988) and use less energy (Karlen et al., 1991). The major advantage of any subsoiling tool is to penetrate the hardpan and encourage root growth below it. Unfortunately, deep profile disruption techniques use substantial amounts of energy (Elkins and Hendrick, 1983; Garner, et al., 1987). It would be beneficial to develop less expensive, less energy intensive practices which disrupt subsoil pans and/or promote root growth.

Slit tillage encourages root penetration of hardpans by cutting macropore size slits through a pan. The development of these slits is cheaper than conventional subsoiling for two reasons. First, the energy required to cut the slits is less than that needed to disrupt the profile or even a thin segment of it. Second, annual deep tillage may not be necessary since infilling of slits with roots keeps them open for more than one year in the Gulf Coastal Plain (Elkins and Hendrick, 1983).

Slit tillage has been effective in soils with shallow traffic or tillage pans of 8 in or less. The objective of this study was to compare slit tillage to in-row subsoiling and no tillage on soils with a deep (8 to 16 in) compacted horizon during the years that the tillage was being performed and for three years following tillage.

Methods

In 1986 plots were established at the Coastal Plains Research Center in Florence SC. Treatments included subsoiling, slit tillage, and no tillage. Plots were arranged in randomized complete blocks with four replicates. Each plot had six 30-in wide rows that were 60-ft long. Data was collected from the center two rows of each plot. The soil was a Norfolk loamy sand (typic Kandiudult) with a hardpan below the plow layer. The soil at the depth of the pan (8 to 16 in) varied from a loamy sand E horizon to a transitional layer grading to a sandy clay loam Bt throughout the field.

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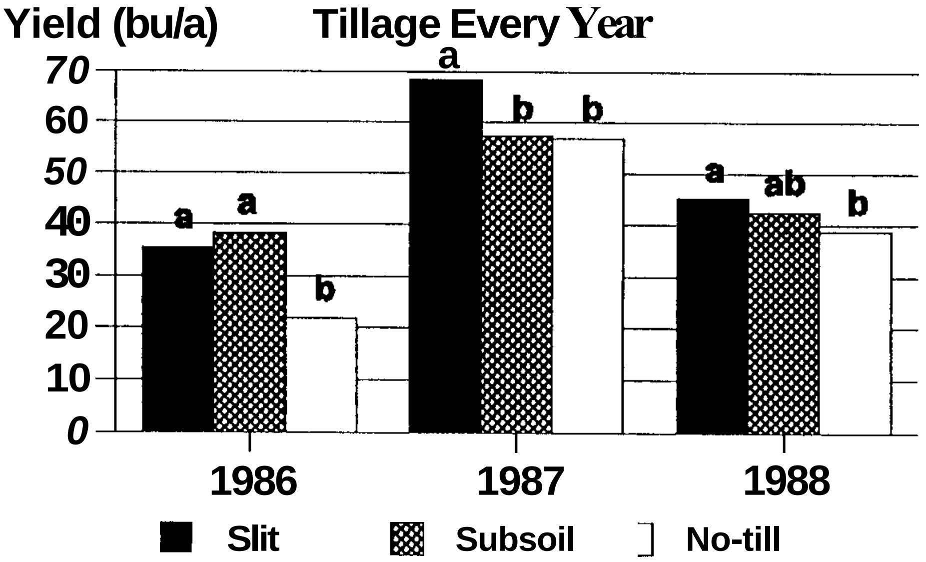
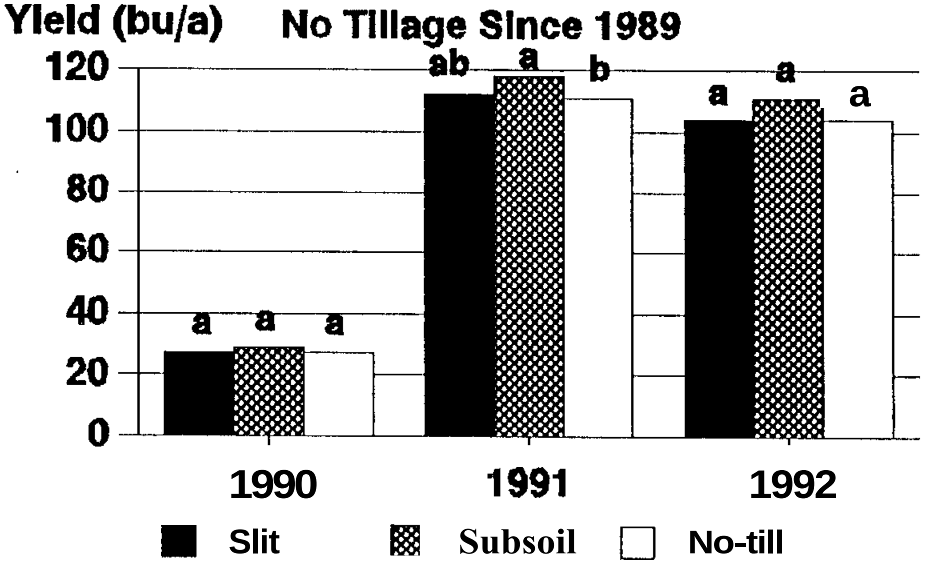
Figure 1. Sorghum Yield



Means with the same letter are not significantly different within year using the lsd test.

Figure 2. Corn Yield



Means with the same letter are not significantly different within year using the lsd test.

There was no surface tillage during any of the study. Winter weeds were controlled with glyphosate or with paraquat and alachlor. Grain sorghum (cv. Savannah 5) was grown in the plots from 1986 through 1989. Corn (cv Pioneer 3165) was grown in 1990, 1991, and 1992. Preplant fertilizer was broadcast at a rate of 50-22-41 lb/a N-P-K for the sorghum and at a rate of 0-16-89 lbla N-P-K for the corn.

The tillage treatments were imposed on the plots with (i) a forward angled shank, disrupting the soil to a depth of 12 in with a knife blade welded to the foot of it to cut a 4-in deep one-eighth-inch wide slit through the pan, the slit tillage treatment, (ii) a longer, forward-angled, nonparabolic subsoil shank, disrupting the soil to a depth of 16 in, the subsoiled treatment, or (iii) no deep tillage. Tillage was moved into mid and quarter row positions from year to year to provide a uniform pattern of slits below the rows.

Paraquat (used with a shielded sprayer) and atrazine were used to control weed growth throughout the growing season. Urea-ammonium nitrate was applied at a rate of 60 lbs N/acre for the sorghum between 1986 and 1989 and at a rate of 120 lbs N/acre for the corn between 1990 and 1992.

Pits were dug each year at the end of selected plots. Pits were used to observe and photograph root growth through the slits and to evaluate root growth through the hardpans.

Soil strength was measured with a 0.5-in, cone-tipped penetrometer (Carter, 1967). Strength was measured across two rows at 3.75-in intervals to a depth of 2 ft and averaged to give readings for a single row.

To obtain draft requirements, a two row parabolic subsoil shank and a similar shorter shank with the slit-tillage knife attached to the bottom of it were hitched to a John Deere 3020 tractor equipped with a dynamometer (Garner and Dodd. (1985). Draft measurements were made approximately 150 ft from the experimental site on the same soil type.

Yield was obtained with a small plot combine and corrected to 15% moisture for the sorghum and 15.5% for the corn. Data were analyzed using GLM and ANOVA in SAS (SAS Institute, 1990).

Results and Discussion

The Norfolk soil had a gray-brown loamy sand surface horizon, the plow layer, which typically extends to a depth of 7 in; a pale brown eluviated horizon from a depth of 7 to 16 in; and a red-brown argillic horizon below that. The eluviated horizon was not continuous across the field. For reps 1 and 2, the pan was an eluviated horizon grading into an argillic horizon; for reps 3 and 4 the pan was essentially an eluviated horizon.

The draft and horsepower requirements of the slit-tillage tool was 75% of that for the subsoiler (Table 1) because of the shallower depth of the subsoiler in the slit tillage treatment. The shank of the slit tillage tool rode on the top of the pan while the blade below the shank did the actual penetration of the pan. The subsoiler had its shank lowered to the bottom of the pan disrupting a larger cross sectional area of the profile.

Sorghum yield was greater for slit tillage than the no-tillage treatment for 1986 through 1988 (Figure 1). Yield for the subsoiled treatment was significantly greater than the no-tillage treatment for 1986. The slit tillage treatment was significantly greater than the subsoiled treatment in 1987 and greater but not significantly in 1988. We speculated that the accumulation of slits from year to year caused the increase in sorghum yield of the slit tilled treatment over the subsoiled treatment.

After 1990, after tillage ceased, corn yield was greater for the subsoiled treatment than for the slit tillage treatment (Figure 2). Corn yield for the subsoiled treatments was highest in 1991, 1992 and 1993, though it was only significantly greater than for no-tillage in 1991. Corn yield was essentially the same for slit tilled and no-tillage treatment for all three years because the

Table 1. Draft and horsepower of slit and subsoil implements.

	Slit	Subsoil
Draft (lbs)	3930	5215
Power (hp/shank)	20.1	26.7

Figure 3 Ranks of Soil Strengths for 1990

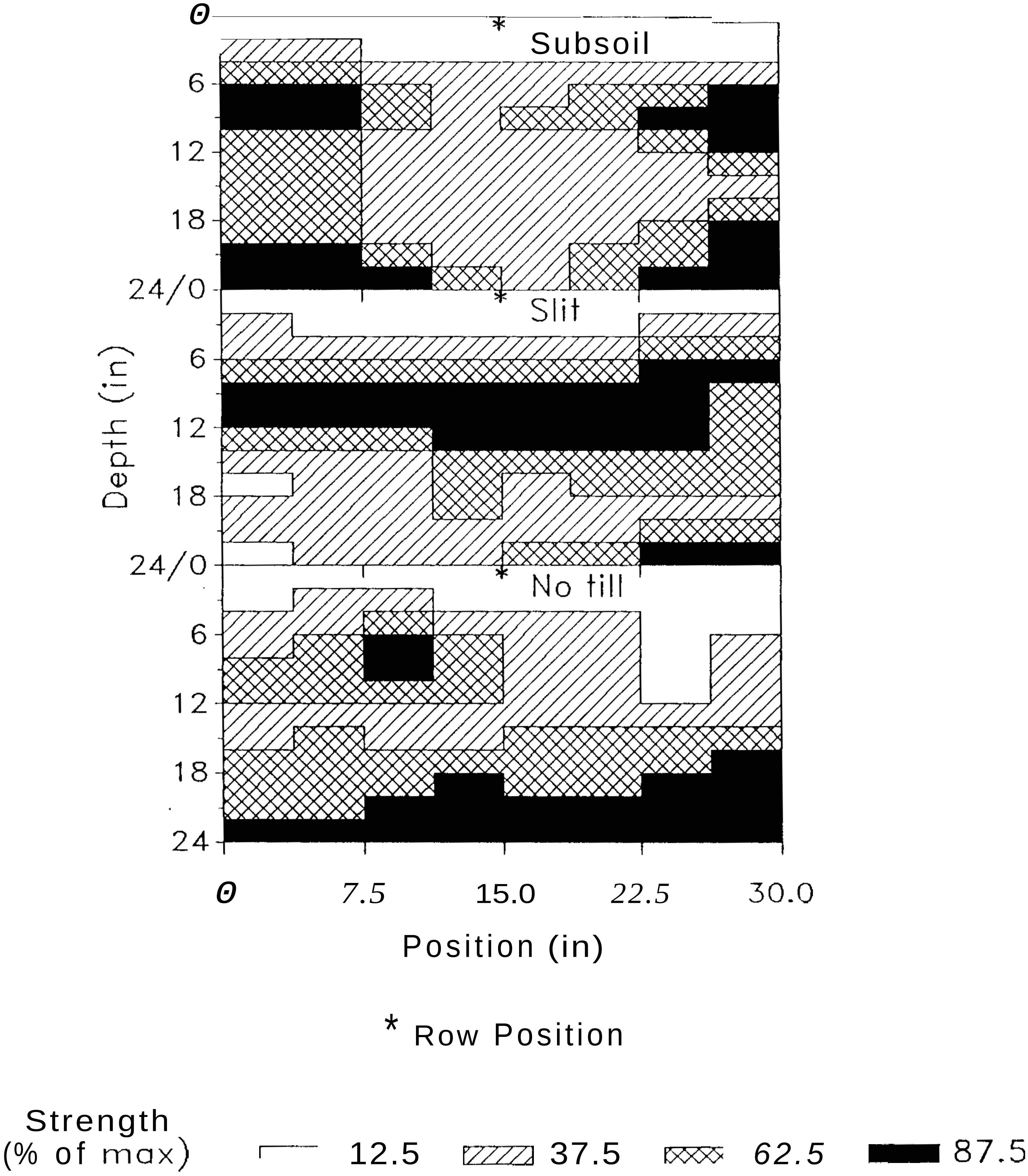
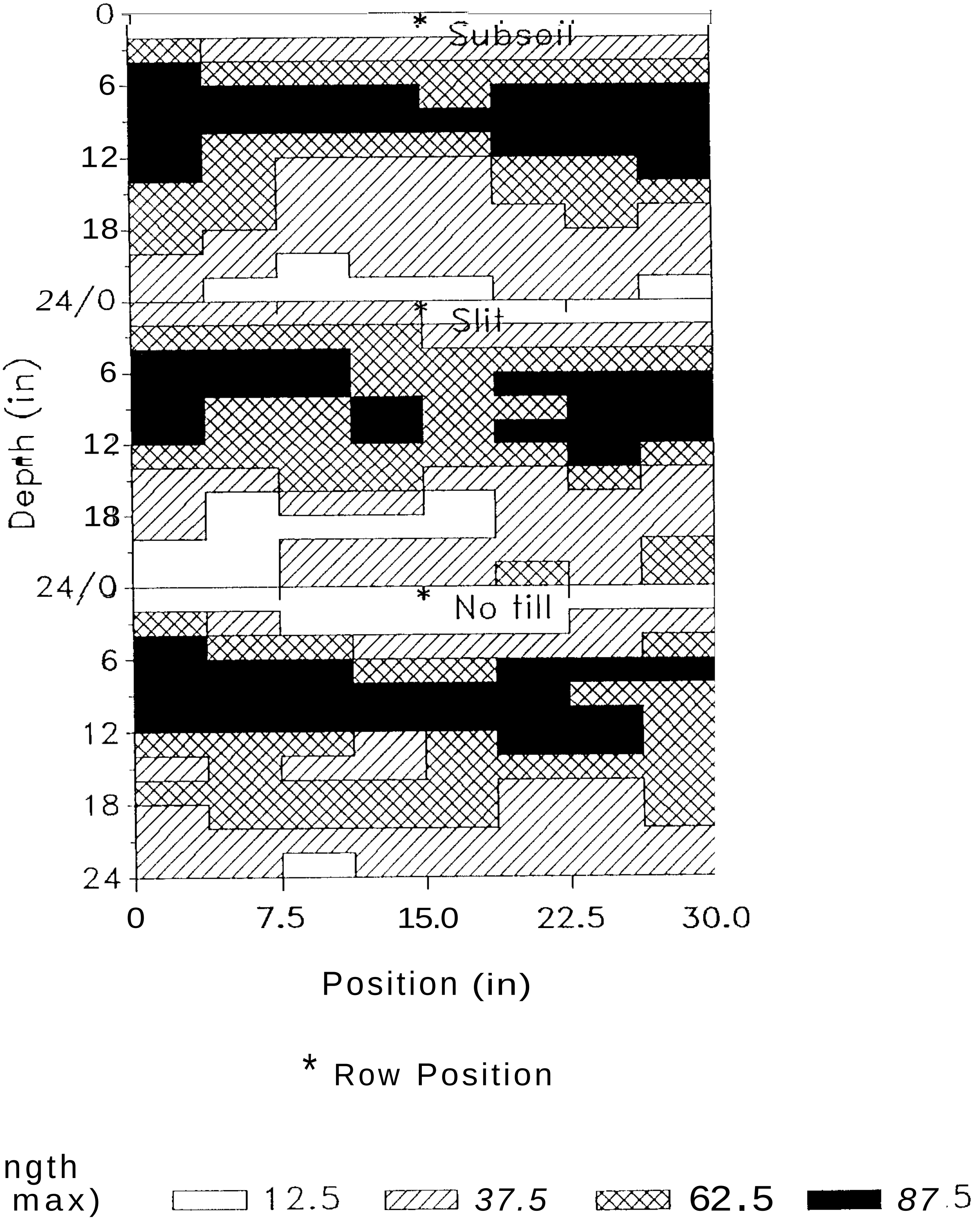


Figure 4. Ranks of Soil Strengths for 1992



slits did not persist in this soil. Observations in the pits that were dug each year showed that most of the slits disappeared after about three years. Despite the lack of tillage and closure of the slits, a few roots were found at a depth of at least 3 ft in each treatment in each of the last three years of the study.

Soil strengths were ranked from highest to lowest and converted to a percent of the maximum. They were illustrated in Figures 3 and 4. Field plots were last tilled in 1989. Figure 3 shows the distribution of the strengths for September 1990, about a year and a half after the most recent tillage. The plot that had been subsoiled still showed the lower strengths below the row and the higher strengths under the mid rows. The slit tillage treatment which was not subsoiled as deeply had a more uniform strength across the profile. By August of 1992, three and a half years after tillage, all of the plots had uniform strengths across the plots and higher strengths within the subsoil pans (6 in to 12 in) than above and below them. From this we speculated that the greater yield of the subsoiled treatment was a result of the larger area of disruption of the subsoil shank when compared to the slit tillage treatment.

Because of the size of the cone (one half inch) used to measure the soil strength, slits (one-eighth-inch wide) could not be measured or seen in the strength diagrams (Figures 3 and 4). Therefore, slits were observed in the faces of the pit walls. Slits did not persist in this southeastern Coastal Plain soil. They disappeared after about three years. However, the lower energy requirement for slit tillage shows that it does have promise as an annual treatment. Its use as a tillage tool for these soils warrants further investigation.

Acknowledgements and Disclaimer

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NITRATE MOVEMENT IN SOUTHEASTERN COASTAL PLAIN SOILS UNDER CONSERVATION-TILLED VEGETABLE PRODUCTION

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ABSTRACT

Movement of soil nitrates by leaching was determined for conservation-tilled vegetable systems in different Southeastern Coastal Plains locations. This study measured soil nitrate-N with depth at planting and after cucumber harvest at Clinton, NC, Florence, SC, and Tifton, GA. Residual soil nitrates were removed by cover crops (both wheat and crimson clover) during the winter and spring growing season. Soil nitrates were greater below the root zone than in the root growing area after vegetable harvest, indicating that some leaching occurred during the summer. Crimson clover residue treatments produced the highest soil nitrates of the three cover treatments at all three locations. Although preliminary, soil nitrate movement affected by treatment during the course of this study has shown similarity among locations by treatment. Climatic conditions and production practices were similar in general, but different enough to affect nitrate leaching rates. Soil taxonomic similarities may predetermine nitrate leaching potential, reducing the need to duplicate nitrate leaching experiments on similar soil types.

INTRODUCTION

Cover crops have been used for recycling nutrients or for N fixation by symbiotic bacteria for cropping systems prior to synthetic N manufacturing in the 1950's (Frye et al., 1985). The use of synthetic N for vegetable production was quickly adopted and the use of cover crops was reduced or eliminated (Hoyt and Hargrove, 1986). Cover crops not only fix and recycle N and other nutrients (Hoyt. 1984). but they also reduce nitrate-N leaching below the root zone during the winter by plant accruement (Ditsch et al., 1993; Hoyt and Mikkelsen, 1991; Morgan et al., 1942). Plant residues are then used as a surface mulch to increase water retention, organic matter, etc. and reduce evaporation, soil erosion, etc. (Gilliam and Hoyt, 1987; Sojka et al., 1991). Few studies have shown soil profile distribution of N fertilizer additions during or after vegetable crop production (Hubbard et al., 1991). Experiments were established to determine the production capabilities of cover crops, tillage reductions, and N rate additions under various environments of the southeastern U.S. This study specifically looked at soil profile inorganic N distribution before and after vegetable crop production over a four year period. This publication reports soil nitrate movement after cucumber harvest in the second year of this study.

METHODS AND MATERIALS

The following field sites were used to compare soil N leaching profiles by geographic and climatic differences among treatment similarities within each location.

CLINTON. NC

This experiment was located near Clinton, North Carolina at the Horticultural Crops Research Station. The field site is in the Coastal Plain on an Orangeburg loamy sand soil series (fine loamy, siliceous, thermic Typic Paleudults).

FLORENCE, SC

This experiment was located near Florence, South Carolina at the Pee Dee Research and Extension Center. The field site is in the Coastal Plain on a Norfolk loamy sand soil series (fine loamy, siliceous, thermic, Typic Paleudults).

TIFTON. GA

This experiment was located near Tifton, Georgia at the Coastal Plain Experiment Station.

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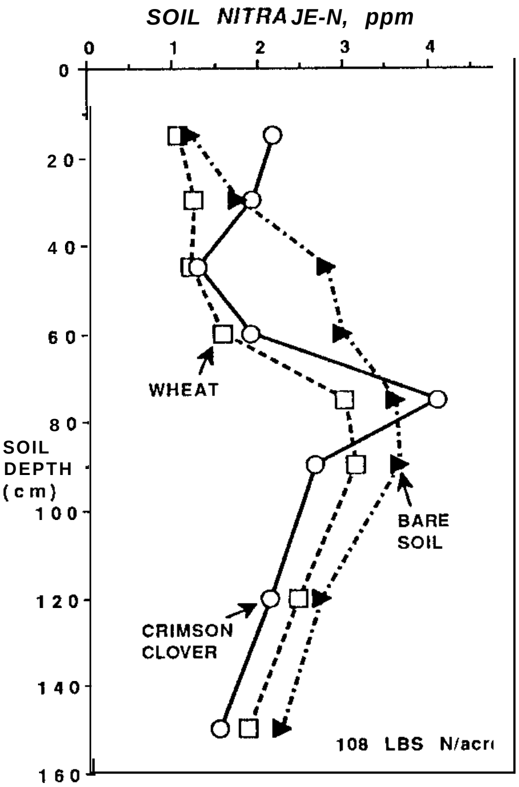

FIGURE 1. SOIL NITRATES BEFORE CUCUMBER PLANTING, FLORENCE, SC, MAY 6, 1992

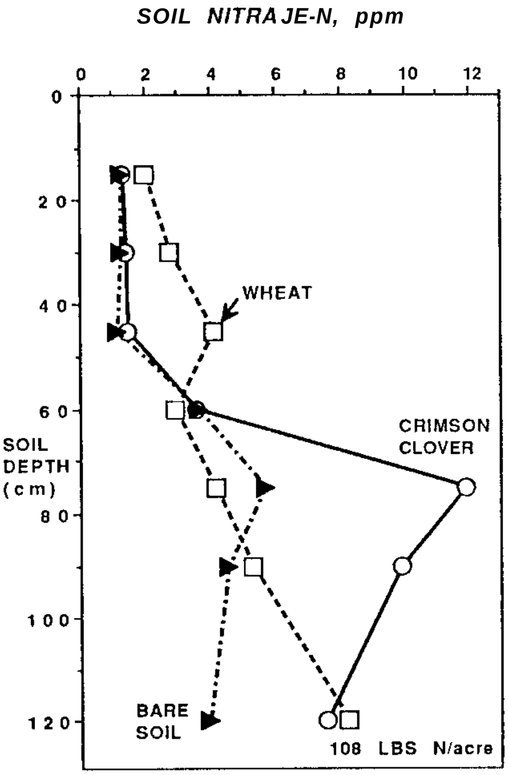

FIGURE 2. SOIL NITRATES AFTER CUCUMBER HARVEST, FLORENCE, SC, AUGUST 26, 1992

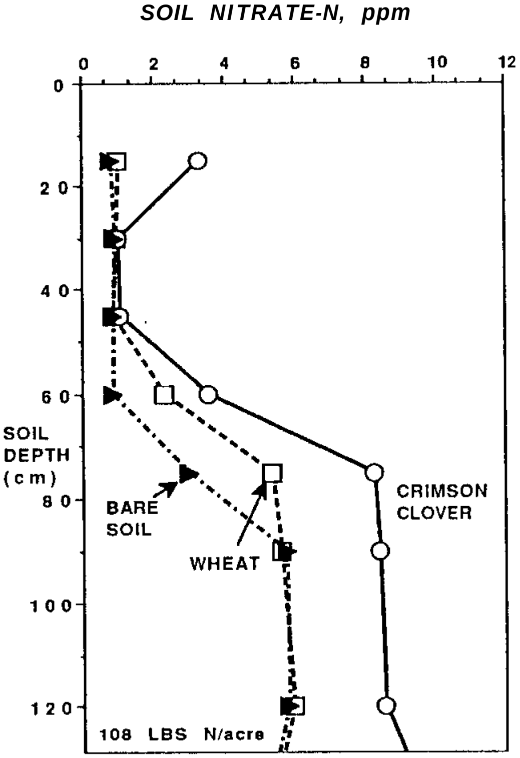

FIGURE 3. SOIL NITRATES AFTER CUCUMBER HARVEST, CLINTON, NC, SEPT. 3, 1992

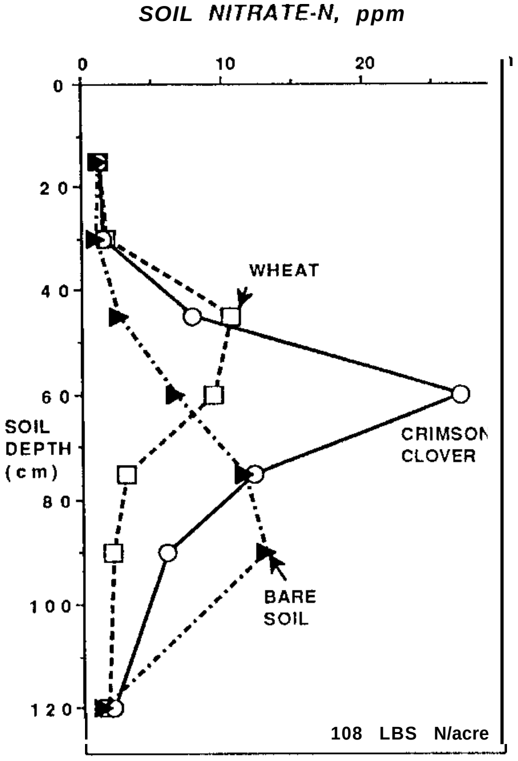

FIGURE 4. SOIL NITRATES AFTER CUCUMBER HARVEST, TIFTON, GA, JULY 16, 1992

The field site is in the Coastal Plain on a Tifton loamy sand soil series (fine loamy, siliceous, thermic Plinthic Paleudults).

Wheat and crimson clover cover crops were planted at each location in the fall of 1990 and 1991 and a bare soil control treatment. Sweetpotatoes were planted (in 1991) in rotation with cucumbers (in 1992). All locations used conservation tillage to plant the summer crop. Three rates of fertilizer at 0, 60 and 120 kg N/ha (0, 54, and 108 lbs N/acre) were applied to each vegetable crop treatment at summer vegetable planting. Soil cores were collected before planting and after final cucumber harvest the second year (Figures 2-4). One soil core was taken from each of the four replicates for each treatment.

All soil cores were taken to a depth of 150 cm using a 5 cm steel tube with a Giddings soil probe. Each soil core was sectioned into the following depths: 0-15 crn, 15-30, 30-45, 45-60, 60-75, 75-90, 90-120, and 120-150. All soil samples were kept cool in the field, then placed in a freezer until extracted. Each soil depth was extracted by weighing 10 g wet weight of thawed soil and shaken for 30 min with 30 ml of 1 N KCI solution. Dry weights *(65°C)* were also taken by gravimetric methods. Extracted soil solutions were analyzed using Technicon Autoanalyzer II spectrophotometer procedures (Technicon Industrial Systems, 1978 a & b).

RESULTS

Soil nitrate measurements before cucumber planting at the Florence, SC location showed that the wheat cover crop treatment removed most of the available soil inorganic-N from the 0-75 cm depth (Figure 1). Below this depth, soil nitrates in the wheat treatment remained lower than the bare treatment. Crimson clover treatment had a higher surface nitrate concentration than the wheat treatment and then a similar but slightly lower nitrate pattern with depth. The bare soil treatment had a greater soil nitrate concentration with depth for most of the soil depths measured. Spring soil nitrates showed similar patterns at the Tifton, GA and Clinton. NC locations (data not shown). Both wheat and crimson clover cover crops removed inorganic nitrogen from the soil profile during the winter and especially during the late spring growing season. The differences in soil nitrate seen between the bare soil treatment and the two cover crops indicated the amount of nitrogen that the cover crop should have accrued into the plant.

Soil nitrates after cucumber harvest at each location showed a similar pattern of soil nitrogen movement by treatments (Figures 241. At each location, soil nitrates were greatest at 60-70 cm depth in the crimson clover treatments. Bare soil tended to have lower nitrates to the 60 cm depth than the two cover treatments. Surface nitrates were low in all locations to the 40 to 60 cm depths. Soil nitrate measurements after harvest showed that crimson clover residues decomposed during the summer and that the cucumber crop did not remove all of the available nitrogen during decomposition. Wheat cover treatments had a slight increase in soil nitrates at many depths over the bare soil treatment at all three locations.

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ROTATING CONSERVATION TILLAGE SYSTEMS: EFFECTS ON CORN AND SOYBEAN PRODUCTIVITY

W. W. Hare and J. H. Grove[1]

INTRODUCTION

Many Kentucky corn and soybean producers have become concerned with improving crop productivity on marginal and sometimes steeply sloping landforms to increase their income. Net income is increased by conservation tillage systems which reduce time and energy requirements, both in terms of labor and fuel consumption (Frye, 1985). Conservation tillage systems leave adequate crop residues to intercept rainfall and also minimize evaporation. This increases soil moisture and reduces soil and agricultural chemical losses to erosion (Seta et al., 1993).

Conservation tillage systems are defined according to the amount of remaining surface residues and the extent of soil mixing. They include no-tillage, chisel, disk, stubble mulch, and rotary tillage (Hayes, 1982a). No tillage has very little or no mechanical mixing of residues or added amendments on the soil surface compared to the other conservation tillage systems. This lack of mixing may cause vertical stratification of immobile nutrients such as P and K. Concerns regard nutrient stratification being coincident with stratification of soil acidity and the possibility for limited nutrient availability in dry years. The latter problem seems most likely when surface residue levels are reduced (Grove, 1986).

Blevins et al. (1986) showed that the upper three inches of no-tillage soil contained twice as much extractable K as that found in the 6-12 inch depth and positively contributed to corn K uptake. Research from the Northern U.S.. however, has shown lower corn uptake of P and K under no-tillage (Randall, 1980; Moncrief et al., 1979). Reasons for reduced uptake were attributed to the colder soil temperatures, reduced diffusion, and lower soil aeration imposed by increased soil density and poor drainage. Tollner et al. (1984) showed that increased soil density also inhibited subsurface root proliferation, hence reducing nutrient uptake. Soil strength and bulk density under no-tillage and conventional tillage systems were not high enough to have an inhibitory effect on plant root growth (Hill et al., 1985).

A summary of yield research data from conservation tillage systems by Hayes (1982) concluded that on soils with little or no slope, there was very little difference between corn yields following moldboard plowing or conservation tillage. One exception was that no-tillage yields were significantly lower on poorly drained soils. No-tillage outyielded conventional tillage where there was considerable slope. For soybean, conventional and other conservation tillage systems yielded higher then no-tillage. Reduced no-tillage soybean yields were associated with lower plant populations and increased weed competition.

Winter cover crops have been used to contribute to nutrient recovery by summer annual crops, especially the legumes for nitrogen (Frye and Blevins. 1989). Potassium is also likely cycled by these winter annual species as it can be taken up by plants in large amounts and does not require mineralization from organic compounds when covers are killed. Eckert (1991) reported that addition of rye cover increased exchangeable potassium on the soil surface. The greater surface residue associated with conservation tillage systems increases organic matter, which has a reduced preference for monovalent cations like K (Grove, 19831.

With the increased surface soil strength and greater nutrient stratification in no-tillage soils, there is interest in determining whether no-till should be rotated with other forms of tillage to provide some mixing and aeration. A study was initiated to evaluate the effect of rotating two conservation tillage systems on corn and soybean yields at different K fertility levels with different winter cover management options.

MATERIALS AND METHODS

Two adjacent areas were subjected to the same treatment protocol on a well drained Loradale silt loam soil (fine silty, mixed, mesic

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Typic Argiudoll) at the Kentucky Agriculture Experiment Station Farm near Lexington, KY. One area was cropped to corn following rye as the winter annual cover and the other area to soybean following wheat. The two crop species and cover crops were reversed over the two areas to give a corn/soybean rotation following rye and wheat, respectively.

The experiment for each area was a split plot laidout in randomized blocks. There was a main plot factorial (2 x 2 x 3) consisting of two types of tillage for current year (no-till vs. chisel plow plus light disk), two types of tillage for the past year (no-till vs chisel plus light disk), and three types of winter annual cover crop management (previous crop fallow vs. cover removed at planting vs. cover killed and left at planting). The combination of past and present tillage results in four tillage rotation treatments: continuous no-tillage, chisel following no-tillage, no-tillage following chisel, and continuous chisel. Sub-plot treatments were fertilizer K rates of 0, 45, 90, and 135 lbs K_2O A^{-1}. Two replications of the randomized block design made a total of 96 plots per area and 192 plots for the two cropping areas in the rotation. Sub-plot size was 12 ft wide by 30 ft long.

Aroostock rye and Verne wheat were planted in mid-October of each year at a 7 inch row spacing at 115 lbs seed A^{-1} using a Lilliston 9680 No-Till drill. Covers were killed in certain plots at the end of March the following year, prior to significant growth, with Gramoxone herbicide to create the fallow no-cover treatment. Cover crops were harvested on the cover removed treatment in mid-April and tillage treatments were performed shortly thereafter. The chisel plow was followed by disking two times. Gramoxone herbicide was again sprayed over the entire area to kill all remaining cover just prior to planting.

Pioneer 3295 corn was planted at the end of April at 23,100 seed A^{-1} using a no-till corn planter set at a 36 inch row spacing. Herbicides for weed control were sprayed at planting. All K treatments and 50 lbs N A^{-1} as NH_4NO_3 were broadcast applied during the first week of May. Shield spraying was for escaped weeds. Another 150 lbs N/A as NH_4NO_3 was applied at the end of May. Sevin insecticide was sprayed for Japanese beetle control in early July. Earleaf samples were taken from each plot at complete silking for analysis. Corn ears were hand harvested the last week of September or in early October from 20 ft sections of the center two rows. Plant counts were taken and the harvested ear weight measured. Five harvested ears were randomly selected, dried, weighed, shelled, and reweighed to determine dry weight, moisture content, shelling fraction and these parameters used in the calculation of grain yield. Yields of corn were expressed at 15.5% moisture. Grain samples were taken for analysis.

Pioneer 9442 (1992) and 9461 (1993) soybean seed were treated with inoculum and planted in late May or early June at 7 seed ft^{-1} in 21 inch rows using the Lilliston 9680 No-Till drill. Weed and insect control measures were implemented according to University of Kentucky recommendations. Leaf tissue samples were taken at growth stage R5 for analysis. The two center rows of each 6 row plot were harvested in early October using a Hege 1258 combine. Soybean grain was dried, weighed, and sampled for analysis. Grain yields are reported at 13.5% moisture.

All grain and tissue samples were analyzed for N, P, and K using wet digestion and atomic absorption spectrocopy for K and micro-Kjeldahl digestion and automated colorimetry for N and P. Results were used to determine plant composition and grain nutrient removal.

Ammonium acetate extractable K was determined on 10 composite soil samples per plot at depths of 0-3, 3-6, 6-9. and 9-12 inches. Samples were taken to include both in- and between- row areas. Soil resistance was measured with a penetrometer at the same depths from which soil was sampled, but also including the surface layer which was also measured from the tip to the top of the penetrometer's cone. Measurements were made at 4 different positions going away from the row in wheel tracked and un-wheel tracked areas within a tillage plot. All data were analyzed using ANOVA in SAS.

RESULTS AND DISCUSSION

Cover crop dry matter production and grain yields were higher in 1992 than 1993 (Table 1). This could be attributed to the higher precipitation during the 1992 growing season (Figure 1). In 1992, K fertility rates did not have

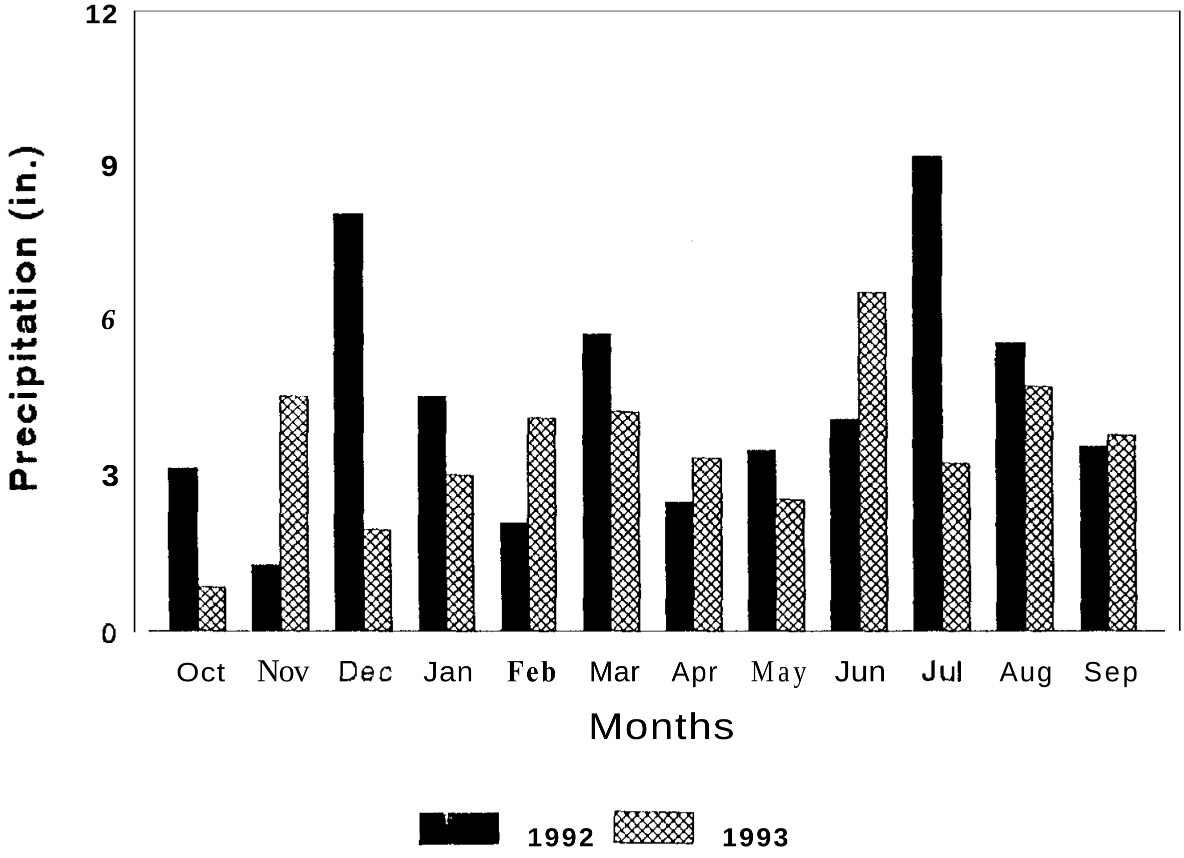

Figure 1. Average monthly precipitation.

a significant effect on rye or wheat dry matter production or on soybean grain yield. However, corn grain yield did increase significantly with increasing K fertility rates (Table 2). In 1993, both corn and soybean yields responded positively to K fertility (Table 3). Cover crop dry matter production did not respond to K fertility in 1993 (Table 3).

Table 1. Average cover crop dry matter production and corn and soybean grain yields.

	---CROP---			
Year	**Rye**	**Wheat**	**Corn**	**Soybean**
	------(lbs/A)-------		--------(bu/A)-------	
1992	2931	4658	185	70.7
1993	1189	3106	156	50.0

Treatments where winter cover was grown (whether cover was left or removed) produced significantly less corn grain than where the area was winter fallowed (Table 2). Lower corn yields could be attributed in part to removal of nutrients in the cover removed treatment and in part to a reduced plant density from a difficult planting operation where the rye cover was left behind. Cover treatments did not have a significant impact on soybean yield in 1992 (Table In). In 1993, both the fallow and cover left treatments contributed to significantly higher corn and soybean yields than the cover removed treatment (Table 3).

Present and past tillage did not have a significant effect on rye or wheat dry matter production or on corn soybean grain yield in 1992 (Table 2). This may be due to the exceptional growing season, where precipitation was higher than normal and largely off set any tillage effects of water availability. Past chisel

Table 2. Management effects on cover crop dry matter production and corn and soybean grain yields, 1992.

	CROP			
Management	Rye	Wheat	Corn	Soybean
	(lbs/A)		(bu/A)	
Fertilizer				
(lbs K/A)				
0	3007a	5336a	174a	68.5a
45	2815a	5174a	183a	69.9a
90	2800a	3638a	198ab	71.8a
135	3102a	4489a	193b	72.7a
Cover				
Fallow	--	--	197a	71.1a
Removed	--	--	177b	70.1a
Left	--	--	180b	71.0a
Past Tillage				
No Till	2882a	4687a	187a	70.5a
Chisel	2981a	4550a	183a	71.0a
Present Tillage				
No Till	3017a	5083a	184a	71.0a
Chisel	2845a	4234a	183a	70.4a

Means in a column followed by the same letter are not significantly different at the 95% level of confidence.

Table 3. Management effect on cover crop dry matter production and corn and soybean grain yields, 1993.

	CROP			
Management	Rye	Wheat	Corn	Soybean
	(lbs/A)		(bu/A)	
Fertilizer				
(lbs K/A)				
0	1067a	3098a	146a	45.9a
45	1267a	3293a	157b	49.7b
90	1167a	2921a	157b	52.0b
135	1253a	3111a	161b	52.2b
Cover				
Fallow	--	--	158a	52.6a
Removed	--	--	148b	46.0b
Left	--	--	161a	51.2a
Past Tillage				
No Till	1131a	2882a	153a	50.4a
Chisel	1247a	3329b	158a	49.3a
Present Tillage				
No Till	1434a	3503a	159a	50.6a
Chisel	944b	2709b	152a	49.3a

Means in a column followed by the same letter are not significantly different at the 95% level of confidence.

and disk produced significantly higher wheat dry matter than no-tillage in 1993. Corn and soybean yields, and rye dry matter production, were not significantly affected by past tillage (Table 3). Present tillage had no effect on corn or soybean yields on this soil in 1993 (Table 3). even though this was a drier season than that observed in 1992. Cover treatments had no significant effect on soil resistance (Table 4). Present year tillage treatments showed significantly different soil strengths as indicated by the penetrometer resistance measurements. No-till soil strength was consistently higher than that under the chisel system. This effect was demonstrated from the surface to a six inch depth in the wheel-track and to 9 inches where not wheel-tracked. Below these depths, there was no difference between the two tillage systems. Continuous no-tillage tended to have the highest soil strength of the tillage rotation systems, while continuous chisel tended to have the lowest. Despite lower compaction where previously no-till plots were

Table 4. Soil resistance as measured by the cone penetrometer, 1992.

	Soil Depth (inches)							
Management	0-3		3-6		6-9		9-12	
	(lbs/in^2)							
	NWT	WT	NWT	WT	NWT	WT	NWT	WT
				Corn Plots				
Cover								
Fallow	85a	115a	83a	117a	98a	131a	128a	133a
Removed	74a	108a	83a	108a	123a	125a	137a	129a
Left	57a	108a	99a	117a	187b	127a	138a	130a
Present Tillage								
NT	107a	128a	109a	124a	123a	131a	135a	132a
CH	49b	92b	69b	103b	104b	125a	133a	129a
Past/Present Tillage								
NT/NT	119a	136a	123a	128a	135a	134a	136a	132a
NT/CH	95a	128a	96a	120a	111a	128a	134a	127a
CH/NT	45b	83b	63b	99b	103a	125a	133a	124a
CH/CH	51b	102b	75b	107ab	104a	126a	133a	140a
Cover								
Fallow	144a	166a	145a	155a	155a	178a	204a	217a
Removed	158a	154a	151a	142a	146a	172a	199a	235a
Left	148a	160a	155a	168a	162a	89a	201a	204a
Present Tillage								
NT	203a	187a	197a	188a	183a	96a	216a	234a
CH	97b	132b	104b	122b	126b	63b	186b	186b
Past/Present Tillage								
NT/NT	199a	182a	196a	196a	182a	192a	210a	233a
NT/CH	103b	136b	116b	122b	133b	160a	196a	208a
CH/NT	205a	193a	197a	179a	182a	199a	222a	233a
CH/CH	90b	127a	91b	122b	119b	164a	179a	198a

Means in a column followed by the same letter are not significantly different at the 95% level of confidence.

NWT - No Wheel Traffic	WT - Wheel Traffic passage
NT - No Tillage	CH- Chisel + disk

Table 5. Tilllage rotation effect on corn and soybean grain yields.

Tillage Rotation	CROP Corn	 Soybean
	(lbs/A)	(bu/A)
Past/Present	1992	
NT/NT	191a	70.3a
NT/CH	182a	70.6a
CH/NT	178a	71.8a
CH/CH	188a	70.1a
	1993	
NT/NT	154a	52.0a
NT/CH	151a	48.8a
CH/NT	164a	49.2a
CH/CH	152a	49.9a

Means in a column followed by the same letter are not significantly different at the 95% level of confidence.

NT- No Tillage CH- Chisel plus light disk

chiseled, rotating conservation tillage systems did not significantly affect cover dry matter production nor grain yields in either years (Table 5).

CONCLUSION

Cover crop dry matter production and grain yields were higher in 1992 than in 1993 due to higher precipitation during the growing season. Increasing K fertility increased grain yields, especially during the dry year. Cover left on the surface contributed to the nutrition in both years (data not shown), but reduced stands due to difficult planting operations that affected grain yields by reducing plant densities. The fallow cover treatment produced high corn and soybean yields in both years. Tillage rotation was not beneficial to cover crop dry matter production or to corn or soybean grain yields despite lower compaction where no-till soils were chiseled. Continuous no-tillage with fallow or winter cover residues left at planting would be the most economical system as it produces high corn and soybean yields, saves labor and fuel consumption, and reduces soil losses.

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COMPARISON OF TILLAGE METHODS ON PEARL MILLET AND TROPICAL CORN FOR SILAGE AND GRAIN

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and Brian T. Kidd[1]

ABSTRACT

Pearl Millet *(Pennisetum americanum* (L) Leek) and tropical corn *(Zea may* L.) can be grown for silage and grain in multicropping systems and can be used after winter crops when it is too late to plant temperate corn. This research was done to compare yields and quality components of these two crops for grain and silage in strip and conventional tillage systems. The research was conducted in **1992** and **1993** years on a Norfolk sandy loam soil at The North Florida Research and Education Center, Quincy, Florida using HGM - **100** Hybrid pearl millet hybrid and Pioneer brand **3072** tropical corn. Both corn and millet growth in the strip till system gave a higher yield of fresh silage than in the conventional system (corn **35680** lb./acre and 31220 lb./acre, and millet 48168 lb./acre and **42816** lb./acre, respectively). However, the fresh matter had less dry matter in the strip till system as compared to the conventional planting and dry matter yield was not different statistically (corn **11328** lb./acre and **10882** lb./acre; millet **11774** lb./acre and **12042** lb./acre, respectively). The fresh matter yield of millet was higher **(45492**lb./acre) than corn **(33004**lb./acre) but dry matter was not different **(11060** lb./acre and 11596 lb./acre). Tillage system did not influence the neutral detergent fiber content of either crop but in vitro organic matter digestibility was higher in conventional planted millet but not different in corn. Tillage system did not influence the grain yield of millet and corn. Grain yield of corn was higher (81.9 Bu/acre) than millet (64.7 Bu/acre).

INTRODUCTION

Pearl millet is a high-quality productive grain or silage crop (Burton et al., **1986** and Kumar et al., 1983), which appears superior to sorghum *(Sorghum bicolor* L. Moench) in establishment (Smith et. al.. **1989b)** and production under limited soil moisture (Smith et al., **1989a).** Critical growth stages receiving stress were flowering and grain fill. Grain yield and grain number, but not grain size are affected by time of stress onset in relation to flowering. Effects of time of stress are also dependent on the intensity and duration of the stress period (Mahalakshmi and Bidinger, **1985).** Bationo et al. **(1990)** showed that increasing fertilization and plant density, increased grain yield of pearl millet in average or wet years and slightly reduces yield in a drought year. Pearl millet is 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).**

Tropical corn has become an important alternate crop in the southern United States in the past few years. It has been estimated that over 50,000 acres were grown in **1991,** mostly for silage. Tropical corn serves as an alternative crop to soybeans *(Glycine max* L.), grains sorghum and temperate corn. Research with corn grown in conventional-tillage systems has generally shown the benefit of delaying application of the majority of N fertilizer until 4 to **6** weeks after planting (Jung et al., **1972;** Bigeriego et al., 1979; Welch et al., 1971). Delayed applications of **N** has also been shown to increase **N** efficiency of corn in no-till systems (Fox et al., 1986; Frye et al., 1981).

Soil erosion is a function of vegetative cover, crop residue and degree of surface roughness (Johnson et al., 1979; Sloneker and Moldenhauer, 1977)c conservation tillage systems such as strip tillage can aid in maintaining cropland productivity. Wagger and Denton (1989) reported consistent yield increases of **8** to **67** % in corn and **36** to **55%** in soybean with strip tillage compared to conventional tillage systems in the Piedmont region of North Carolina. They noted greater soil water availability with strip tillage and attributed it to reduced runoff. Residue cover Improves infiltration of rainfall by protecting the soil against rain drop impact and subsequent crusting and slowing the velocity of runoff

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Table 1. Influence of tillage systems on parameters of Tropical corn, 1992-1993.

Parameter	Tillage system	1992	1993	Mean
Height of plants (ft)	Conventional	6.76a	6.56a	6.66a
	strip till	6.72a	6.80a	6.76a
Thickness of stalk (inch)	Conventional	0.86a	0.86a	0.86a
	strip till	0.84a	0.86a	0.85a
Weight of wet roots (lbs)	Conventional	0.20a	0.45b	0.33b
	strip till	0.23a	0.72a	0.47a
Weight of dry roots (lbs)	Conventional	0.10a	0.16b	0.13a
	strip till	0.11a	0.30a	0.21a
Weight of 200 kernels (gms)	Conventional	48.45a	60.19a	54.32a
	strip till	43.67a	59.86a	51.77a
% Moisture	Conventional	42.99b	84.55a	63.77a
Bu/A - Yield	strip till	43.40b	79.22a	61.31a
Number of plants/A	Conventional	17657a	16698a	17177a
	strip till	20130a	14885b	17507a

Numbers in the same column for each separate parameter followed by the same letter indicate no difference as determined by LSD comparison at 5% level of probability.

(Denton and Cassel, 1989). Winter annual cover crops provide plant canopy cover and root mass to hold soil during the winter and spring months, which effectively reduces the soil erosion potential (Hargrove et al., 1984). In strip tillage systems, the winter crop residue remaining on the soil surface after the summer crop is planted, can serve as a moisture-conserving mulch that can considerably increase yields (Moschler et al., 1967). This research was done to compare two relatively new alternate crops in conventional vs. strip-tillage plantings for silage and grain.

MATERIALS AND METHODS

These studies were conducted 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 in this study was the W.W. Hanna developed hybrid from Georgia-Agra Tech HGM-100 and tropical corn was Pioneer brand 3072.

The experiment was conducted on a winter fallow field. The experimental design was a split plot with 4 replications with corn or millet being the main plots. Plots were 8 rows wide by 30 feet long with 10 ft. spaces between plot and tillage treatments being the sub plots. Before starting the experiment, the field was mowed and the conventional section was chisel plowed on May 12 and s-tine harrowed. On May 18 the entire study area was irrigated and on May 21 s-tine harrowed again. All plots were planted using a Brown-Ro-Till with in-row subsoiling and KMC planters. Row spacing was 3 feet. Seeds of millet were planted 1/4 inch deep at 6.0 lbs/A and tropical corn seeds were planting 3/4 inches deep and 20,000 plants/A. On May 22 Roundup was applied at 32 oz./A for weed control in the strip till section. Corn emerged on June 2 and Atrazine at 2.0 Ib./A and Dual at 2.0 pt./A were applied on June 5 for weed control. The emergence of millet was not uniform therefore the stand was treating with Gramoxone Extra 2.0 pt./A and Atrazine 1.5 Ib./A to kill the existing stand. On June 10 millet was replanted and both crops were irrigated with 1" of water. Starter fertilizer, 50 lbs/A ammonium nitrate + 50 lbs/A 4-18-6 N-P-K, was applied beside rows at planting followed by 100 lbs/A N as ammonium-nitrate when corn and millet were **5-7"** tall. Millet was harvested for silage 75 days after planting and corn at 35 ***Yo*** dry matter. Grain was harvested from both crops when moisture dropped below 20 ***Yo.***

RESULTS AND DISCUSSION

Tillage did not influence height or stalk diameter of corn [Table 1). Tropical corn grown in the strip till system had a bigger mass of wet and dry roots (Table 1). Number of plants of corn were higher in the conventional system than with strip tillage while kernel weight, moisture and grains yield were not different (Table 1).

Theoretical grains yield of millet were calculated based on the regression equation $y = -0.0317 + 0.0048x$ where y = pearl millet head yield in Ib./head and x = head length in inches (Wright, et al., 1994) because of bird damage. There was no difference between strip till and conventional plantings. Millet tended to have a higher number of heads per unit area in strip tillage, and longer heads in conventional tillage and grain yield was higher for millet in the strip till system but only plant height was significantly different (Table 2).

The fresh silage matter yield was different between corn and millet and between conventional and strip till plantings. Millet had the highest fresh silage yield from strip till (48168 Ib./acre), followed by millet conventionally planted (42816 Ib./acre) and then strip till corn (35680 Ib./acre), with the lowest being conventional corn 131220 Ib./acre) (Table 3). However, ***Yo*** dry matter was inversely related to yields of fresh matter. The highest ***Yo*** dry matter was for corn planted conventionally and the lowest for millet planted with the strip till system (Table 3). This resulted in there being no difference in dry matter yields between crops or tillage systems (Table 3). Both millet and corn yield grown in the strip till system were not different from conventional plantings in yield and most measured parameters. However silage moisture was higher for both crops in the strip till system.

Table 2. Influence of tillage systems on paramters of Pearl millet, 1993.

Parameter	Tillage system	Mean
Height of plants (ft)	Conventional	5.8b
	strip till	6.3a
Length of heads (inch)	Conventional	12.7a
	strip till	12.5a
Number of heads/A	Conventional	118100a
	strip till	124400a
Yield in Bu/A	Conventional	63.0a
	strip till	66.3a

Numbers in the same column for each separate parameter followed by the same letter indicate no difference as determined by LSD comparison at 5% level probability.

Table 3. Comparison of Tillage Methods on parameters of Pearl millet and Tropical corn

Parameter	Tillage system	Corn	Millet	Mean
Yield of fresh silage in lb/A	Conv.	31220d	42816b	37464b
	No-till	35680c	48168a	41924a
		33004b	45492a	
Yield of dry silage in lb/A	Conv.	10882b	12042a	11507a
	No-till	11328ab	11774ab	11507a
		11061a	11864a	
% dry matter	Conv.	35.6a	27.8c	31.7a
	No-till	31.5b	24.3d	27.9b
		33.5a	26.1b	
% organic matter	Conv.	95.1a	92.2b	93.7a
	No-till	94.6a	91.6b	93.0a
		94.8a	91.8b	
In vitro organic matter digestibility (5)	Conv.	63.5a	50.7b	57.1a
	No-till	62.1a	43.9c	53.0a
		6328a	47.3b	
Neutral detergent fiber total (%)	Conv.	63.3a	66.0a	64.8a
	No-till	63.5a	67.0a	65.2a
		63.6a	66.5a	
% neutral detergent fiber ash free	Conv.	63.5a	65.1a	64.3a
	No-till	63.9a	66.6a	65.2a
		63.7a	65.8a	

Numbers in the same column and row for each separate parameter followed by the same letter indicate no difference as determined by LSD comparison at 5% level of probability.

Laboratory analysis showed that % organic matter, % neutral detergent fiber total (% NDFt) and % neutral detergent fiber ash free (NDFaf) were not different between tillage systems or crops (Table 3). However. organic matter and in vitro organic matter digestibility were higher for corn than for millet (Table **3**). Higher digestibility was expected with corn because of the higher grain content. Tillage did not influence in vitro organic matter digestibility in corn but strip till millet was lower (43.81 as compare to millet grown conventionally (50.7) (Table 3).

CONCLUSIONS

1. Grain yield of corn was higher in 1993 than grain yield of millet, tillage did not influence grain yield of corn or millet.

2. Green forage was different with tillage and was higher on both crops in the strip till system and was higher for millet than for corn.

3. Dry matter yield of conventionally planted millet was significantly higher than dry matter yield of conventionally planted corn.

4. Organic matter content was higher for corn than for millet.

5. There was a trend for higher root weight of tropical corn in strip till in 1992 and was significantly higher in 1993 than conventional planted corn.

6. IVOMD % of corn was not influenced by tillage but was lower with strip till millet than conventional planted millet.

7. NDF % was not different with tillage.

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TRAFFICABILITY AND ROOTING DEPTH COMPARISONS BETWEEN NO-TILL AND TILLED SOYBEANS

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ABSTRACT

No-tillage production has gained increased popularity in Tennessee due to the following reasons: demand to meet conservation compliance requirements, less time spent in spring planting operations, savings in fuel and labor and improvements in weed control in no-till agriculture. Differences have been measured in soil properties between no-till and conventional tillage. These differences raise concerns about how they affect plant growth and rooting. This experiment was designed to evaluate soybean root distribution under conventional (CT) and no-tillage (NT), to evaluate trafficability of conventional and no-tillage and to evaluate the effect of trafficking on soybean root distribution. The experiment was conducted on long term tillage plots of Lexington silt loam (fine silty, mixed, thermic, Typic Paleudalf) at the West Tennessee Experiment Station at Jackson, Tennessee. Experimental design was a randomized complete block with tillage as the treatment, set up with four replications in 1992. In 1993, the design was a randomized complete block with split plots. Tillage was the whole plot treatment and traffic was the subplot treatment. There were four replications. Soybean root distribution was evaluated using minirhizotrons. Trafficking was done in 1993 using a tractor and evaluated by measuring changes in soil surface profile and bulk density. In 1992, there were no differences in root, distribution until late in the season. In 1993, at 30 days after emergence, no-tillage had greater root length at shallow (< 10 inches) depths and conventional tillage had greater root length below 10 inches. At 60 days after emergence, there were no differences in root length between tillage by depth. At 30 days after emergence, there were greater root lengths within- row in the trafficked zone of the traffic treatment, and by 60 days after emergence there were no differences in root lengths related to traffic. The no-tillage had greater trafficability, as indicated by less soil displacement, and lower bulk density increases than conventional tillage. Due to high soil displacement in conventional tillage from trafficking, soil leveling was required. In 1992, no-tillage had greater yields than conventional tillage. There were no differences in yields from tillage or traffic in 1993. There were no agronomically significant differences observed in yields or root lengths from tillage or traffic in this study.

INTRODUCTION

The ability of the soil to support weight, especially heavy equipment Itrafficability) without compaction and/or rut formation has been observed to differ depending on the tillage systems used. No-tillage INTI seems to greatly increase trafficability even under excessively wet soil conditions.

The effect of no-tillage on soil properties such as bulk density and aggregate stability may partly explain possible changes in soil structural stability. The effects of no-tillage on bulk density have been variable depending on soil type and tillage system with higher (Rhoton, 1993) or very little differences in bulk density measured (Blevins et al., 1983). Changes in bulk density and penetrometer resistance, as a measure of soil compaction may not indicate the need for deep-tillage for maximum yields (Tyler and McCutchen, 1980: Tyler et al. 1983: Bicki and Siemens, 1991). This seems to be especially the situation on medium-textured soils. In contrast, on many soils in the coastal plain, especially the sandier soils, in the southeastern U.S., increases in bulk density and penetrometer resistance can indicate sufficient compaction to reduce yields (Denton et al., 1986; Wagger and Denton. 1989).

In conjunction with bulk density, soil aggregate stability is also affected by different types of tillage systems. It has been found to improve under no-tillage (Kladivko et al., 1986; Sutarman, 1991).

No-tillage systems also result in less trafficking due to fewer equipment passes. This can allow more timely equipment operations that avoid trafficking when the soil is too wet. Observations of improvement in soil structural

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stability with no-tillage as compared to tillage under adverse wet soil conditions was one impetus for this study. The dynamics of rut formulation and subsequent effects on soybean rooting between the tillage systems was also studied. Rooting patterns were evaluated using minirhizotrons (Brown and Upchurch, 1987).

MATERIALS AND METHODS

Tillage Experiment

The experimental plots used in this study were established in 1979 at the West Tennessee Experiment Station, Jackson, Tennessee as part of a long term tillage study. The soil is a Lexington silt loam, a fine silty, mixed, thermic, Typic Paleudalf.

Four replications of two tillage treatments were used in this study. The plots consist of eight 30 in. wide rows, 40 ft. long. One treatment has been continuously moldboard plowed (CT) to a depth of 10 inches followed by disking to a depth of 4 inches each season since 1979. Single-crop soybeans have been planted each season in mid-May. No winter cover crop was present. The other treatment was no-tillage single-crop soybeans (NT) planted in previous soybean crop residue each season since 1983. Details of treatments on these plots prior to 1983 are given in Tyler and Overton (1982) and Tyler et al., (1987). In 1992, soybeans were planted on 18 June. In 1993, soybeans were planted on 7 June. The variety used was TN-486 both years, planted at 160,000 plants/acre. Weed control used was 0.63 lb ai acre paraquat, 0.37 lb ai acre 6:l ratio of metribuzin and chlorimuron and 2 lbs ai acre alachlor with 0.25% vlv nonionic surfactant prior to planting both years. Post-emergence grass control was accomplished using 0.12 lb ai acre clethodim applied with 0.25 gal acre-' crop oil concentrate.

Wet Trafficking

Trafficking was done on 4 May 1993, after 3 inches of rainfall in the previous two days, with a John Deere 4455 tractor that weighed approximately 8.9 tons. The tractor was equipped with Goodyear Special Sure Grip TD8 20.8R38 rear tires. The original intention was to impose traffic in the late fall following harvesting or during winter, but there was not a large enough rainfall event in that time to sufficiently wet the plots for trafficking. The CT plots were disked twice on 19 April 1993 to simulate tillage before planting. The trafficking was done between row 1 and 2 and 3 and 4 on one half of the plots. Ruts from the trafficking were measured with a pin drop profile meter for measuring irregular surfaces. Prior to trafficking, base pins were driven in to hold the profile meter. An undisturbed cross sectional profile was taken at four locations on each side of the split plots. Height of the drop pins was recorded on a paper chart before trafficking. After the trafficking was done, the new surface was remarked on the same chart. The charts were then put on a digitizing tablet and the points were digitized into a computer and put into a spreadsheet so they could be graphed. Graphs of the before and after profiles were printed and overlaid and the area of soil displaced and heaved during trafficking.

Root Measuring Technique

The polybuterate minirhizotron tubes were 2 in. inside diameter and 4.3 ft. in length. They were installed at a 30° angle from vertical, parallel to row position to a depth of 3.3 ft. The tops of the tubes were wrapped in electrical tape and capped with a PVC cap to prevent surface light from entering the tube. Tubes were installed in probe holes in rows 2, 3, 6, and 7 of each plot in 1992. The probe holes were made with a Concord hydraulic probe mounted on a 100 horsepower tractor. In 1993, CT plots were disked after trafficking to smooth them for planting. The 1993 rows were then planted directly above the tracked zones by offsetting them half of a row width from their 1992 position. The tubes from the 1992 installation were left intact from the previous year, and after row offsetting were between the new rows. Tubes were installed in the new row positions.

The camera used was a Bartz color fiber optic camera with white and UV light that was linked to a VHS recorder/player and a television for monitoring the recording. In 1993, the camera was linked to a Sony Super Eight video camera for recording. The Super 8 cassettes were then transferred to VHS for evaluation. Readings were taken at 2 inch depth increments in the tubes and recorded on VHS tape. Four readings were taken at each depth by rotating the camera 0, 90. 180, and 270°. The 0° reading was oriented toward the soil surface. They were measured using a LASICO model 71A linear probe, by frame advancing the VCR and a 19-inch color television. A piece of plexiglass was placed over the television screen to prevent slippage of the linear probe wheel. Relative length values were determined by tracing the roots on the television screen. These values were used for the statistical analysis. Emergence date in 1992 was 23 June and measurements were taken on 7 July, 6 August and 24 September, 14, 44, and 93 days after emergence respectively. In 1993, emergence was 11 June and measurements were taken on 12 July and 10 August, 31 and 60 days after emergence respectively. A later measurement was not taken in 1993 because plants were at or near physiological maturity and roots would soon start to disintegrate as was determined in 1992 from the late reading. Selected root measuring dates are discussed in this paper.

Yields

Soybeans were harvested with a plot combine. The rows harvested in 1992 were the two middle rows of each plot. In 1993, the harvested rows were the rows oriented over the traffic tracks and corresponding untrafficked rows on each split-plot of each tillage treatment. Both year's yields were adjusted to 13% moisture.

RESULTS AND DISCUSSION

At 44 days after emergence in 1992 tillage had no significant effect on soybean root length (Figure 1.). The majority of observed roots were at depth of 10 to 20 inches. This distribution is similar to that of Upchurch and Ritchie (1983) with lower than expected densities at shallower depth. This is due to the minirhizotron method underestimating roots length at depths down to about 8 inches. At depth below 8 inches, the minirhizotron method results in similar data to that obtained from soil cores (Upchurch and Ritchie, 1983).

Trafficking and Rooting

Trafficking was done on May 4, 1993 after a total of about 3 inches of rain the previous two days. After trafficking, there were very obvious difference in the soil surfaces (Figure 2). No-till plots did not look any different than before trafficking under visual observation. Conventional tillage plots had a large amount of

Table 1. 1993 Soybean Root Lengths Within the Row for Tillage and Traffic Treatments 31 Days After Emergence Averaged Across Depth.

Tillage	Trafficking	Root Length cm roots cm'' soil
Conventional	No	0.36
Conventional	Yes	0.45
No-Tillage	No	0.27
No-Tillage	Yes	0.45

Table 2. Surface Bulk Densities by Tillage and Traffic Combinations.

Treatment	Bulk Density $Mg\ m^{-3}$
Conventional Tillage Trafficked	1.61a
No-Tillage Trafficked	1.46b
Conventional Tillage No Traffic	1.45b
No-Tillage No Traffic	1.38c

Bulk densities with the same letter are not different a $P \geq 0.05$.

Table 3. Soybean Yields by Tillage and Traffic 1993.

Tillage	Trafficked	Yield bu acre-'
Conventional	Yes	19
Conventional	No	19
No-tillage	Yes	16
No-tillage	No	18
		NS

No significant differences when tested at a = 0.05.

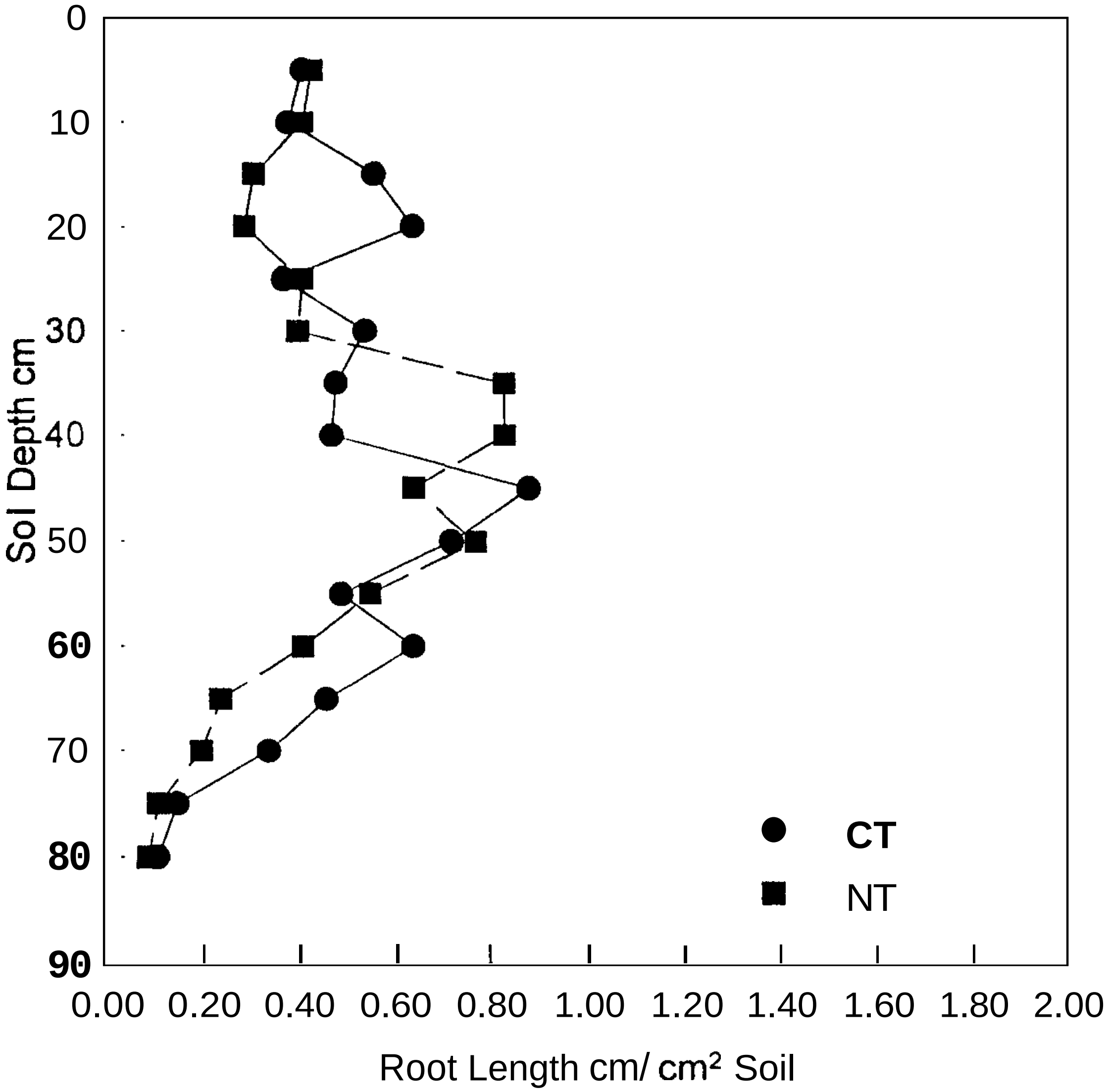

Figure 1. Soybean root length by soil depth, conventional vs no-tillage 44 days after emergence.

soil displaced and had to be disked before they were suitable for planting. At 31 days after emergence, average root length was greater in the trafficked as compared to non trafficked treatments (Table 1). Voorhees (1992) observed similar distributions of greater root density under the row in compacted conditions under CT.

The amount of soil displaced by trafficking was also significantly affected by tillage. Trafficking in CT plots displaced an average cross-sectional area of 38 sq. inches from the original soil surface profile (Figure 2). NT only averaged an area of 8 sq. inches of displaced soil. This displaced soil is the cross sectional area of the track below the original surface that was removed and does not include the heaved soil. The average rut on CT plots was about 26 inches across from peak to peak of the heaved soil, 19 inches across on the inside of the heaved soil and about 6 to 7 inches deep measuring from the top of the heaved soil to the bottom of the rut. The NT plots had only lug marks in the soil from the tractor tires as visible evidence of the trafficking.

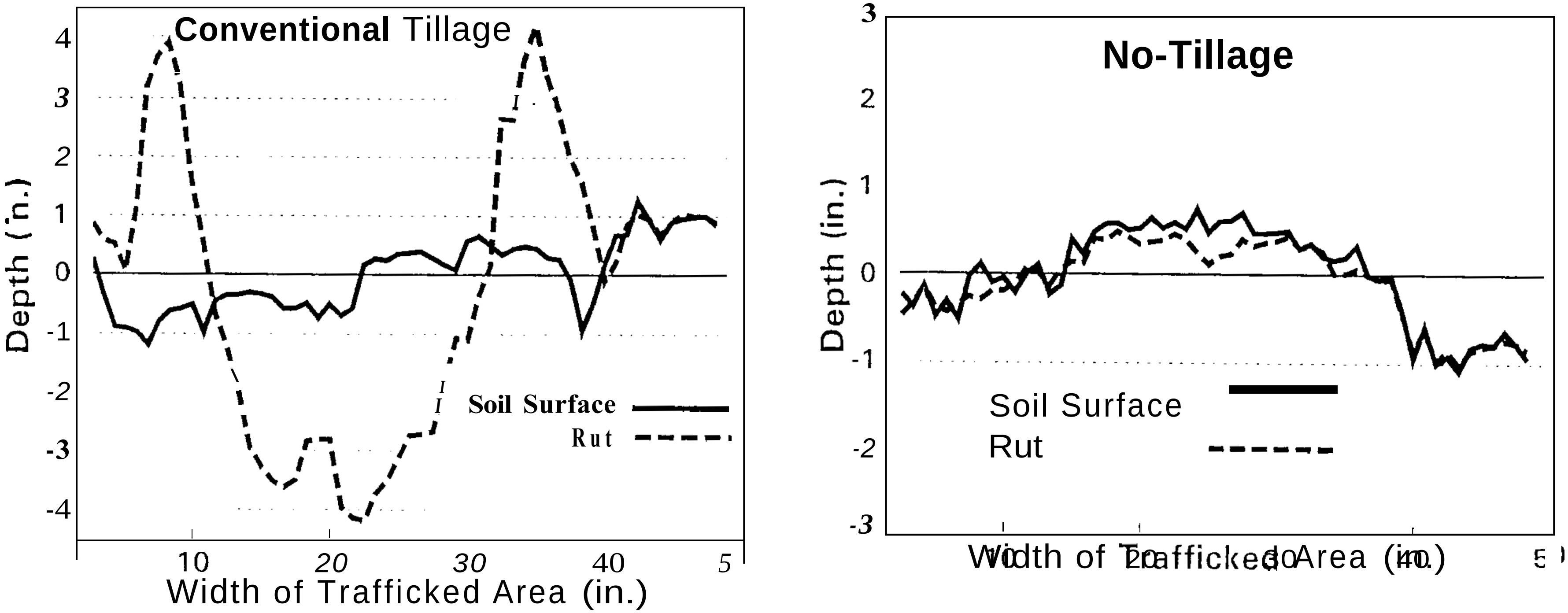

Figure 2. Row areas in conventional and no-tillage as measured by a rill meter before and after trafficking.

An area of soil equal to about 64% of the area of soil displaced was heaved up higher than the original soil surface on the side of the tire ruts in the CT plots. If the bulk density of the heaved soil was the same as the original soil then 36% of the soil displaced was accounted for by compaction to the bottom and sides of the rut. Assuming the heaved soil had a lower bulk density than the original soil, due to the many large cracks in the heaved soil, more than 36% of the soil displaced ended up being compacted.

Differences in tillage response to traffic may be attributed to differences in structural development and aggregate stability in the surface horizons associated with the tillages (Sutarman. 1991). Under NT conditions there is greater structure development and aggregate stability near the surface (Sutarman, 1991; Kladivko, 1986; Blevins, 1983). This increased structural stability in NT allowed the tractor to travel across the soil without deformation and soil displacement. No-till has a greater ability to handle traffic under wet conditions due to better structural development and aggregate stability of the soil surface.

Surface Bulk Densities

Conventional tillage had greater bulk density with no trafficking than NT. Trafficking significantly compacted CT soil from 1.45 to 1.61 mg m^{-3}, more than NT soil. from 1.38 to 1.46 Mg m^{-3} (Table 2.). Bulk density in CT may have been greater than NT because it had recently been disked twice. These differences in bulk density were statistically different, but from a soybean root distribution standpoint were not inhibitory. In some cases, 31 day after emergence the areas of higher bulk density had a greater root density than the areas of lower bulk density. Sixty days after emergence the differences in root distribution due to compaction had disappeared. Voorhees (1992) and Fausey and Dylla (1984) observed similar results in traffic compaction studies on soybean root distribution. There was no observed inhibition of soybean roots from the increases in bulk density from trafficking or tillage.

Yields

In 1992, a year with good rainfall, NT had significantly greater yields than CT. No-tillage averaged 44.6 bu/acre while CT averaged 38.7 bu ac^{-1}. These results are similar to those of Tyler and Overton (1982). and Tyler et al., (1983). Significant yield differences have varied over year between NT and CT. Some years NT may have slightly greater yields and other years there may be no difference in yield (Tyler and Overton, 1982). In 1993, a year of low rainfall, there were no significant differences in yield between CT and NT. CT averaged 19 bu ac^{-1}, while NT averaged 17 bu ac^{-1}. There were also no differences in yields due to traffic. The lack of differences due to traffic indicates that the differences in bulk densities and root distributions observed from the trafficking were not detrimental to yields.

SUMMARY AND CONCLUSION

There were no differences related to tillage in root distribution early in the season in 1992. In 1993, there were differences in root distribution. At 31 days NT had greater root length at shallow depth (< 10 inches) than CT (data not shown). At 60 days there were no differences between NT and CT by depth (data not shown). There was a slight increase in roots above 20 inches at 31 days in the trafficked treatment. By 60 days there was no difference between trafficked and non-trafficked treatments in the top 20 inches of soil. There is no evidence of tillage or trafficking being detrimental to root growth and development.

Increased aggregate stability and better structure development (Sutarman, 19911 apparently led to greater load bearing and better trafficability under wet conditions. NT tractor tracks only had an average cross section area of 8 sq. in^2 of soil displaced while CT had an average cross sectional area of 38 sq. in^2 of soil displaced. Further tillage was required after trafficking CT before planting was possible. Further operations were not needed under the NT conditions. CT had greater increases in bulk density from trafficking. In 1992, NT had greater yields, but in 1993, there were no differences in yields. Neither tillage nor trafficking had detrimental affects on yields or root development in this study. NT had much better trafficability under wert soil conditions as compared to CT.

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WHEAT RESPONSE TO VARIOUS ROW SPACINGS IN RELAY INTERCROPPING SYSTEMS

P.M. Porter and A. Khalilian[1]

INTRODUCTION

In the southern USA there is considerable research interest in relay intercropping of soybeans and cotton into wheat before harvest. Sequentially doublecropped soybeans or cotton after wheat harvest delays the planting of those crops, and can result in poor stands (Beatty et al.. 1982) and reduced yields (Coale and Grove, 1990; Garner et al., 1992). Numerous relay intercropping systems involving different planting schemes and associated equipment have been developed and successfully tested (Hood et al., 1991). The systems usually involve controlled-traffic for planting, fertilization, pesticide applications, and wheat harvest. Because controlled-traffic causes soil compaction only in non-cropped traffic lanes, spring tillage operations usually necessary on Coastal Plain soils before planting the summer crop are not required, resulting in the potential for reduced fuel requirements (Khalilian et al., 1991a and 1991b) for the intercropping system as compared to conventional doublecropping systems Elimination of tillage operations prior to summer crop planting and inhibition of weed emergence by shading from the wheat crop can reduce herbicide inputs for the summer crop in the interseeding system (Buehring et al., 1990; Khalilian et al., 1990).

Clemson University has been developing equipment and planting schemes to interseed soybeans and cotton into standing wheat using controlled-traffic production methods since 1985. Hood et al. (1992) describes the evolution of the Clemson Interseeder. a planter which can be modified to plant wheat, cotton and soybeans with a variety of row spacings

One of the problems in conducting controlled-traffic operations is that the wheel spacings can vary for the equipment employed for planting, combining, and fertilizer and pesticide applications. Many farmers in the Southeast currently are using tractors with a 1.93 m center wheel spacing and combines with a 2.44 m center wheel spacing.

One interseeding scheme employs 1.93 m wheel centers to match the wheel traffic of many of the tractors currently used in the Southeast as well as several models of older combines. This planting scheme provides for planting 11 rows of wheat spaced 33.0 cm apart with two zones of 61.0 cm provided for the tractor, interseeder and combine wheel traffic. With this system, up to eight rows of soybeans or four rows of cotton can be planted (Fig. 1a). The cotton can be picked with a conventional 96.5 cm four-row cotton picker.

Several newer model combines use a wheel center spacing of at least 2.44 m., and thus another interseeding scheme was designed to accommodate those combines (Hood et al., 1992). This scheme involves planting 14 rows of wheat with 5 row widths of 30.5 cm to accommodate the interseeding of 5 rows of cotton or soybeans, 2 row widths of 61.0 cm to accommodate the tractor, interseeder and combine wheel traffic zones, and 7 row widths of 15.2 cm (Fig. 1b).

This study compared the yield and yield component response of wheat produced with these interseeding production schemes to the yield and yield component response of conventionally grown wheat.

MATERIALS AND METHODS

The study was conducted at the Edisto Research and Education Center near Blackville, SC, on a Varina loamy sand. It involved four planting systems with six replications in a randomized complete block design. Treatment descriptions are detailed in Table 1. Treatment A involved conventionally planted wheat with row widths equally spaced. Treatment **B** utilized the Clemson Interseeder and the 11-row planting system (Fig. 1a). Treatments C & D utilized the Clemson Interseeder and the 14-row planting system (Fig. 1b). A paraplow and French Durou plow was employed for deep tillage prior to wheat planting for treatments C and D,

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Table 1. Treatment descriptions of a two-year study conducted at the Edisto Research and Education Center near Blackville, SC.

	Trt A		**Trt B**		**Trt C**		**Trt D**	
Harvest year	**1992**	**1993**	**1992**	**1993**	**1992**	**1993**	**1992**	**1993**
Planting date	No~21	Dec. 14	Nov. 21	Dec. 14	Nov. 21	Dec. 14	Dec. 3	Dec.14
Harvest date	June 1	June 7	June 1	June 7	June 1	June 7	June 1	June 7
Number of wheat rows	16	24	11		14		14	
Row width (cm)	19.6	15.2	33.0 & 61.0		15.2, 30.5 & 61.0		15.2, 30.5 & 61.0	
Seeding rate’								
kg ha"	112.1	112.1	112.1		112.1		112.1	
seed (linear m)$^{-1}$	64.4	50.3	125.6		93.3		93.3	
Planter[2]	Drill		Clemson I.		Clemson I.		Clemson I.	
Fall tillage’	Chisel		Paraplow		Paraplow		Durou plow	
Tire spacing (cm)	193		193		244		244	

[1] Number of seeds planted per meter of row was calculated using an average seed weight of 0.034 g seed”.

[2] Trt A (conventionally planted wheat) was planted with 16-row Amazone in 1991 and a 24-row JD450 in 1992. All other treatments were planted with the Clemson Interseeder.

[3] The chisel plow had 30 cm shank spacings and operated 28 cm deep, the paraplow had 53 cm shank spacings and operated 30 to 33 cm deep, and the French Durou plow had 96 cm shank spacings and operated 33 to 36 cm deep.

respectively, to compare the effect of these two new conservation tillage implements for wheat production in coastal plain soils.

The experimental area was limed with 2.24 Mg ha^{-1} on Oct. 8, 1991 and disked. On Oct. 18 the area was fertilized with 30.8 kg N ha^{-1} and 106.5 kg K ha^{-1}, and again disked. Plots in three of the four treatments were deep tilled on Nov. 19 and planted with ’NK Coker 9835‘ wheat on Nov. 21. The other treatment (Durou plow) was tilled to 35.6 cm and planted on Dec. 3, after the tillage equipment had arrived. Wheat was top dressed on Feb. 5, 1992 with 67.3 kg N ha^{-1}. The second year of the study, 67.3 kg K ha^{-1} was applied on Dec. 8 and disked to 20.3 cm. Deep tillage occurred on Dec. 14, and the same day all plots were planted. Planting occurred later than normal because of the extremely wet conditions in Nov. and Dec. of 1992. The nitrogen application was split with 33.6 kg N ha^{-1} applied as S-25 on Dec. 16, 1992 and Feb. 18 and Mar. 2, 1993. Weeds and diseases were controlled using appropriate pesticides. Soybeans were interseeded into appropriate plots on May 19, 1992 and May 20, 1993. Wheat harvest occurred on June 1. 1992 and June 7. 1993. with 61.0 cm of each row cut at ground level, and oven dried at 60°C for 48 hours. Above-ground dry matter and number of heads with viable seeds were determined. After threshing the wheat in an Almaco plot combine, the weight and number of seeds from each harvest row were determined.

For each year, and for the 2-year combined data, statistical analysis comparing individual rows within each of the four treatments was conducted. In addition, a system analysis of the four treatments was conducted employing two methods: a) using the entire set of individual row data, except the outside rows, to eliminate the border effect of leaving 0.61 m between two adjacent plots, and b) using the entire set of individual row data. The area for the outside row was calculated by adding 30.5 cm to one-half the distance between the outside row and the adjacent row, and multiplying that sum by the harvest length. SAS was employed for the statistical analysis, and the LSD reported only if the significance level was at $a \leq 0.05$.

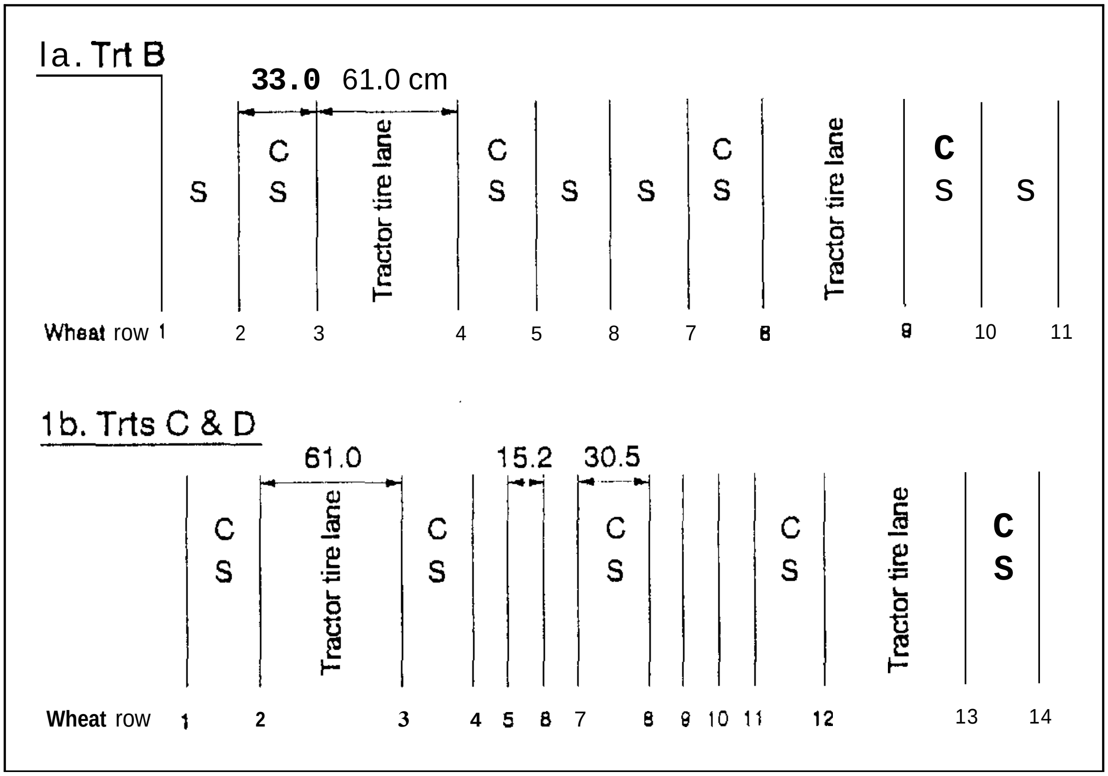

Figure 1. Planting pattern for wheat, cotton (C) and soybeans (S) for a) the 1.93 m tractor wheel spacing, and b) the 2.44 m tractor wheel spacing schemes.

RESULTS AND DISCUSSION

System Analysis

Analysis of the entire system, whether including or excluding the outside rows in the analysis, did not affect the interpretation of the results for the yield and yield components measured (Tables 2 and 3). The climatic conditions were better for the 1992 growing season as compared to the 1993 growing season, and there was a significant year effect for all yield and yield components measured. There was no significant year by treatment interactions for above-ground dry matter yield, seed yield, kernels per unit area, or kernel weight. However, there were year by treatment interactions for heads per unit area and kernels per head.

In 1992, 1993 and for the 2-year combined data, there was no significant difference between the four treatments for the above-ground dry matter yield, seed yield, kernels per unit area or kernel weight. Whether or not the outside row on each side of the plot was included in the analysis did not change the interpretation of the results (Tables 2 and 3). These data indicate wheat yields were not adversely affected by wide row planting under the given experimental parameters.

In 1992 and the 2-year combined data, treatment D had fewer heads per unit area but more kernels per head than the other treatments. In the 1992 season, treatment D was planted two weeks later than the other treatments. Delaying the planting date probably resulted in poor tillering, and caused the reduction in heads per unit area and increase in kernels per head as compared to the other treatments. The next season, when all treatments were planted on the same date, these differences were not observed.

In 1992 and the 2-year combined data, the conventionally planted wheat (treatment A) had more heads per unit area than the other treatments. Both years treatment A had the lowest number of kernels per head. For the

Table 2. Statistical analysis of wheat yields for entire system including outside rows.

	Trt	Total dry wt.	Kernel wt.	Kernels per m^2	Heads per m^2	Wt. per kernel	Kernels per head
		$g\ m^{-2}$	$g\ m^{-2}$			9	
1992							
	A	1079	516	17246	549a	0.0299	31.4b
	B	964	483	15750	468b	0.0307	33.9b
	C	992	490	16106	464b	0.0305	34.8b
	D	932	466	15494	383c	0.0300	40.3a
	mean	992	489	16149	466	0.0303	35.1
	CV	10.6	10.7	9.7	9.3	2.6	8.4
Analysis of variance							
Trt effect		NS	NS	NS	***	NS	***
FLSD					53.2		3.6
1993							
	A	618	282	8580	371	0.0328	23.1b
	B	607	285	8754	346	0.0325	25.3a
	C	604	284	8882	349	0.0320	25.5a
	D	566	264	8240	336	0.0320	24.6ab
	mean	599	279	8614	351	0.0323	24.6
	CV	10.6	10.3	9.2	7.5	2.6	5.5
Analysis of variance							
Trt effect		NS	NS	NS	NS	NS	**
FLSD			-				1.7
2-year combined data							
	A	848	399	12913	460a	0.0314	27.3c
	B	786	384	12252	407b	0.0316	29.6b
	C	798	387	12494	406b	0.0312	30.1b
	D	749	365	11867	360c	0.0310	32.5a
	mean	795	384	12302	408	0.0313	29.9
	CV	10.9	11.0	10.1	8.8	2.6	7.7
Analysis of variance							
Trt effect		NS	NS	NS	***	NS	***
Year effect		***	***	***	***	***	***
Trt*Year		NS	NS	NS	**	NS	***
Trt FLSD					29.9		1.9

***, **, * and NS refer to $P\leq0.001$, 0.01, 0.05, and $P\geq0.05$, respectively.

combined 2-year data, the number of kernels per head was significantly lower than for the other treatments. These data can be explained by looking at the individual row data and the effect of tire-traffic on the wheat rows of the conventionally planted wheat.

Individual Row Analysis

For the conventionally planted wheat, the seed yield on both a linear and area basis, kernel weight and kernels per head all decreased dramatically in the rows where tire compaction occurred (rows 4 & 14 in 1992, and rows 6 & 7

Table 3. Statistical analysis of wheat yields for entire system excluding outside rows.

Trt	Total dry wt.	Kernel wt.	Kernels per m^2	Heads per m^2	Wt. per kernel	Kernels per head
	$g\ m^{-2}$	$g\ m^{-2}$			g	
1992						
A	**1061**	**514**	**17140**	**569a**	**0.0301**	**30.1b**
B	**953**	**482**	**15668**	**473b**	**0.0308**	**33.5b**
C	**968**	**484**	**15899**	**471b**	**0.0305**	**33.8b**
D	**970**	**489**	**16240**	**401c**	**0.0300**	**40.4a**
mean	**988**	**492**	**16237**	**479**	**0.0303**	**34.5**
CV	**11.5**	**11.3**	**10.1**	**10.8**	**3.2**	**9.2**
Analysis of variance						
Trt effect	**NS**	**NS**	**NS**	***	**NS**	***
FLSD	-	-	-	**63.8**	-	**3.9**
1993						
A	639	292	8828	387	0.0329	**22.7b**
B	633	296	9043	356	0.0326	**25.4a**
C	622	290	9057	367	0.0320	**24.8a**
D	587	273	8473	355	0.0322	**24.0ab**
mean	620	288	8851	366	0.0324	24.2
CV	10.5	10.2	9.2	8.7	2.9	5.4
Analysis of variance						
Trt effect	NS	**NS**	**NS**	**NS**	**NS**	•
FLSD						1.6
2-year combined data						
A	850	403	12984	478a	0.0315	**26.4c**
B	793	389	12356	414b	0.0317	**29.5b**
C	795	387	12478	419b	0.0312	**29.3b**
D	779	381	12357	**378c**	0.0311	**32.2a**
mean	804	390	12544	422	0.0314	29.4
CV	11.5	11.4	10.4	10.2	3.0	8.3
Analysis of variance						
Trt effect	NS	**NS**	**NS**	***	**NS**	***
Year effect	***	***	***	***	**u	***
Trt*Year	NS	**NS**	**NS**	***	**NS**	***
FLSD			-	35.9		2.0

***, **, • and NS refer to $P \leq 0.001$, 0.01, 0.05, and $P \geq 0.05$, respectively.

and 18 & 19 in 1993) (Fig. 2a-d, treatment A). Tire-traffic rows had more, but smaller and later maturing heads than the other rows. The tire compaction was a result of three passes over the wheat plots for application of a herbicide, spring N and a fungicide. In the other treatments no wheat was run over by those passes over the plots because of the wheat-row spacing allowance for the tire track (Fig. 1a and 1b).

For the 11-row wheat system (Fig. 1a, treatment B) the rows most widely spaced (rows 1, 3, 4, 8, 9 & 11) tended to have the highest

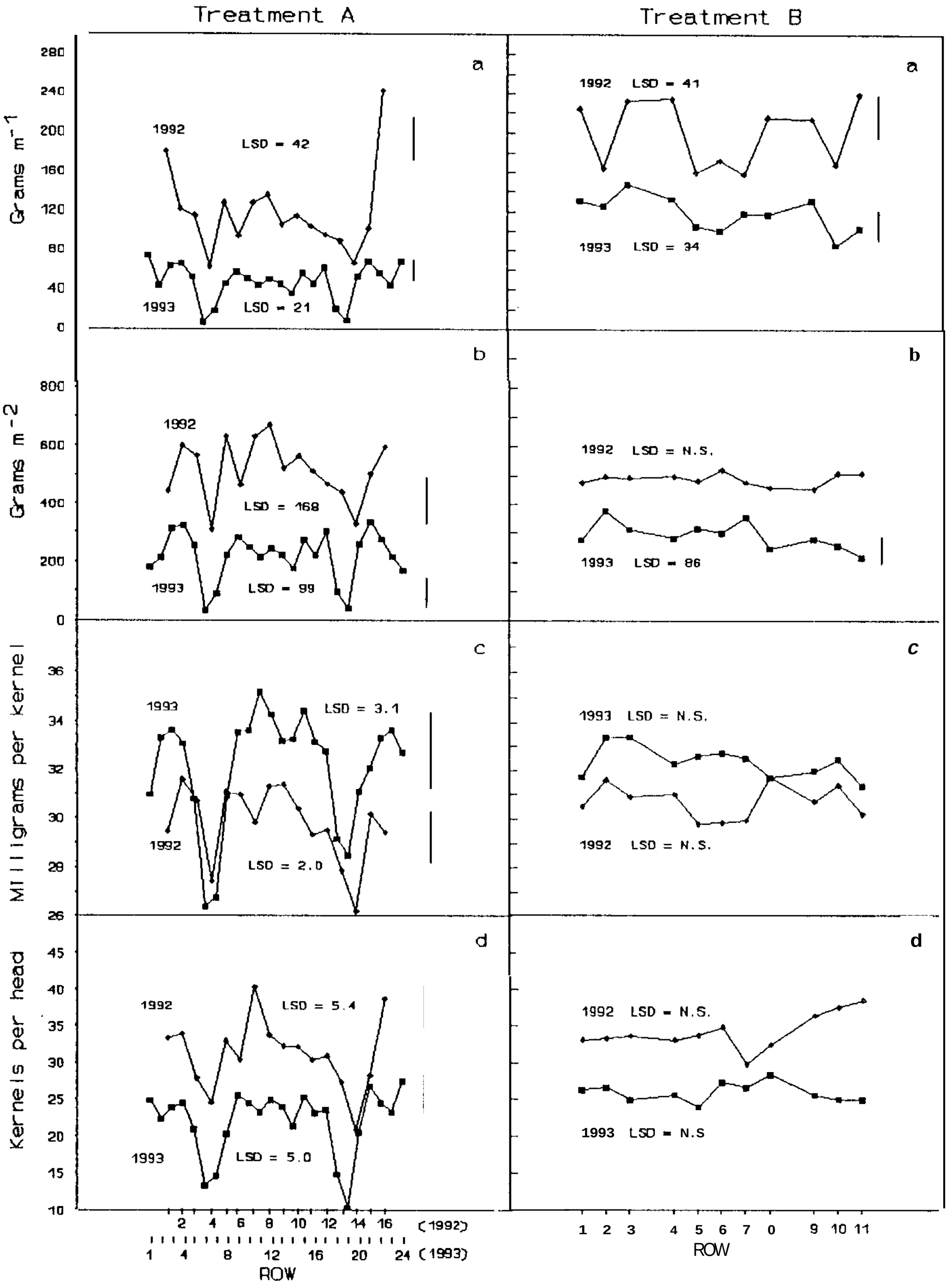

Figure 2. Seed yield on a linear basis (a) and area basis (b), kernel weight (c), and kernels per head (d) from individual wheat rows of treatments A and B.

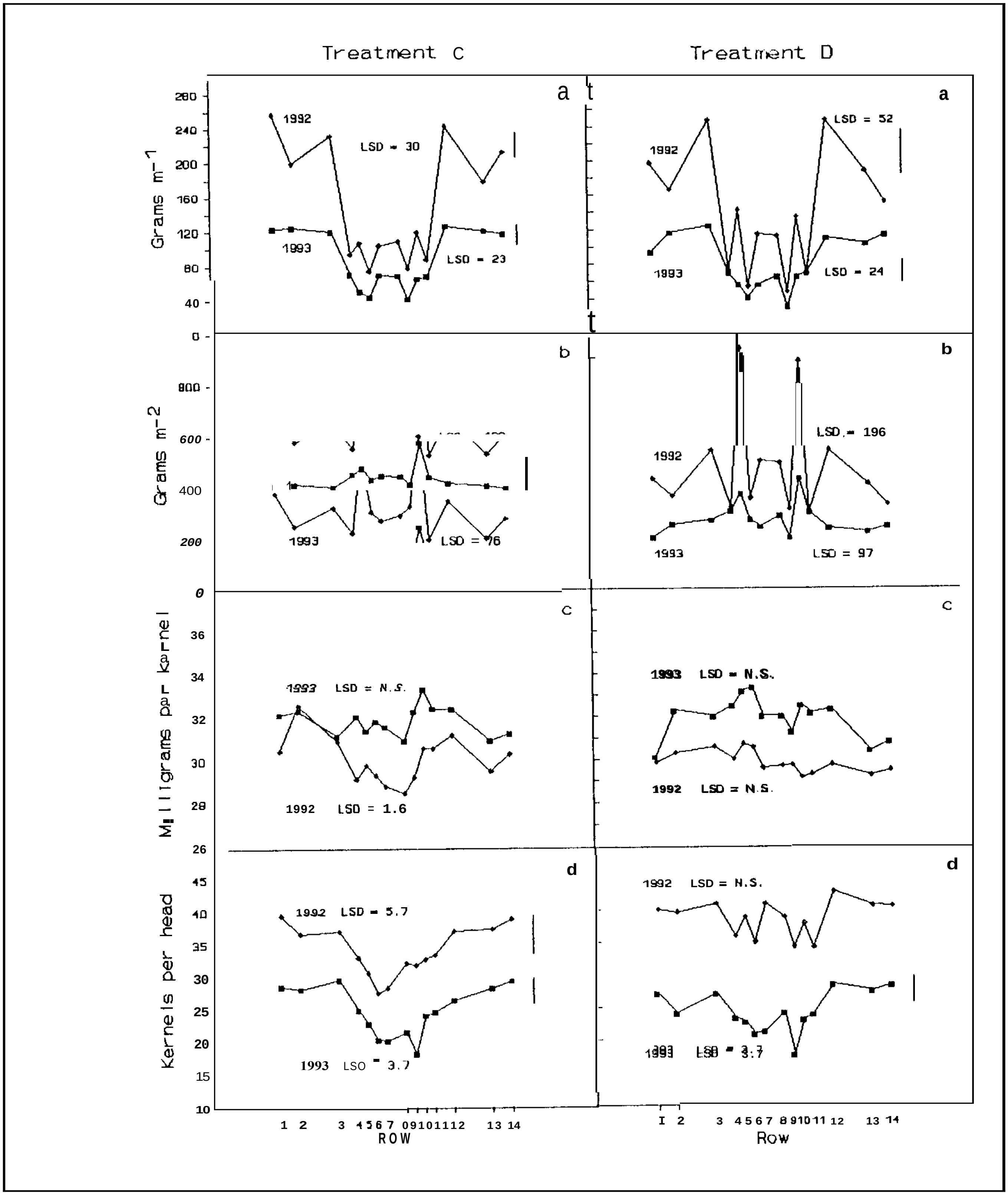

Figure 3. Seed yield on a linear basis (a) and area basis (b), kernel weight (c), and kernels per head (d) from individual wheat rows of treatment C and D.

seed yield on a linear basis (Fig. 2a. treatment B), but when calculated on an area basis, the row spacing did not affect yield Fig. 2b. treatment B). Kernel weight and the number of kernels per head were unaffected by row spacing (Fig. 2c & 2d. treatment B).

For the two 14-row wheat systems (Fig. 1b), the rows most widely spaced (rows 1, 2, 3, 12, 13 & 14) consistently yielded more than the other rows on a linear and area basis (Fig. 3a and 3b. treatments C & D). Kernel weight was generally unaffected by row spacing (Fig. 3c. treatments C & D), but the rows most widely spaced tended to have more kernels per head than the narrower spaced rows (Fig. 3d. treatments C & D).

In summary, yield of conventionally planted wheat was not significantly different from yields of skip-row schemes designed to allow for relay intercropping of either soybeans or cotton. For the conventionally planted wheat, tractor traffic on top of certain wheat rows reduced yields of those rows as compared to non-traffic rows. Wheat grown in wider-spaced rows adjacent to the controlled-traffic tire lanes in the schemes designed to allow for relay intercropping compensated yield-wise on an area basis as compared to narrower-spaced rows.

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UTILIZATION OF CONSERVATION TILLAGE AND COVER CROPS IN SNAP BEAN PRODUCTION

D.S. NeSmith and D.V. McCracken[1]

ABSTRACT

Experiments were conducted during 1992 and 1993 near Blairsville, GA to determine the potential for using conservation tillage and cover crops in the production of snap beans in the Mountain region of Georgia. One experiment compared no-tillage and conventional tillage snap beans following either a rye or hairy vetch cover crop. A second experiment examined the need for sidedressed nitrogen for no-tillage and conventional tillage snap beans following a hairy vetch cover crop. The rye cover crop contained **30** and 95 Ibs N/acre, respectively, during 1992 and 1993, and hairy vetch contained 71 and 68 Ibs N/acre during the two years. There was a trend for increased inorganic N in the upper 12" of soil following conventional tillage. There were no significant differences of tillage, cover crop, or sidedressed N on plant stand or shoot dry weight. Total yields from the cover crop experiment were similar for the treatment combinations; however, early yield during 1992 was 62% greater using no-tillage. Total yields from the sidedressing experiment were similar for the various treatments, but in 1993 no-tillage resulted in 44% greater early yield. These results indicate that conservation tillage and cover crops could prove useful in sustainable production of snap beans in the Mountain region.

INTRODUCTION

Excessive use of N fertilizer and tillage-intensive land preparation practices in the production of vegetable crops threatens the agricultural productivity, environmental quality, and ultimately, the economy and sustainability of rural communities throughout the southeastern USA, where the potential for soil erosion and surface runoff is often great. Pressure is increasing throughout the region for growers to adopt sustainable crop production strategies. Use of conservation tillage practices and winter cover crops are often effective management options for control of soil erosion and supply of N to cash crops (Blevins et al., 1983; Langdale et al., 1979; McVay et al., 1989).

Investigations of snap bean yield response to tillage have shown greater yields for conventional tillage (Knavel and Herron, 1986; Mullins et al., 1988). equal or greater yields for no-tillage (Skarphol et al., 19871, or inconsistent differences between the two soil preparation methods fBellinder et al., 1987; Grenoble et al., 1989; Mascianica et al., 19'86; Mullins et al., 1980). The few published reports concerning the use of cover crops in snap bean production have shown little or no difference in yields following legumes (such as hairy vetch and red clover) or cereals (such as wheat and rye), when supplemental N was used (Grenoble et al., 1989; Skarphol et al., 1987).

Additional research regarding the effects of cover cropping, tillage, and fertilizer N rate on vegetable crop production is needed in order to further refine production recommendations (Phatak, 1992). The objectives of this research were to investigate the effects of tillage and cover crops on snap bean production in the Mountain region of Georgia, and to determine whether sidedress N fertilizer is required to maintain snap bean yield in conventional and no-tillage soil management systems that utilize a winter cover crop of hairy vetch.

MATERIALS AND METHODS

Two experiments were conducted during 1992 and 1993 at the Georgia Mountain Experiment Station in Blairsville, GA. One experiment consisted of a 2 x 2 factorial experiment of cover crop and tillage. The cover crops were rye *(Secale cereale)* and hairy vetch (*Vicia villosa),* and tillage systems were conventional tillage with a moldboard plow (CT) and no-tillage (NT). The second experiment was a 2 x 2 factorial of tillage and nitrogen sidedress following a winter cover crop of hairy vetch. Nitrogen variables were sidedressing of 50 lbs

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Table 1. Average monthly minimum and maximum air temperatures and total precipitation from May to August during 1992 and 1993 at Blairsville, GA.

	Temperature					
	Minimum		Maximum		Precipitation	
Month	1992	1993	1992	1993	1992	1993
	- - - - - - - - F	- - - - - - - -			- - - in - - -	
May	47	49	73	75	2.2	3.5
June	57	59	78	83	6.4	3.6
July	62	63	84	92	6.9	0.7
August	57	61	80	85	8.9	4.2

Table 2. Dry weight and nitrogen content of rye and hairy vetch cover crops prior to snap bean planting in 1992 and 1993.

	Dry weight		N content	
Cover crop	1992	1993	1992	1993
	- - - - - - - - - lbs/acre	- - - - - - - - -		
Rye	2143	4550	29	95
Hairy vetch	1964	2321	71	68

N/acre 3 weeks after planting (+N) or no sidedressing (-N), and again tillage was CT and NT.

Crops in both experiments were planted in 32" wide rows, with a stand density of 6 plantslft. Individual plot size was 6 rows wide by 25 ft. long, and all treatments were replicated 4 times. The cultivar Pod-squad was used in the first experiment, and the cultivar Sentry was used in the second experiment. All plots received 25 lbs N/acre at planting, and those plots in the first experiment received the nitrogen sidedressing as well. Crops were produced dryland except for irrigation after planting to activate herbicides and promote rapid stand establishment.

To assess soil inorganic N concentrations early in the snap bean growing season, six cores per plot were composited from the 0" to 6" and 6" to 12" soil depths at planting in 1992, and at five weeks after planting (WAP) in both years. Soil NH$_4$-N and NO$_3$-N concentrations were determined colorimetrically with a Lachat flow injection analyzer. Snap bean above ground dry matter production was determined every 10 to 14 days, beginning at three WAP, for a 3 ft segment of nonharvest row on each plot. Plants were counted, cut at the soil surface. separated into shoots and pods, dried, and weighed. For yield determination, marketable pods were hand-harvested from a 15 ft segment of an undisturbed center row of each plot at approximately weekly intervals three times each year. Pods taken in the first harvest represented early yield. Data were analyzed by analysis of variance (ANOVA) procedures appropriate for the experimental design.

RESULTS AND DISCUSSION

Average monthly minimum and maximum temperatures and monthly rainfall totals are given in Table 1. Temperatures were generally greater in 1993 than in 1992, particularly maximum temperatures during June, July, and August. The early part of the 1992 growing season was drier than in 1993. However, the bulk of the 1993 growing season (June, July, August) was substantially drier than in 1992. These variable weather conditions are typical of those experienced in the southeastern USA.

Cover crops produced enough biomass each year (Table 2) to provide nearly complete soil coverage by late spring. The cover crops were easily killed with glyphosate, eliminating regrowth and direct competition with snap bean during its production cycle. When killed in the spring, the hairy vetch cover crop contained 68 to 71 lbs N/acre and the rye contained 30 to 95 lbs N/acre each year (Table 2). It is generally well established that legume cover crops provide greater N than nonlegumes (Ebelhar et al.. 1984; Hargrove, 19861. However, this depends on the total biomass produced by the cover crop and on relative N content (Skarphol et al., 1987).

In the current experiment there was typically greater soil nitrogen at planting at both soil depths with the hairy vetch cover crop as compared to the rye in 1992 (Table 3). By 5 weeks after planting differences were not apparent at the 0" to 6" depth, although they

Table 3. Effects of tillage and cover crop on the concentration of inorganic nitrogen in the 0" to 6" and 6" to 12" soil depths under snap beans in 1992. These plots received 50 lbs N/acre sidedressed 3 weeks after planting.

	At planting		5 weeks after planting	
	0-6"	6-12"	0-6"	6-12"
	- - - - - - - - - ppm - - - - - - - - -			
Tillage				
NT	18.8	7.0	14.4	7.9
CT	17.7	8.5	16.5	13.7
Cover crop				
Rye	8.3	5.6	11.8	7.5
Hairy vetch	28.1	9.9	19.1	14.1
Significance				
Tillage (T)	NS	NS	NS	NS
Cover crop (C)	**	**	NS	**
T X C	NS	*	NS	NS

NS, *, or ** represent no significance or significance at the 5% and 1% level for main effects and their interaction.

Table 4. Effects of tillage and cover crops on early and total snap bean fresh weight yields in 1992 and 1993.

	Early yield		Total yield	
	1992	1993	1992	1993
	- - - - - - - tons/acre - - - - - -			
Tillage				
NT	3.0	3.3	6.9	5.0
CT	1.2	2.4	6.8	3.8
Cover crop				
Rye	2.3	3.3	6.9	5.0
Hairy vetch	1.9	2.5	6.8	3.9
Significance				
Tillage (T)	**	NS	NS	NS
Cover crop (C)	NS	NS	NS	NS
T X C	*	NS	NS	NS

NS, *, or ** represent no significance or significance at the 5% and 1% level for main effects and their interaction.

remained at the 6" to 12" depth. Samples taken 5 weeks after planting in 1993 [data not shown) revealed no differences between cover crops at either depth during the second year. Others have shown that after 4 to 6 weeks, differences in plant available soil nitrogen in systems utilizing winter cover crops tend to diminish [Ebelhar et al., 1984; Skarphol et al., 1987). There was a trend for increased inorganic N in the upper 12" of soil following conventional tillage.

There were no differences in snap bean stands or shoot dry weight in either year in response to cover crop, tillage, or sidedressing in the two experiments (data not shown). There have been variable reports on the effects of tillage on stand establishment of snap bean (Bellinder et al., 1987; Knavel and Herron, 1986; Mullins et al., 1980; Mullins et al., 1988). It is difficult to predict the influence of tillage on stand establishment with certainty because weather greatly influences crop germination, emergence, and persistence.

Table 5. Effects of tillage and sidedress nitrogen on early and total snap bean fresh weight yields following a hairy vetch cover crop in 1992 and 1993.

	Early yield		Total yield	
Treatment	1992	1993	1992	1993
	- - - - - - - tons/acre - - - - - - -			
NT + N	3.0	3.5	6.3	5.5
CT + N	2.5	1.9	6.1	4.8
NT - N	2.3	3.7	5.0	6.6
CT - N	2.7	2.1	6.3	5.3
Significance				
Tillage (T)	NS	*	NS	NS
Nitrogen (N)	NS	NS	NS	NS
T X N	NS	NS	NS	NS

[1] NS or * represent no significance or significance at the 5% level for main effects and their interaction.

[2] NT and CT refer to no-tillage and conventional tillage, and + N and - N refer to the presence or absence of nitrogen sidedressing.

Yields from the two years of these experiments are presented in Tables 4 and 5. There was no influence of cover crop on early or total yield over the two years. Tillage did not significantly influence total yields during either year of the experiments. However, early yields in 1992 were 62% greater for NT as compared to CT in the cover crop experiment (Table 4). and were 44% greater for NT than for CT in 1993 for the sidedressing experiment (Table 5). There was no significant effect of sidedress N, or its interaction with tillage, on early or total yield in either year (Table 5). According to Mullins (1987), maximum yield of snap beans usually occurs at fertilizer N rates between 15 and 50 lbs/acre when legume cover crops are not used: however, positive yield responses to higher fertilizer N rates have been observed where the potential for N loss is great, such as on sandy soils.

These studies indicate that successful snap bean production is possible using either conventional tillage or no-tillage following a winter cover crops such as rye and hairy vetch. Snap bean yields for the two tillage extremes should be similar if soil temperatures at planting are high and weeds are controlled in no-tillage, and if soil crusting is not severe and dry periods are not prolonged in conventional tillage. Our results indicate that a hairy vetch cover crop and a modest amount of fertilizer N applied at planting can supply sufficient N for snap bean production in the Mountain region of Georgia. These results suggest that adoption of resource-conserving vegetable production systems based on no-tillage soil management and use of winter cover crops could result in improved water quality, sustained soil productivity, and greater production efficiency in the southern Appalachians.

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MANAGEMENT OF YARD WASTE COMPOST FOR SOIL AMENDMENT AND CORN YIELD

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ABSTRACT

Grass clippings, shrubbery trimmings and tree parts from urban homesites comprise a large quantity of plant derived organic matter waste requiring environmentally safe disposal. The objective of this study was to determine the effect of yard waste compost (YWC) on soil properties, corn (*Zea mays*) nutrition. phytoparasitic nematodes, and yield of corn. Treatments applied on a field near Gainesville, Florida were 120 tons YWC and 60 tons YWC/acre compared to control plots receiving no YWC. Pioneer Brand 3154 hybrid corn (*Zea* mays L.) was planted 3 March 1992 in rows 30 inches apart for a final population of 14,800 plants/acre. Soil and corn leaf tissue samples were taken three times during the corn growing season to assess the soil properties and nutritional status of the corn. Whole plant dry matter and grain yields were estimated at corn maturity. Initial (Pi) and final (Pf) nematode counts were made from the soil samples three weeks after planting and at corn harvest time. Within each YWC plot a split plot analysis was performed on time of sampling and depth of sampling for all soil and plant chemical analyses. Averages and standard deviations were calculated for nematodes. Soil organic matter decreased with soil depth, and increased over the growing season, especially in the 120 ton YWC/acre rate. The immediate plowdown and planting of corn resulted in N deficiency in the young corn. Calcium and Mg were also deficient in corn leaf tissue. Three of four nematodes were suppressed from use of YWC.

INTRODUCTION

Florida law requires lined landfills while federal law will prohibit use of unlined landfills in the U.S. by 1994 (Kidder. 1993). Florida law already restricts the disposal of organic yard waste in landfills. A large industry is developing in Florida whose objective is to make wood chip mulch and compost from yard waste, products which should be environmentally safe to apply to the land and result in potential benefits. For example, yard waste compost (YWC) can be applied in large quantities to farm fields to help improve soil properties and crop yield. Applying large quantities of organic waste to land can potentially result in increased soil organic matter. Soil organic matter is highly correlated with soil cation exchange capacity, water holding capacity, and generally improves yield of crops. It takes only a small increase in soil organic matter to slow pesticide leaching in soil and help restrict its movement into ground water (Arthur, 1989). Therefore, application of YWC to crop land where large inputs of chemicals are used in production could have the potential benefit of stopping or slowing the movement of chemicals through the soil and reduce the potential for ground water pollution. Disposal of municipal leaves on agricultural lands was highly successful and beneficial in New Jersey (Kluchinski, et al., 1993). They reported that soil water and crop yields were increased and nematodes were generally decreased from use of leaf mulching as a soil amendment.

Microorganisms play a major role in decomposition of organic matter such as composts, crop residues, animal manures or green manure. Their success in decomposition and subsequent use of N by higher plants is dependent on the ratio of C:N in the wastes. For organic matter with a C:N ratio greater than 20:1, N will temporarily be immobilized in microbial tissue and will create N-deficient soil for plants being grown following the addition of such organic matter wastes. For wastes or residues with a C:N ratio less than 20:1, N will be mineralized in the form of NH_4^+ or NO_3 for absorption and uptake by plant roots (Jones. 1982).

The objective of this study was to determine the effect of disposal of YWC on soil properties, corn (*Zea mays* L.) nutrition, phytoparasitic nematodes and yield of corn.

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MATERIALS AND METHODS

Wood Resource Recovery of Gainesville, Florida donated YWC under the supervision of Mr. Rodney Douglas, and Mr. Dale Haufler and Mr. Donnie Haufler applied 120 tons and 60 tons/acre on 2 112 acre plots on their farm on 2 February 1992 to compare with control plots receiving no compost. The research/ demonstration plots were in a field near Gainesville, Florida. On 10 February 1992 the field was moldboard plowed which buried the compost to a depth of 6 to 10 inches. Pioneer brand 3154 hybrid corn was planted 4 March 1992 in rows 30 inches apart for a final population of 14,800 plants/acre. During the planting operation 70 pounds N/acre from anhydrous ammonia was injected 8 inches under the row behind subsoil shanks. In addition an application of 250 pounds 7-18-14 (N-P_2O_6-K_2O) was applied during the planting operation 2 inches below and 2 inches beside the seed. An additional 300 pounds of muriate of potash (KCl) was broadcast over the corn on 25 March. On 15 April when corn was about 6 to 10 inches tall, 165 pounds N/acre as anhydrous ammonia (NH_3) was knifed into every other row middle.

Soil and plant samples were replicated four times from each treatment. Soil samples were taken from the 0 to 8, 8 to 16 and 16 to 24 inch depths beginning on 2 March 1992. Additional soil samples were taken three times during the corn growing season. Corn leaf samples were also taken three times for measurement of nutritional status. Four samples of YWC were collected from the Haufler's field at the time of plowdown and four additional samples were collected from the Wood Resource Recovery compost yard. Whole plant dry matter and grain yields were estimated at corn maturity.

Soil analyses included OM, extractable nutrients, pH, N and water content. Nitrogen, P, K, Ca, Mg, Cu, Fe, Mn, and Zn concentrations were determined in corn leaf tissue, the whole plant samples at maturity and the YWC. Percent dry matter and organic matter was also determined in the YWC. Nutrient contents were determined in the whole plant samples. Initial (Pi) and final (Pf) nematode counts were made from the soil samples three weeks after planting and at harvest of the corn. Within each YWC researchldemonstration plot a split plot analysis was performed on time of sampling and depth of sampling for all soil and plant chemical analyses. Averages and standard deviations were calculated for nematodes.

Table 1. Analysis of yard waste compost used in the Haufler farm demonstration plots in 1992.

	Compost sample site	
Analysis	Haufler farm	Company yard
Dry matter (%)	57.2	45.1
Organic matter (OM) (%)	77.2	78.0
C from carbon analyzer (%)	39.8	39.2
N (%)	0.859	0.944
C:N ratio	46.3	41.5
pH chopped	5.7	6.2
pH ground	5.8	6.3
Ca (%)	1.43	1.75
Mg (%)	0.128	0.176
K (%)	0.193	0.255
P (%)	0.080	0.116
Cu (ppm)	11.7	11.8
Fe (ppm)	1580.	1448.
Mn (ppm)	146.	176.
Zn (ppm)	91.2	151.3

Table 2. Corn leaf analysis affected by yard waste compost.

Compost	Sample date and type of tissue		
	22 April(<12 in)	12 May(YML)	6 May(EL)
ton/acre	%		
	Nitrogen		
120	1.90b def	2.66a def	2.63a def
60	2.39a def	2.56a def	2.51a def
0	3.01a def	2.45b def	2.64b def
Sufficiency Range	3.5-5.0	3.0-3.5	2.75-3.2
	Potassium		
120	3.15a	2.80b	2.75b
60	3.08a	3.33a	2.63a
0	3.60a	2.93b	2.50c
Sufficiency Range	2.5-4.0	2.0-2.5	1.75-2.25
	Magnesium		
120	0.11b def	0.10b def	0.13a
60	0.12a def	0.12a def	0.13a
0	0.15a	0.13a	0.13a
Sufficiency Range	0.15-0.45	0.13-0.30	0.13-0.30
	Calcium		
120	0.25b def	0.29b	0.37a
60	0.24c def	0.32b def	0.36a
0	0.32b	0.33b	0.38a
Sufficiency Range	0.30-0.70	0.25-0.50	0.25-0.50

< 12 in = whole corn plant less than 12 inches tall; YML = youngest mature leaf; EL = ear leaf; def = deficient concentration; Sufficiency range is according to Jones, et al., 1991.

RESULTS AND DISCUSSION

From the analysis of the YWC applied on the Haufler research/demonstration plots we learned that it had a C:N ratio of 46.3 (Table 1). Because the C:N ratio is larger than 20:l we should have expected the YWC to immobilize soil N, the effect being greatest for the 120 ton/acre treatment. Our observations on 22 March confirmed this prediction. Nitrogen deficiency symptoms were very severe in the 120 ton/acre treatment and moderate in the 60 ton/acre treatment. No observable N deficiency was evident in the control plots.

The YWC applied to the field had a N concentration of 0.859 % (Table 1) and a content of 1179 lb/acre and 590 lb/acre for the 120 ton and 60 ton/acre treatments, respectively. In order to have a 20:1 C:N ratio the YWC would have had to contain 2732 and 1366 lb N for the 120 and 60 ton YWC/acre treatments, respectively in order for soil N to not be immobilized by microorganisms. In this case the YWC was short by 1553 and 777 lb N/acre for the 120 ton and 60 ton/acre treatments, respectively to keep N immobilization from occurring. The Hauflers added 165 lb N/acre as anhydrous ammonia on 15 April using a coulter and knife injector implement in every other middle

Table 3. Effect of yard waste compost and soil depth on nematode densities on two sampling dates.

Soil Depth	Sample Date	Compost, ton/acre					
		0		60		120	
inch		No/100 cm^3 soil					
		no	sd	no	sd	no	sd
		Criconemella spp.					
0-08	27 Apr	73	17	105	21	112	19
8-16	27 Apr	95	18	93	21	108	33
16-24	27 Apr	88	15	86	18	196	94
0-08	30 Jun	379	135	366	76	274	106
8-16	30 Jun	554	164	386	88	537	136
16-24	30 Jun	330	46	228	41	564	284
		Meloidogyne incognita					
0-08	27 Apr	6	5	3	2	1	1
8-16	27 Apr	10	4	3	2	5	2
16-24	27 Apr	3	1	5	3	6	3
0-08	30 Jun	286	163	88	37	68	43
8-16	30 Jun	531	327	225	74	85	58
16-24	30 Jun	130	62	104	53	17	12
		Paratrichodorus minor					
0-08	27 Apr	69	6	38	6	26	3
8-16	27 Apr	98	16	49	13	16	4
16-24	27 Apr	42	8	18	5	6	1
0-08	30 Jun	161	32	80	22	79	14
8-16	30 Jun	120	26	61	18	54	11
16-24	30 Jun	65	3	51	17	28	7
		Pratylenchus spp.					
0-08	27 Apr	6	3	2	1	4	2
8-16	27 Apr	9	4	1	1	7	3
16-24	27 Apr	24	17	5	3	8	4
0-08	30 Jun	264	94	103	35	228	163
8-16	30 Jun	452	58	78	24	195	53
16-24	30 Jun	192	65	59	23	107	73

no = number of nematodes; sd = standard deviation

of the corn rows. This method of application concentrated the N in a small area limiting its contact with the YWC but accessible to corn root. This procedure should have assisted in limiting immobilization by microorganisms. The observed N deficiency symptoms disappeared quickly after this fertilizer application. Estimated silage yields at 30 % dry matter were not different among the treatments; 120 ton YWC = 11.7 ton/acre, standard deviation (sd) = 3.7; 60 ton YWC = 10.0 ton/acre, sd = 2.1; 0 ton YWC = 12.5 ton/acre, sd = 1.3. Incorporation of the YWC 4 to 6 months before planting of corn would likely have allowed time for the YWC to breakdown and equilibrate in the soil. If this had been done the N deficiency would likely have not occurred and yields would have likely been greater in the YWC plots than was observed in our study. Additional research will test this hypothesis as well as look at the longer term benefits to soil properties and yield.

SUMMARY AND CONCLUSIONS

Soil organic matter decreased with soil depth and increased significantly over the growing season, especially in the 120 ton YWC/acre plot. Soil test N, K, and P generally decreased with soil depth. These test values at corn harvest time generally increased over the test values at planting in YWC plots compared to the control plot. Immediate plowdown of YWC resulted in apparent tie-up of N and N deficiency symptoms in corn in proportion to the amount applied. The corn plants were deficient in N in all treatments throughout the season, which was likely due to timing of N application (Table 2). Calcium and Mg deficiency occurred in the compost treated plots during vegetative growth (Table **2)**. This was likely due to heavy application of K and N fertilizer. All nematode numbers were greater at time of corn maturity compared to numbers at the beginning of the study (Table 3). Meloidoqvne incoqnita (Kofoid & Whitel Chitwood, Paratrichodorus minor (Colbran) Siddiqi and Pratvlenchus spp. appeared to be suppressed by use of compost. The greatest suppression by compost was on Meloidogyne incognita. These three nematodes generally were in lower numbers in the 16-24 inch soil depth. Criconemella spp. were more evenly distributed in the soil.

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SOYBEAN NUTRIENT STATUS RESPONSE TO NO-TILLAGE VERSUS NO-TILLAGE PLUS SUBSOILING

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ABSTRACT

Nutrient supply is crucial to the proper development of the plant. This study was conducted to determine the effects of no-tillage (NT) without and plus subsoiling (NT + S) on the nutrient status of the soil and the soybean (Glvcine max plant at three reproductive stages R3, R6 and R8. Whole plant samples were taken from one square meter of treatment rows replicated three times. Whole plant samples were partitioned into root, stem, leaf, and pod parts. Soil samples were taken from the sample rows at depths of 0-2, **2-4,** 4-6 and 6-12 inch. All plant tissue and soil samples were analyzed for N, P, K, Ca, Mg, Mn, Zn, Cu and Fe. There was a decline in content of mobile nutrients (N, P, K and Mg) for plants in both tillage methods from R3 to R8. There was a trend for nutrient content of most nutrients to be greater for NT+S soybean because of the generally higher dry matter and bean yield for this treatment. Whole plant and seed dry matter yields were 30% and 72% higher for NT + S compared to NT, respectively. Subsoiling not only gave higher dry matter yield but also resulted in greater uptake of plant nutrients from the soil.

INTRODUCTION

Tillage practices affect soil properties such as pH (Blevins et al., 1977) and organic matter (Gallaher, 1984). and may influence nutrient availability. Generally, soils under no-tillage (NT) have greater organic C and N concentrations (Gallaher, 1984; Wood et al., 1991). Above ground growth of soybean *(Glycine max* (L.) Merrill) was found to be a good indicator of root growth, with rooting depth about twice the plant height and about 50% of the roots concentrated in the upper 6 inch layer of soil under dry land conditions (Mayaki et al., 1976). The soybean plant has deep rooting and nutrient extraction capabilities (Al-Ithawi et al., 1980).

The objective of this experiment was to determine the effects of NT and no-tillage plus subsoiling (NT+S) on the nutrient status of the soil and the soybean plant at three reproductive stages R3, R6 and R8. Specifically, we were determining the nutrient content of the plant parts--roots, stems, leaves, pods and seeds–at each reproductive stage as affected by tillage method.

MATERIALS AND METHODS

'Cook' soybean was sown in the summer of 1993 at the Green Acres Farm; the University of Florida, Agronomy Department's farm. The soil is an Arredondo loamy sand to sand (Grossarenic Paleudult) (Soil Survey Staff, 19841.

Treatments included NT+S (the Subsoiler was passed through the rows before the seeds were dropped into the soil) and NT in a randomized complete block design with three replications. Samples for nutrient analysis were taken at three reproductive (Rl stages; R3, R6 and R8 (R3 is the beginning of pod formation with pods measuring 5-mm long at one of the four uppermost nodes on the main stem with a fully developed leaf, R6 stage is the stage at which a green seed fills the pod cavity at one of the four uppermost nodes on the main stem with a fully developed leaf and R8 is full maturity when 95% of the pods have reached their mature pod color) (Ferr and Caviness, 1977). Samples were taken from the healthy-looking one square meter of each treatment. The collected samples were separated into leaves (petioles remained on stems, and all leaves were collected as they were ready to drop and those remaining on the plant to ensure total leaf weights), stems, pods and roots. The samples were dried in a forced-air drier at 70°C, weighed on a Mettler PN2210 top-loading scale for DM, chopped, then ground using a Wiley Mill fitted with a 1-mm stainless steel screen, and were placed into plastic air-tight Whirl-pak bags.

Samples were dry ashed to determine the mineral concentrations and solutions were taken to the instruments (in the IFAS Extension Soil Testing Laboratory) for analysis. Readings were done for P (colorimetry) K (flame emission spectrophotometry), and Ca, Mg, Cu, Mn. Fe and Zn by atomic absorption spectrophotometry using a Perkin-Elmer (model 603) Atomic Absorption Spectrophotometer. The N concentration of the

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plant samples were determined by Micro-Kjeldahl techniques (Gallaher et al., 1975; Gallaher et al., 1976).

Soil samples were taken in the rows where the plant samples had been taken. A soil probe was inserted in the top 12 inches of the soil in about 12 places and the soil was mixed in small brown bags. The soil samples were air dried and sent to the IFAS Extension Soil Testing Laboratory to be analyzed by the double acid procedure (Mehlich, 1953). The pH was determined by electrode. Phosphorus was determined by colorimetry, K by flame emission and Ca, Mg, Cu, Mn, Fe, and Zn by atomic absorption spectrophotometry. Soil N concentration was analyzed by the same procedure used for plants except that 2.0 g of each sample were used without addition of glass boiling beads. Soil organic matter was determined using the potassium-Dichromate procedure (Walkley, 1947).

Data collected in this experiment was entered into a computer spreadsheet (Quattro pro 4.0.. 1987) for manipulation and transformations. Analysis of variance (ANOVA) of a randomized complete block design was computed with MSTAT (Version 4.0-C, 19871.

RESULTS AND DISCUSSION

Soil Analysis

Fertilizer recommendations from the IFAS Extension Soil Testing Laboratory at the University of Florida indicated that K and Ca were deficient whereas P and Mg were high among the macronutrients at all soil depths analyzed. The pH and OM of the soil decreased with depth (Table 1).

Diagnostic Leaf

The results from the diagnostic leaves revealed a deficiency of K among the macronutrients confirming what was observed in the soil. Manganese was high among the micronutrients and Cu was deficient based on sufficiency ranges of nutrients for soybean (Jones et al., 1991) (Table 2).

Table 1. Mehlich 1 extractible nutrients, pH and organic matter affected by depth and subsoil treatment in no-tillage soybean plots.

			Macronutrient				Micronutrient		
Soil Depth	pH	OM	P	K	Mg	Ca	Zn	Cu	Mn
---- in ----		- % -	ppm				ppm		
0 - 2	5.7	2.496	43h	21d	54h	607	1.10	0.09	2.31
2 - 4	5.3	1.716	57h	14d	43h	345	0.27	0.07	0.87
4 - 6	5.1	1.950	47h	11d	36h	255	0.19	0.06	0.78
6 - 12	4.7	1.248	33h	6d	12d	80	0.10	0.05	0.37
Subsoil'									
yes	5.1		45	16	25	211	0.29	0.06	1.57
No	5.2		49	14	27	334	0.35	0.07	0.96

*) Average of three replications
h) high
d) deficient

For future soybean production, application of 4,000 lb calcitic or dolomitic limestone/acre was recommended to adjust soil pH. A recommendation of 60 lb K/acre was also recommended for growing soybean.

Table 2. A comparison of the soybean table of interpretive nutrient values from Jones et al. 1991 and values from the diagnostic leaves.

	Jones et al. 1991			Diagnostic leaves	
Element	**Low**	**Sufficient**	**High**	**No-tillage + Subsoiling**	**No-tillage**
	%				
N	3.10-4.00	4.01-5.50	5.51-7.00	4.43 s	4.38 s
P	0.16-0.25	0.26-0.50	0.51-0.80	0.28 s	0.30 s
K	1.26-1.70	1.71-2.50	2.51-2.75	1.17 d	1.19 d
Ca	0.21-0.35	0.36-2.00	2.01-3.00	1.12 s	1.13 s
Mg	0.11-0.25	0.26-1.00	1.01-1.50	0.48 s	0.49 s
	ppm				
Mn	15-20	21-100	101-250	105 h	116 h
Zn	10-20	21-50	51-75	46 s	46 s
CU	5-9	10-30	31-50	6 d	6 d
Fe	31-50	51-350	350-500	113 s	120 s

s = sufficient; d = deficient; h = high

Nutrient Content Analysis

Whole plant macronutrient contents were higher at 105 days after planting (DAP) (Table 3). Whereas micronutrients were higher at 129 DAP, Fe was higher at 105 DAP (Table 4). There were no significant differences between tillage treatments on micronutrients. Nevertheless, macronutrients were affected by tillage. Contents of N, P, and Ca ($p=0.10$) and K and Mg ($p=0.05$) were significantly higher for NT+S compared to NT.

Drv Matter Analysis

Root, Stem, and leaf DM increased throughout the vegetative period and decreased after 105 DAP (after the onset of reproductive growth). Tillage treatments did not show any significant difference on roots. On the contrary, tillage affected stems ($p=0.10$) and leaves ($p=0.05$) with NT+S having larger values. Pods experienced an increase in DM at harvest time (129 DAP). The increase of DM in this new sink is reflected in the decrease in the DM of leaves and stems after vegetative growth. No-tillage plus subsoiling had higher whole plant DM ($p=0.05$). This was due to the good root development in NT+S plots supporting what Mayaki et al (1976) reported. Final seed yield was higher for NT+ S than NT ($p=0.05$) (Table 5). From the foregoing discussion, it is likely that the tillage differences observed with macronutrients did not result from differences in nutrient concentration but from differences in dry matter per unit area.

Table 3. Whole plant soybean (<u>Glycine</u> max L.) macronutrient content response to no-tillage treatment.

Days After Planting	R Stage	No-Tillage plus subsoil		Mean	CV(%)
		Yes	No		
		lb/acre			
			Nitrogen		
84	3	120.8	76.4	98.5 b	20.16
105	6	174.2	149.4	161.8 a	
129	8	177.8	134.1	155.9 a	
Mean		157.5	120.0 +		
LSD				54.2	
			Phosphorous		
84	3	13.68	8.19	10.93 b	22.65
105	6	20.41	17.44	18.93 a	
129	8	18.18	14.18	16.18 a	
Mean		17.43	13.27 +		
LSD				4.63	
			Potassium		
84	3	83.0	43.0	63.0 b	28.30
105	6	115.3	84.6	100.0 a	
129	8	101.6	77.3	89.5 ab	
Mean		99.9	67.5 •		
LSD				31.7	
			Calcium		
84	3	38.69	23.26	30.97 b	18.98
105	6	47.55	39.61	43.06 a	
129	8	42.93	33.17	38.05 ab	
Mean		43.06	32.01 +		
LSD				9.48	
			Magnesium		
84	3	20.14	13.06	16.60 b	21.90
105	6	26.91	23.29	25.10 a	
129	8	26.10	19.05	22.58 ab	
Mean		24.39	18.46 *		
LSD				6.25	

Values in columns among Days After Planting for each nutrient followed by the same letter are not significantly different at the 5 % level of probability according to LSD test. Values in rows between tillage with * and + are significantly different at the 5 % and 10 % level of probability, respectively.

Table 4. Whole plant soybean (Glycine max **L.)** micronutrient content response to no-tillage treatment.

Days After Planting	R Stage	No-Tillage plus subsoil Yes	 No	Mean	**CV(%)**
		b/acre			
			Manganese		
84	3	0.329	0.228	0.279 a	21.72
105	6	0.381	0.287	0.334 a	
129	8	0.379	0.315	0.347 a	
Mean		0.363	0.277 NS		
LSD				**NS**	
			Zinc		
84	3	0.182	0.121	0.151 b	31.93
105	6	0.278	0.250	0.264 ab	
129	8	0.347	0.325	0.336 a	
Mean		0.269	0.231 NS		
LSD				0.170	
			Copper		
84	3	0.025	0.017	0.021 a	21.08
105	6	0.027	0.026	0.027 a	
129	8	0.032	0.024	0.031 a	
Mean		0.029	0.022 NS		
LSD				NS	
			Iron		
84	3	0.646	0.594	0.619 a	27.90
105	6	0.822	0.949	0.886 a	
129	8	0.796	0.606	0.701 a	
Mean		0.755	0.717 **NS**		
LSD				NS	

Values in columns among Days After Planting for each element followed by the same letter are not significantly different at the 5 % level of probability according to LSD test. Values in rows between tillage with NS = not significant at the 5 % level of probability.

Table **5**. Dry matter weight of soybean (*Glycine max* L.) plant part, response to no-tillage treatment.

Days After Planting	R Stage	No-Tillage plus subsoil Yes	No		Mean	CV(%)
		lb/acre				
			Roots			
84	3	714.7	472.6		593.6 b	22.59
105	6	946.1	990.6		968.3 a	
129	8	704.0	572.3		636.4 b	
Mean		788.5	678.2	NS		
LSD					219.8	
			Stems			
84	3	2848.0	1668.8		2258.4 ab	18.98
105	6	3008.2	2497.3		2752.8 a	
129	8	1945.5	1771.1		1858.3 b	
Mean		2600.6	1979.4	•		
LSD					578.5	
			Leaves			
84	3	1599.3	1057.3		1328.8 a	16.79
105	6	1462.3	1174.8		1318.1 a	
129	8	939.8	867.8		903.3 b	
Mean		1334.1	1033.3	+		
LSD					264.3	
			Pods			
84	3	358.7	237.6		298.2 c	35.11
105	6	1818.3	1417.8		1618.0 b	
129	8	2993.1	2091.5		2542.7 a	
Mean		1723.0	1248.7	+		
LSD					695.1	
			Whole plant			
84	3	5520.7	3438.1		4479.4 b	17.37
105	6	7235.7	6081.4		6658.1 a	
129	8	6583.3	5300.0		5941.6 a	
Mean		6446.3	4940.4	•		
LSD					1316.3	
			Seeds			
129		1937.5	1180.1	*	1558.4	

Values in columns among Days After Planting for each plant part followed by the same letter are not significantly different at the 5% level of probability according to LSD test. Values in rows between tillage with NS= not significant at the 5 % level of probability. Values in rows between tillage with * and + are significantly different at the 5 % and 10 % level of probability, respectively.

CONCLUSIONS

To summarize we found that mobile macronutrient concentrations declined as the plants grew older. From the data it is likely that tillage treatments did not affect nutrient concentration but because of conditions for greater dry matter production NT+S resulted in greater nutrient contents for most macronutrients. Diagnostic leaf tissue was deficient in K. Low soil pH and low soil K was also found. Improved yield and plant nutrition of NT soybean could occur from application of 4000 lb calcitic or dolomitic limestone/acre and 60 lb K/acre for future soybean plantings, and the recommended tillage for these conditions is NT+S.

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PREPLANT AND POST PLANT TILLAGE FOR FULL SEASON SOYBEANS ON CLAYEY AND SILT LOAM SOILS

T.C. Keisling[1], C.R. Dillon[2], L.R. Oliver[3], F.L. Baldwin[4],
L.O. Ashlock[4]. and E.E. Evans[1]

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 and changed 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 seed bed preparation and post-plant tillage on soybean production on a Sharkey and Loring soil.

MATERIALS AND METHODS

Experiments were continued in 1993 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 the Mississippi State University budget generator (Spurlock, 1992) and a soybean price of $6.02 per bu.

RESULTS AND DISCUSSION

The yield results obtained for 1993 are presented in Table 2. It should be noted that 1993 was an extremely dry growing season. 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 statistically significant at CBES.

The economic returns for each treatment combination is 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 data strongly suggests that tillage is just an added expense on clay soils.
On the silt loam soil, preplant tillage was the most profitable practice. One trip with a disk and do-all increased profits 1400%. This shows the importance of preplant tillage on these soils during dry growing seasons. During a wet season (1992), tillage made no difference and was reported at the conservation tillage conference last year.

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Table 1. Selected site characteristics, cultural practices, and temporal log for tillage experiments at NEREC and CBES.

	Location	
	NEREC	CBES
Soil Type	Sharkey silty clay	Loring si.l
Planting Date	5-26-93	5-27-93
Seed Bed Prep.		
Disking	5-26-93	5-27-93
Chem.Burn Down[1]	5-26-93	5-27-93
Soybean Variety	Pioneer 9592	N.K. 59-60
Seeds/Row-ft	3-5	3-5
Row Spacing	19 inches	19 inches
Harvest Date	10-27-93	10-26-93
No. Reps		
Preplant Tillage	6	9
Post-plant Tillage	8	4

[1] Burn down was with Roundup® at 1.5 pints/acre of 4.7 lb 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/Acre					
NEREC	53.3b*	51.5a	1.8	52.4a	52.5a	-0.1
CBES	26.9a	15.9b	11.0	22.7a	20.0b	2.7

* 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.

Table 3. Economic returns estimated for various tillage regimes for $6.02 soybeans.

Tillage				
Preplant	Yes		No	
Post-plant	Yes	No	Yes	No
NEREC				
Operating cost	$ 72.42	$ 70.55	$ 62.35	$ 60.47
Total Cost	$ 99.24	$ 95.90	$ 85.76	$ 82.42
Profit	$220.42	$226.17	$224.87	$227.61
CBES				
Operating cost	$ 47.73	$ 45.84	$ 50.73	$ 54.39
Total Cost	$ 72.68	$ 69.32	$ 74.15	$ 76.34
Profit	$ 91.06	$ 89.60	$ 4.11	$ 6.14

Table 4. Component analysis for pre and post plant tillage operations.

	Yield (bu)	**Operating Cost**	**Total Cost**	**Profit**
NEREC				
	---------------$/acre	---------------	---------------	---------------
Base (No-Till)	51.5	$60.47	$82.42	$227.61
Adding Pre Plant Tillage	1.8	$10.08	$13.48	- $1.44
Adding Post-Plant Tillage	- 0.1	$ 1.88	$ 3.34	- $2.74
Total	53.2	$72.43	$99.24	$223.43
CBES				
Base (No-Till)	13.7	$54.39	$76.34	$ 6.14
Adding Pre Plant Tillage	11.0	- $8.55	- $7.02	$ 83.46
Adding Post-Plant Tillage	2.7	- $3.66	- $2.19	- $ 2.03
Total	27.4	$42.18	$67.13	$ 87.57

SUCCESSFUL RIDGE-TILL IMPLIMENTATION ON A PRODUCTION COTTON FIELD

T.C. Keisling[1], C.R. Dillon[2], and E.E. Evans[1]

ABSTRACT

During field scale implementation of ridge-till cotton production system, several problems were encountered that would not normally be considered problems in small plot work. These problems involved bed forming, cover crop selection and establishment, burn-down, planting, cultivation and stalk destruction. This paper discusses how the problems arose, how to avoid them, and how we dealt with some of them.

INTRODUCTION

The need to be in compliance (meet requirements to participate in USDA farm program) on highly erodible soils used in cotton production has made many growers look at alternative production systems that do not incorporate crop residue. One system that appears favorable for cotton production is a ridge-till system. The ridge-till system could have several advantages which are (Anon. b., 1988):

1. Will reduce water erosion.
2. Will reduce chemical run off.
3. Will reduce time requirement of crop production.
4. Will reduce machinery cost.
5. Will reduce soil compaction.
6. Will allow for earlier planting.
7. Will improve soil structure beneath the ridge.
8. Will provide excellent seed bed at planting time.
9. Will protect young cotton seedlings from wind injury.
10. Will promote earliness.

This ridge-till production system was evaluated on silt loam soils in Northeast Louisiana (Hutchinson et al.. 1991 and Paxton et al., 1993) and found to be as profitable as conventional or no-till systems.

Arkansas has many loess derived soils that are very similar to those found in the Macon Ridge area of Northeast Louisiana. Many Arkansas farmers are confronted with needing to convert to soil conserving systems to continue to be in compliance. We initiated experimental plots, at the Cotton Branch Experiment Station located at Marianna, AR, on loess derived soils in 1993 to confirm results obtained in Louisiana. We also used ridge-till in an 18 acre field in cooperation with a local farmer. Our idea here was to verify the feasibility of the ridge-till system on a production scale field. We also wanted to identify problems that occur in field scale systems that are not apparent in small plots. Our experience with the field scale implementation is reported herein.

MATERIALS AND METHODS

A field classed as highly erodible consisting of a Loring-Calloway-Henry (Anon. a, 1977.) soil complex was selected. This field had been planted with ryegrass at 30 lbs. per acre on Sept. 8, 1992. The ryegrass cover crop was burned down about the first of April using 12 oz. of Roundup" D-Pak plus 1% surfactant and again the middle of April using 24 oz. of Roundup D-Pak plus 1% surfactant. (Mention of manufacturers is for the convenience of the reader only and implies no endorsement on the part of the authors or the University of Arkansas.) The field was planted on May 8 with 5 to 7 DPL5O cotton seed per foot. The cover crop was again burned down on May 12 using 1.5 pt. per acre Gramoxone plus 0.5% surfactant. The crop was cultivated using a Sukup high residue cultivator on June 3, July 1, and July 23. Fertilizer consisted of 40 lbs. N per acre applied preplant and 60 lbs. N per acre side-dressed on June 8. Weed control consisted of 1.5 lb. Cotoran and 2 qt. MSMA applied on a 14 inch directed band on July 1 and 23. Hand hoeing was used for a few weed escapes and bad spots on July 23. Beds were built for the 1994 crop on August 3, 1993 using a Sukup bed shaper on a high residue cultivator.

The crop was defoliated on Sept. 30 with 1.5 pt. Folex and 1 pt. Prep. The crop was harvested twice, Oct. 14 and Nov. 15. A wheat

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cover crop for 1994 was planted about Oct. 15. 1993.

DISCUSSION

For practical implementation of ridge-till systems, we found several factors which are not normally considered to be of practical importance to require very close attention. We have labeled these as keys to success and will discuss them in temporal order.

Key 1: Bed Forming. Beds need to be established at the lay-by cultivation of this years crop for next year. The height and symmetry of the beds is extremely important. The Sukup manufacture recommends 9 inch high beds. However, on the hard loess soils a 5 to 6 inch bed was as tall as the high residue cultivator would cultivate properly. Higher beds resulted in the plow not going under the debris in the center of the furrow and clogging up. Disc bedders make a non-symmetrical bed that the planting equipment will not follow properly. To obtain a bed with the correct symmetry it is almost essential to form it with the ridging attachment on the high residue cultivator.

Key 2: Cover Crop Selection and Establishment. Attention needs to be paid to selecting a cover crop. Factors to consider are (1) seed cost, (2) growth habit, and (3) ease of killing in the spring. In our area ryegrass, rye, wheat, vetch, and crimson clover are currently recommended. Ryegrass is extremely hard to kill and is a noxious weed if the field is rotated to wheat. Rye has a high seed cost and grows very fast in the spring and may not be manageable. Wheat is cheap, does not produce too much stover, and is easily killed with 12 oz. of Roundup D-Pak. Vetch has expensive seed and can be hard to kill in the spring.

In this area with seedling rice in the vicinity (within 1 mile), Gramoxone drift can give severe rice injury. Crimson clover has expensive seed. Cover crops need to be established early enough in the fall to allow enough heat units for growth and development prior to extended cold weather. For our area a establishment window is from Oct. 1 to Oct. 15. Adequate soil moisture needs to be available for germination and establishment. If adequate moisture is unavailable, delay planting until enough rain has occurred to provide moisture. Seed after defoliation so that sufficient residue is on the soil surface to help hold the seed on the beds. It makes little difference if the crop is drilled or aerial seeded. Utilizing the above window, we have obtained a stand of clover, rye, and vetch every year for the last 20 years in a cover crop study.

Key 3: Burn-down. Burn-down at least 10 days prior to planting so that insect problems will be minimized. Burn-down can be earlier for various reasons such as:

(1) Insurance so that if the cover crop is not killed you have another opportunity to spray it again prior to planting.

(2) The bio-mass of the cover crop is becoming too great so that equipment utilized later will not work properly. If too much stover is produced, then consider Shredding the cover crop at about a 10 inch height. Frail mowers give a much more even distribution of stover and make subsequent operations more trouble free.

(3) It appears to be a dry spring and the cover crop is using up the stored soil water.

Key 4: Planting. Beds need to have top barred off so that there is a clean area to plant in. Some soils will require this operation to be done separate from the planting to keep the planter from "balling" up with mud. Herbicide incorporation is best done as a separate operation prior to planting. It is almost essential that planters have a guidance system of some sort to hold them on the center of the bed. The seedling rate needs to be increased about 20% compared to conventional tillage.

Key 5: Cultivation. A high residue cultivator is a must for first cultivation. If beds are too high, then use smaller sweeps to loosen the soil and then plow with wider sweeps.

Key 6: Stalk Destruction. A key to subsequent operations is uniform distribution of crop residue. Rotary mowers tend to concentrate the debris on one of two rows and will occasionally leave a large pile. Frail mowers do a much better job of evenly distributing stalk residue. In addition Arkansas law requires a frail mower be used if stalks are not incorporated into soil.

Even though 1993 was a terrible cotton year, the ridge-till yields were about the same as conventional production. A cost comparison (Table

1) shows that cover crop seed and burn down gives almost equivalent costs as conventional mechanical seedbed preparation.

Table 1. Costs and income from cotton production under ridge-till and conventional tillage systems.

	Ridae-Till	Conventional[1]
Seed Bed Prep	$ 16.23	$ 20.16
Fert. & App.	$ 22.65	$ 22.65
Planting	$ 19.70	$ 16.37
Post Plt. Cult. &Weed Cont.	$ 64.77	$ 64.77
Insect Cont.	$108.38	$108.38
Harvest	$ 86.38	$ 86.38
Total Costs	$318.11	$318.71
Total Income[2]	$339.34	$339.34
Net Income[3]	$ 21.23	$ 20.63

[1] Conventional was same as ridge-till except for planting and burning down a cover crop and the addition of two disking, floatation, bedding, and do-alling operation in seedbed preparation.

[2] Yield times ten year avg. price of $0.59 per lb. plus USDA deficiency payment of $0.2055 per lb. (estimated) for base yield of 500 lbs. per acre.

[3] Total income minus total cost.

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AN ENGINEERING BASED, ECONOMIC ANALYSIS OF TILLAGE OPTIONS FOR PEANUT

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INTRODUCTION

Farmers need simpler, less expensive systems for tillage and other farm operations. Peanut, cotton, corn, and soybean produced in rotations in the Southeast Coastal Plain traditionally have required separate tillage systems. Ownership and upkeep of a variety of implements used on only one part of the farm have reduced overall farm income. Managing as many as 18 trips over a field creates a labor nightmare in a labor-short market.

Modern conservation tillage methods were introduced to provide more effective control of soil erosion than expensive and difficult to maintain field structures such as terraces, diversions and waterways. All conservation tillage practices seek to maintain partial cover through the management of crop residues and living vegetation. Depending on soil type they may also seek to loosen topsoil or disrupt hard pans. Adoption of conservation tillage often involves purchase of new types of implements, changes in tractor sizes, and changes in timing of labor use.

Any decision regarding changes in tillage practice must include bottom-line considerations. While the change may be initiated to adopt conservation tillage, control hard-pan development, or control persistent weeds, the selection among implement types, sizes, and features should be guided by potential economic returns to land and management. The new practices should maintain or improve profitability or simplify management by reducing labor and equipment.

Tillage comparisons conducted on farms and experimental plots have often included economic analyses. These analyses provide good comparisons of the primary tillage changes, but they seldom include evaluation of these tillage options in view of how these changes fit into the entire season management of the cropping enterprise or the entire farm enterprise. Field studies usually include four or fewer direct comparisons and are limited to one brand or type of tillage implement, to available tractor sizes, and to planting date, growing season and other cultural practices.

A new effort was begun to systematically analyze tillage options. Several goals were identified for this analysis: to calculate the energy and field time requirements for all tractor/implement practices used during a growing season; to calculate variable and fixed costs associated with each operation and with the entire crop enterprise; to determine how often selected tillage and other field operations will be delayed by inclement weather; to determine how planting schedules, affected by tractor/implement selection and weather will influence harvest schedules and crop yield; to allow partial assignment of fixed costs for each implement to a crop enterprise based on its shared use with other crop enterprises on a farm. A computer program (EVTOPS) was written and a data base of tractors and implements assembled to accomplish these goals. The program provided the means to screen many options and do sensitivity evaluations. The purpose is report is to describe the methodology used in the analysis and to discuss some of the results from the analysis of three tillage options for peanut.

METHODOLOGY

Program Development

Implement Data Base. To provide the greatest flexibility, an external data base was assembled containing purchase price and specifications that affect power. labor, and operating costs. For tractors and self-propelled equipment, purchase price (NAEDA, **1993,** and survey of dealers in the Tifton, Ga., area), horsepower and weight (specified by manufacturers), and repair and maintenance factors (ASAE D497, 1990) were included. For tillage and other implements specifications included effective treatment width or number of crop rows treated, weight, PTO power requirement, average draft force created by the implement under average operating conditions in sandy loam soils, field operation efficiency. minimum and maximum operating speeds, purchase price (survey of dealers in the Tifton, Ga., area) and

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repair and maintenance factors. Where they were not available from manufacturers, engineering specifications were computed from ASAE D497 (1990) for comparable implements. Draft force for multi-component tillage implements were computed from a sum of forces for individual components, such as coulters, chisels, and various disks. In addition to the complete implements in the data base, individual components were added to allow the user to try out potential new equipment configurations. Each tractor and implement also included an percent assignment to the crop being assessed. For peanut, diggers and combines were assigned 100% of the time to the crop, but tractors, sprayers, and tillage implements could be shared with other enterprises on the farm to distribute fixed costs more appropriately.

In addition to the implement data base, a default data base was constructed for acres to be planted, average slope of the fields, unit prices for fuel, oil, labor, and commodity, and interest rate on capital. Finally, a default scenario data base was constructed. A scenario was a sequence of field operations to be used in the production of the crop. Scenarios are comparisons for which engineering and economic analyses are desired. They may consist of nearly identical series of field operations where only one tractor or implement is being varied, or they may be completely different systems of production, such as, comparisons between moldboard plow based production with nine field operations versus conservation tillage based system with just four operations.

Each operation in a scenario is a separate pass over the field. When, for example, subsoilling, row cultivation, planting, fertilizer application are accomplished in a single pass it is one operation. Conversely, each pass with a disk harrow was a separate operation. For each operation, an implement from the equipment data base, a maximum number of hours per day for the operation, and preferred date or dates were specified. For most operations the preferred date was the date on which the operation would begin unless delayed by inclement weather, poor soil conditions, or incomplete prior operations in the scenario. For cultivation, a period of delay could also be specified so that cultivation would be delayed a fixed number of days after planting or after previous cultivation. For planting, four dates were supplied: the earliest possible date to begin planting assuming soil temperature was high enough; the planned or normal planting date; the date by which planting must begin even if not all field areas are prepared; and the last date on which planting could be done. The latter two dates involved abandoning some of the planting intentions in order to obtain an acceptable yield. They were not used unless weather delays or inadequate equipment was specified for the intended acreage. For harvest (digging), the planned date will be the maturity date for that portion of the field as predicted from the planting date and intervening weather, but a must-start-harvest date and must-stop-harvest date can be specified to prevent late delivery to the market.

Engineering calculations. The procedures followed methods outlined in Parmar et al. (1991) and were used to calculate hours required for each operation. Hours required are field size divided by implement speed and width. Implement speed was calculated from power requirements of the implements selected and available power of the tractor selected. Power for PTO and draft force were supplied in the equipment data base. Rolling resistance force was computed for tractors and wheeled implements from weights for tractor or implement plus mean contents of sprayers, fertilizer spreaders, etc., and average land slope using methods outlined by Hunt (1989). If the calculated speed fell below the minimum speed for operation, the tractor was too small and a higher powered tractor was required. If the speed exceeded the maximum operating speed, then the speed was limited to that maximum.

Economic Analyses. Once hours required for each operation were known, costs could be computed. Fuel and oil costs were calculated from tractor horsepower, operating hours and fuel costs as outlined by Hunt (1989). Labor was calculated from operating hours and labor costs. Repair and maintenance for each implement and tractor were based on purchase price and repair factors supplied in the equipment data base. Computation followed ASAE EP496 (1990). Annual fixed costs were computed from supplied interest rate and purchase price using capital consumption equations of Hunt (1979). These assumed a 10-year life of machinery, salvage value of 10% of purchase price, and tax, shelter, and insurance costs equal to 2% of the purchase price. When equipment, such as tractors, was shared over operations, fixed costs for each operation were prorated over shared operations based on hours required for each. Unshared items, such as peanut diggers, had all fixed costs assigned to that operation.

Crop and Weather Interactions An important component of the analysis of tillage options is the affect of changed practices on timeliness of operations. If an alternative practice requires more time, it increases the likelihood that inclement weather will delay operations. When the delayed operation is planting or harvest, yield can be affected. To determine how tillage scenarios interact with weather and crop yield, the PNUTGRO model was run for 25 years (1973 to 1992) of weather from the Tifton, Ga., region. When soil in the upper 15 in. had water content above field capacity, the field was too wet and all field operations were suspended. Other delays were caused by rainy days and by very cold (average air temperature below 40 F or maximum below 45 F). Additionally, planting was delayed if soil temperatures during the three days before scheduled planting were below 70 F. Digging was forced by the first freeze because vines would be killed in late maturing peanuts. All weather affected delays were recorded and continuation of the delayed field operation scheduled to resume as soon as weather or soil conditions permitted.

When planting operations began the portion of the field planted on a given day was handled as a cell for which a maturity [digging) date and yield were computed for each year using the PNUTGRO model and that year's weather. Planting that extended over many days, particularly when delayed by rain, created fields that had uneven maturity and yield. Three days before peanuts matured in the first cell, harvest was started. As each day's harvest was complete a yield was computed for that harvested area from the composite of cells harvested that day. Early and late harvests for each crop reduced yield as described by Parmar et al. (1991). A composite seasonal yield was computed and average yield and economic return calculated for the 25 years of weather. These long term average minimized biases in tillage options caused by conducting tests in exceptional years.

Analysis of Peanut Tiilage Options

In the example shown here, the engineering based, economic analyses EVTOPS was run for three common tillage systems: slot planting (strict no-till), row-till (conservation tillage including in-row subsoil and row cultivation), and moldboard plow (conventional). Operations included digging and combining in all cases. early spring herbicide application for the first two systems, and rototilling and field cultivation in the moldboard plow scenario. For the conservation tillage a 155 hp tractor was required to pull the integral, 6-row, subsoiller/planter. The 6-row. no-till planter and the 2-row moldboard plow and rototiller could be operated with a 100 hp tractor. In the cases examined here, all equipment was assumed to be 100% dedicated to the peanut crop enterprise.

RESULTS AND DISCUSSION

Initial runs show that costs are highly affected by the tillage and tractor required. Table 1 summarizes operations, field time required, and costs for the three scenarios for a 320 acre peanut field. The moldboard plowing required the greatest field time and, hence, had the highest labor costs. The total fixed costs for the moldboard plow scenario was the same as for the slot planting system since the same 100 hp tractor was charged against this enterprise. but the more expensive 155 hp tractor added substantially to the tractor fixed cost. The tractor variable cost is largely dependent upon time, but the higher power requirements adds additional fuel cost with the large tractor, and the repair and maintenance costs are affected by the purchase price. The implement fixed costs were highest for the conservation tillage because the subsoiller/row tilllplanter was more expensive than the 6-row planter used in the slot planting and moldboard plow systems. Implement fixed costs are for the entire season since most are used only in one operation per year.

The yields predicted for these three scenarios were similar, approximately 3200 lb/acre pod yield, since we selected large enough tractors to plant and harvest in a short time. If we switched the conservation tillage equipment to 2-row to allow use of the 100 hp tractor, then the longer planting season caused lower yields with conservation till. Over 25 years of weather for the Tifton. Georgia, area, the average number of delayed field days was 7.0 for the moldboard plow, 4.0 for the slot planting and 4.6 for the conservation tillage. Delays would be greater with larger field areas and for locations with a less favorable spring or fall weather.

EVTOPS can help identify tillage options that can lower overall costs and not reduce potential yields due to planting delays. The program cannot determine the yield response to the tillage itself. however. In this example, slot planting was the least expensive tillage scenario, $192/acre

Table 1. Fixed and variable costs, time required for operations and labor costs for three tillage systems. All tractor and equipment costs are assigned to this 320 acre enterprise.

Operation	Time Used	Tractor Fixed	Tractor Variable	Implement Fixed	Implement Variable	Labor Costs
	hours	Dollars/acre				
Slot planting - 320 acre - 100 hp tractor						
Herbicide	34.7	3.10	1.07	1.42	0.25	0.65
Plant	35.3	3.15	1.17	11.14	1.43	0.66
Dig/Invert	61.2	5.45	1.88	6.95	0.65	1.15
Combine	169.3	15.10	5.21	11.34	3.12	3.17
Total	300.5	26.80	9.25	30.85	5.52	5.64
Conservation till - 320 acre - 155 hp tractor						
Herbicide	34.7	3.60	1.61	1.42	0.25	0.65
Subsoil/plant	118.1	12.23	5.51	25.52	10.96	2.21
Dig/Invert	61.2	6.70	2.85	6.95	0.65	1.15
Combine	169.3	17.54	7.90	11.34	3.12	3.17
Total	383.3	40.07	17.89	45.23	14.98	7.18
Moldboard plow - 320 acre - 100 hp tractor						
Disk	29.6	1.27	0.91	5.67	0.27	0.55
Disk	29.6	1.27	0.91	0.00	0.27	0.55
Plow	148.8	6.36	4.58	3.97	2.44	2.79
Rototill	103.6	2.58	3.47	1.05	0.32	1.94
Plant	25.2	1.08	0.77	8.10	0.74	0.47
Cultivate	29.6	1.27	0.91	2.83	0.11	0.55
Cultivate	29.6	1.27	0.91	0.00	0.11	0.55
Dig/Invert	61.2	2.62	1.84	6.95	0.65	1.15
Combine	169.3	8.95	5.18	11.34	3.12	3.17
Total	626.5	26.80	19.28	39.92	8.04	11.74

compared with $308 for conservation and $261 for moldboard. However, in soils that have hard pans the loss in yields may offset part of these cost savings. Field trials will be needed to verify yield effects. The costs, space, and time requirements for field tillage studies precludes use of large numbers of variables in long-term studies. Evaluation of Tillage Options (EVTOPS) enables a screening method for planning and evaluation a large number of tillage options.

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COMPARISON OF TILLAGE METHODS FOR COTTON FOLLOWING FESCUE SOD IN CRP LAND

Joseph R. Johnson[1] and Keith McGregor[2]

INTRODUCTION

The current acres enrolled in the Conservation Reserve Program (CRP) in the Brown Loam soil resource area in North Mississippi probably had already become an economic risk to the soybean producers before the CRP contracts. CRP is a contract program between USDA and producers to take fields with highly erodible land out of production for 10 years. Declining soybean prices and land productivity through the late ***70's*** and early 80's caused soybean producers to abandon many of the fields before entering the CRP contracts. By far, most of the CRP acres of the Brown Loam was once pasture land brought into soybean production in the early and mid-seventies.

Cotton again has become the dominate crop of the Brown Loam soil area. Soybean acreage declined ***70%*** during the decade of the 80's. The soybean acreage in the hill section continues to decline (USDA Statistical Reporting Service, 1981-82; 1991).. Brown Loam soil is of the ideal texture and structure for cotton production. Even though the hill land is considered droughty in the summer. cotton still can be very productive and return a favorable profit on the hills.

If considerable strength in cotton commodity prices were possible by the time CRP contracts expire, some of the land could return to cotton production. This, however, is speculative. The Agricultural Stabilization Conservation Service (ASCS) classified these fields as cropland. A Soil Conservation Service (SCS) farm plan will be necessary to bring the land back into production to avoid violating the Sodbuster Provision of the Food Security Act of 1985 Farm Bill. Type of cropping system allowed will depend on the Conservation Compliance Standards. The SCS has not determined if the compliance standards will be equal to the tolerance level (T) or 2T. On the average, 50% of the land per field is not classified as highly erodible (HE). Therefore, on a per field basis it could be possible to exceed the erosion standards on the HE portion of land and still be in compliance within the field. Consequently, the choice of tillage practices a producer uses in a field can be much broader than just what applies to the HE land.

With these factors in mind, research was started to evaluate the tillage procedures for handling CRP land going into cotton. The objective of this study was to evaluate the effects of alternative tillage practices and procedures (described in Methods and Materials) on cotton yields during the first year of cotton production following sod.

METHODS AND MATERIALS

Research described in this report supports and complements broader cooperative studies between the North Mississippi Branch of MAFES and the National Sedimentation Laboratory (USDA-ARS) that evaluate effects on runoff and erosion of returning idle upland watersheds (similar to CRP land) to row crop production. Those studies include runoff and sediment yield measurements on a 4.4-acre watershed before and after implementation of conservation tillage treatments (contoured, no-till planted cotton rows and 20-foot wide grassed buffer strips) following fescue sod extablished in 1986. Soils on the watershed are a mixture of Memphis, Loring, and Providence silt loams. The Providence soil has a fragipan which is sometimes very shallow. This tillage study site was adjacent to the watershed, contained similar soils, and was treated in the same manner as the watershed prior to the beginning of this study.

The experimental design is a randomized complete block with five replications. Fragipan depth was measured at eight locations within each replication and was within 2 in in each replication. Tillage treatments were: (1) fall hipped and spring rehipped; (2) no-till; (3) conventional tillage (disk-chisel, disk, hip); (4) no-till with two cultivations; (5) spring 2X hipped. Two postemergence cultivations were made on all treatments except the (2) no-till treatment.

Roundup (2.0 lb ai/ac) was sprayed as a burndown treatment in October of 1992 over the entire study area before any fall tillage. A second Roundup (1.0 lb ai/ac) spray was made in the spring of 1993 on the no-till planted plots. Dual

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(0.5 lb ailac) and Cotoran (.75 lb ai/ac) were broadcast sprayed immediately after planting. The cotton was planted on April 29, 1993. Measurements for plant height, canopy cover, residue cover, and percent weeds were made on May 26, July 7, Aug. 11, and Sept. 14. The cultivations were made using a no-till cultivator on June 3 and July 2. An early post directed spray was made on June 14 using MSMA (1.5 lb ailac) and Cotoran 10.75 lb ai/ac) + Probe 10.67 lb ai/ac). A layby treatment was made on July 9 using Bladex 10.5 lb ai/ac) plus a 1% surfactant on vlv. Insecticide treatments were sprayed starting in early June with pinhead square for bollweevil and continuing throughout the growing season as needed according to scouting reports made by personnel on the station. Cotton was defoliated on October 1 using Def 11.2 lb ailac) + Prep 1.03 lb ailac) and machine harvested on October 22. After shredding stalks with a rotary cutter, residue cover was made using a transect line. A second residue cover will be made in May, 1994 after the second year's planting.

RESULTS AND DISCUSSION

The conventional tilled system produced well-structured mellow beds for planting. The fall hipped beds were rough, cloddy, and uneven at planting. These beds had large air pockets. The sod rolled when it was hipped and the beds were inverted sod rolls on top of sod. The rehipping of the fall beds in the spring covered the cloddy surface with loose soil but didn't help in the overall bed structure. On the other hand, spring hipping resulted in beds that tilled easier and improved the bed structure. The rehipping of the spring beds, however, did make for a well developed seedbed. The no-till plots were planted flat into killed sod.

Table 1. Seasonal residue in cotton plot with different tillage practices.

Tillage Practices	May 26	July 7	Aug. 11	Sept. 14
	Percent ground cover			
Fall Hipped	6	6	*7*	44
No-Till	*97*	95	95	84
Conventional Till	6	2	3	55
No-Till + Cult.	94	36	*31*	56
Spring Hipped	16	14	14	54

Plant residue at four weeks after planting averaged 80% higher for the no-till cotton than for the tilled cotton (Table 1). After the cultivations, the no-till plots without cultivations continued to average above 80% residue whereas the cultivated no-till cotton dropped below 40% residue. The sweep action of the cultivator covered more of the residue and exposed more soil in the no-till cotton than was realized by the eye.

Abundance of rainfall and water logged conditions the first four weeks after planting resulted in poor rooting systems in the no-till planted cotton. From personal observation, the rooting system of the cotton on the raised beds at six weeks after planting was superior to that of the cotton planted no-till on flat ground. The exposure of no-till plants to stress due to excess water produced a poor rooting system. The weather then turned hot and dry resulting in drought stress for the plants especially the no-till with the poor rooting system.

Plant population was statistically significant (P.05) for the no-till planted cotton versus the tilled plots (Table 2). Yet, the average population of all tillage practices ranged from 40,000 to 50,000 plants per acre, which are ideal plant population rates for North Mississippi Brown Loam soils IMcCarty, et al, 1990). Three weeks after emergence there was no difference in plant height in the tillage plots (Table 3). At eight weeks after emergence a big difference was observed in plant height. Preplant tilled cotton averaged 22 inches in height compared to 17 inches for cotton with no preplant tillage.

Table 2. **Plant population of cotton within different tillage practices at three weeks after emergence.**

	TILLAGE PRACTICE	
	Preplant Tillage	No Preplant Tillage
Plant population/acre	50,666	*43.499*
LSD (0.5)	6,248	

Table 3. Seasonal growth and development in plant height and canopy closure of cotton plants grown using different tillage practices.

	PLANT HEIGHT (IN)				CANOPY COVER (%)			
Tillage Practices	May 26	July 7	Aug. 11	Sept. 14	May 26	July 7	Aug. 11	Sept. 14
Full Hipped	2	21	27	30	4	41	64	59
No-Till	2	16	29	33	3	32	59	59
Conventional Till	2	22	31	36	4	45	76	76
No-Till + Cult.	2	17	28	34	3	32	59	61
Spring-Hipped	2	23	31	34	3	46	75	74

Table 4. Seasonal weed **population/50 ft** of row in cotton grown using different tillage practices.

Tillage Practices	May 26	July 7	Aug. 11	Sept. 14
		(%)---------------------------		
Fall Hipped	0	2	2	3
No-Till	0	2	8	14
Conventional Till	0	1	1	2
No-Till + Cult.	0	1	9	15
Spring Hipped	0	1	1	2

Table 5. Seed cotton yield of cotton grown using different practices.

TILLAGE PRACTICES	SEED COTTON YIELD
	-----------lb/ac-----------
Fall hipped	1594
No-till	1540
Conventional till	1793
No-till + cultivation	1355
Spring hipped	1824
LSD .05	320

Cultivation was made on June 3 and July 2 in all cotton with preplant tillage and in the designated no-till plot. Cultivation at these growth stages did not appear to have any beneficial effect on the plant growth and development- certainly not any that could be measured in terms of height or canopy. The cotton in the fall-hipped plots grew similar to the other tilled plots until about eight weeks after emergence. From that point until maturity there was very little growth in plant height for the fall hipped cotton. This lack of plant growth was probably a result of the structure of the seedbed, which dried out rapidly.

Closure of plant canopy closely followed the same pattern as plant height for the different tillage systems. The spring hipped cotton and the conventional tilled cotton had a higher percentage of canopy closure after August 11 than the fall hipped, no-tilled plus cultivate, and no-till cotton. Cultivation of the no-till cotton after plants were four and eight weeks old did not have any effect on plant canopy closure.

Weed population was higher in the no-till and no-till plus cultivate at 12 and 17 weeks after emergence than in the plots that had preplant tillage (Table 4). The plots with no preplant tillage had shorter plants with less canopy cover at eight weeks after planting thereby allowing more light on the row, which enhanced weed seed germination.

Yields were significantly lower (P.05) for the no-till plus cultivate plots (Table 5). Yields were more of a reflection of available soil moisture and rooting system than any other factor.

CONCLUSION

The no-till planted plots had a significantly lower plant population. However, the population of the no-till plots were within the recommended range. Plant height and canopy closure were the highest for the conventional tilled plots. Residue as ground cover decreased as tillage increased. Yields were significantly lower for the no-till plus cultivate plots.

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POPULATION DYNAMICS OF TOBACCO BUDWORM AND COTTON BOLLWORM AND THEIR NATURAL ENEMIES IN CONSERVATION TILLAGE COTTON

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and James R. Frederick[4]

ABSTRACT

Populations of the tobacco budworm, Heliothis virescens (F.1, the cotton bollworm, Helicoverpa zea (Boddie), and their natural enemies were monitored from 27 April through 8 September 1993 in crimson clover (Trifolium incarnatum L.) and a subsequent conservation tillage cotton (Gossvpium hirsutum L.) crop. Predaceous arthropods (mostly the big-eyed bug, Geocoris spp.) and parasitoids (Braconidae) were very active against H. zea (65%) and H. virescens (35%) populations during May. Predaceous arthropods were also very active during June and July in cotton. The parasitic wasp, Trichogramma spp., became very effective in regulating H. zea during August. Arthropod populations through the season did not differ between plots treated with herbicide and mechanically cultivated for weed control in winter covers of clover and fallow. Future research will detect pattern of moth emergence during the spring.

INTRODUCTION

There has been increased interest in conservation tillage because of its potential to control soil erosion and use energy more efficiently. Most of the cotton (Gossvpium hirsutum L.) pest management research has focused on conventional tillage systems. Because of the relationship of some arthropods (both pest and beneficial) with the soil and various cover crops such as crimson clover (Trifolium incarnatum L.), it is important to explore the effects of conservation tillage on specific arthropods.

The major lepidopterous pest in cotton in South Carolina is the tobacco budworm (Heliothis virescens (F.))/cotton bollworm (Helicoverpa zea (Boddie)) complex. These pests overwinter as diapausing pupae in earthen cells as deep as six inches. Overwintered moths emerge largely during May through exit tunnels made by the prepupae the previous year (Neunzig, 1969). Through the cotton growing season, prepupae drop to the soil before pupation and tunnel about one inch deep. There can be up to four generations in South Carolina cotton fields. Roach (1981a) reported that while greater numbers of moths emerged from conservation-tillage plots, conservation-tillage and plow-tillage systems in cotton had similar Heliothis/Helicovepa populations (Roach 1981b).

The complex of predaceous arthropods and parasitoids that attack the TBW/CBW complex has the potential to be quite effective in cotton. Higher populations of natural enemies may occur with conservation tillage (All and Musick, 1986) compared to conventional. For optimum pest control, it is important to ensure the conservation and enhancement of natural enemies (McCutcheon and Turnipseed, 1981). Therefore, we must avoid practices that interfere with biological control and utilize procedures that favor the biological potential of natural enemies. Altering diversity of vegetation will favor some biological control agents.

The purpose of this study was to document seasonal occurrence and population density of TBW/CBW and their natural enemies in conservation tillage systems.

MATERIALS AND METHODS

Eggs and larvae of the tobacco budworm/cotton bollworm (TBW/CBW) were monitored and sampled twice per week from 27 April through 8 September, 1993 in a winter cover of crimson clover and a subsequent conservation tillage cotton crop. Research was conducted at the Pee Dee Research and Education Center near Florence, South Carolina.

Treatments included winter cover (crimson clover and fallow), planting date of 'DES-119' (15

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April, 29 April, and 25 May) and midrow weed control method (herbicide-glyphosate and V-blade cultivator). Treatments were arranged in a randomized complete block design with a split plot arrangement. Winter cover and planting date combinations were the main plots, and the midrow weed control methods were subplots. Crop management and treatment applications are described by Bauer et al. 1994.

Larvae were collected from crimson clover by using a heavy sweep net (37.5 cm diameter). Eggs and larvae were collected and population estimates recorded from the visual examination of 100 cotton plants per treatment once or twice per week. Predaceous arthropod populations were estimated by using a 15 quart dishpan (14⅝" X 13" X 6⅛"). The plants were bent gently over and shaken into the dishpan in order to count predators. Two 1-m sections were sampled in each plot.

Each larva detected was placed individually in a 30-ml plastic cup containing artificial diet (Greene et al. 1976). Eggs were transported to the laboratory and placed individually in size 0 gelatin capsules. Larvae and eggs were held at 26 ± 2° C, 60 ± 5% RH, and a 14:10 LD regimen and checked every 1 to 2 d for hatching, parasitoid emergence, pupation, and disease symptoms. Egg para- sitoids were prepared and mounted on slides for identifications. Adult parasitoids that emerged from pest larvae, along with their cocoons, were preserved in vials of 95% ethyl alcohol.

Table 1. Percent composition of predaceous arthropods in crimson clover and a subsequent conservation tillage cotton crop. 1993, Florence, S.C.

	Clover - May	Cotton -June
Geocoris spp.	45.8	59.5
Coccinellidae	24.3	
Araneida	15.3	9.7
Nabis spp.	7.6	9.7
Formicidae	4.2%	6.5
Notoxus spp.		13.0

RESULTS AND DISCUSSION

Natural enemies of TBW/CBW were very active during May 1993. Predaceous arthropods were prevalent in crimson clover reaching 79 per sweep net sample (100 sweeps). The big-eyed bugs, *Geocoris* spp., were the most abundant, comprising 45.8% of the predator complex (Table 1). Ladybird beetles (Coccinellidae) were common in the clover 24.3%. Parasitism of TBW/CBW larvae was high, reaching 66% during mid-May. Parasitoids were braconid wasps (Family Braconidae) and included *Cardiochiles nioriceos, Meteorus autoaraohae, Cotesia maroiniventris,* and *Microolitis croceipes* (Table 2).

During June, TBW/CBW larval estimates reached only 5 per 100 plants. Asana was applied on 24 June. Predators detected with the dishpan were quite abundant in cotton, reaching 37 per 8 m of row. Again *Geocoris* spp. were the most prevalent, and antlike flower beetles, (*Notoxus* spp.), damsel bugs (Nabis spp.), spiders (Araneida), and ants (Formicidae) occurred. Ladybird beetles (Coccinellidae) were not detected in the cotton during June (Table 1).

The eggs of TBW/CBW reached their peak population during late July at 84 per 100 plants. Predaceous arthropods were abundant in mid July reaching 74 per 8 m of row (Fig. 1). It appears that the high number of *Geocoris* helped to regulate pest population. Larval estimates reached only 2 per 100 plants. Insecticide was also used 21 (Larvin) and 27 (Scout) July. Predators followed a density dependent trend; therefore, when TBW/CBW eggs were available, predators were very abundant.

During August, egg counts were relatively low. In late August, H. zea approached economic threshold levels for a brief period of time. In addition to predators, which reached 38 per 8 m of row on 12 August (Fig. 2). *Trichoaramma* spp. became active. Percent parasitism was high throughout the month, reaching 42% on 25 August. *Trichoqramma* remained active following an application of Asana on 12 August. This parasitoid was rarely detected during June and July.

There were no significant differences among planting dates, winter cover, or weed control methods in arthropod populations season-long.

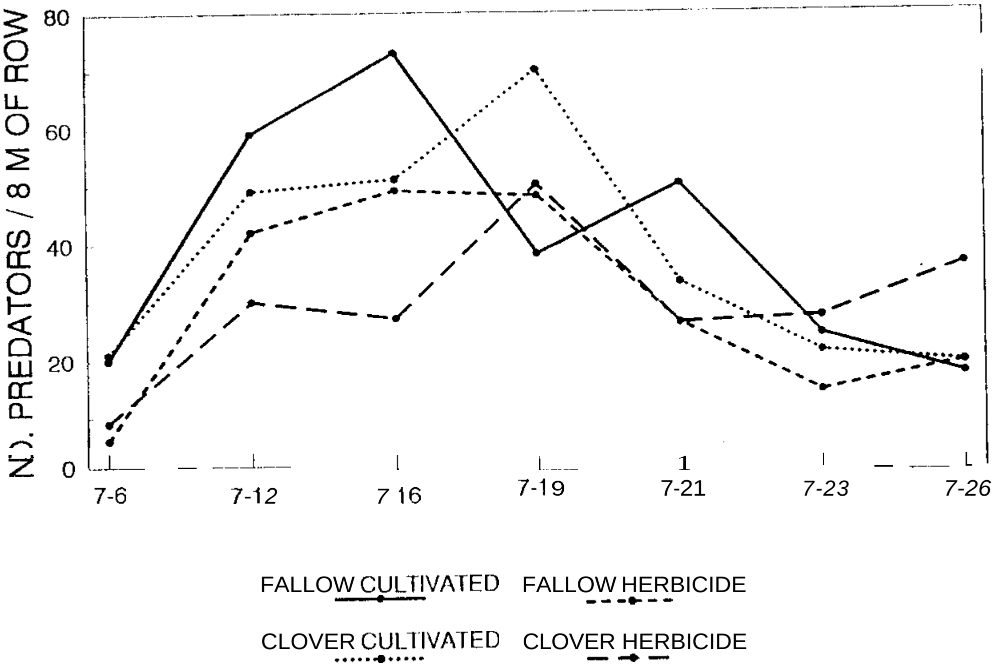

Figure 1. Population estimates of predaceous arthropods in conservation-tillage cotton. Florence, SC. July 1993.

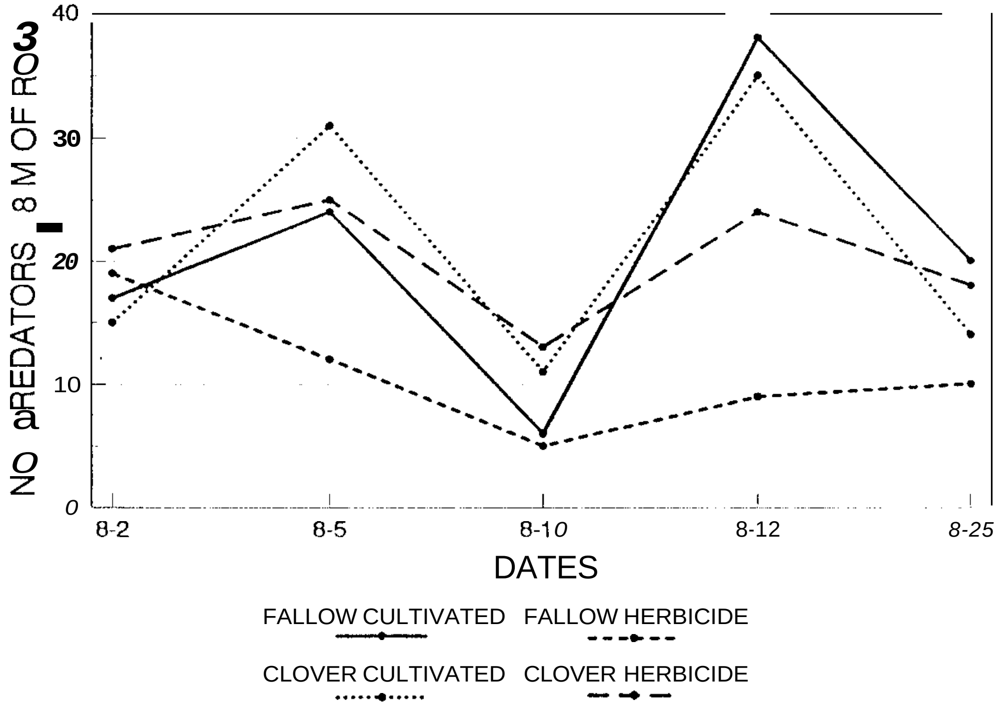

Figure 2. Population estimates of predaceous arthropods in conservation-tillage cotton. Florence, SC. August 1993.

Table 2. Percent parasitism by braconid wasps on budworm/bollworm larvae collected from crimson clover. 1993. Florence, S.C.

	n	Cotesia marginiventris	Cardiochiles nigriceps	Microplitis croceipes	Meteorus autographae
May 11	65	7.7	3.1	1.5	0.0
May 17	71	11.3	22.5	16.9	15.5
May 25	41	0.0	19.5	0.0	2.4
May 27	28	0.0	10.7	10.7	7.1
May 28	9	11.1	22.2	0.0	0.0

Table 3. Percent composition of two lepidopterous species in crimson clover during May and cotton during June, July, and August. 1993. Florence, S. C.

	n	Heliothis virescens	Helicoverpa zea
May	153	35.3	64.7
June	48	79.2	20.8
July	211	25.6	74.4
August	78	< 1.0%	99.6%

Percent composition of TBW and CBW is listed in Table 3 for May, June, July, and August.

Future research will measure patterns of moth emergence in these plots. Also, in 1994, arthropod populations will be monitored.

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WEED MANAGEMENT SYSTEMS IN SOUTHERN PIEDMONT COTTON *(Gossypium hirsutum)*

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ABSTRACT

Field studies were conducted at the Southern Piedmont Research Center in Watkinsville, GA to examine weed management strategies for conservation-tillage cotton. Weed management systems that included a post-directed or postemergence herbicide application provided greater weed control than those with preemergence herbicides only. Differences in tillage were specific among weed management systems and varieties were observed. In weed management systems without postemergence weed control, tillage differences were not observed. When a preemergence only weed management system was utilized, cotton grown in the conventional-tillage system yielded the highest. The paraplow followed by in-row chisel planter yielded higher than the other tillage systems. DS119 cotton yielded higher than the DPL9O and Tifcot 56 in plots in which cotton was planted with a in-row chisel either behind fall paraplow or disk-harrow. Varietal differences were not observed when a fluted coulter was used to plant cotton. In the conventional-tillage system, DPL9O yielded higher than DS119 and Tifcot56. Economic analysis showed that net returns were greater with DS119 at the two higher weed management systems under all tillage regimes. Economic returns from DPL9O and Tifcot56 were negative except in conventional-tillage and high weed management systems.

INTRODUCTION

Cotton acreage has increased in Georgia by 500,000 acres in the last ten years and is expected to be approximately 1,000,000 acres by the end of the decade (Crawford, personal communication). Economics and legislation such as the 1990 Farm Bill have lead to an increase in conservation-tillage cotton acres in Georgia overall and particularly in the highly-erodible soils of the piedmont regions.

The objectives of this research were to evaluate four conservation-tillage systems compared to conventional-tillage in cotton. Within these tillage systems, four weed management systems, and three cotton varieties. A crop enterprise cost analysis was utilized to compare the net returns from tillage systems, weed management, and varieties used.

METHODS

These studies were conducted from 1991 to 1993 at the Southern Piedmont Research Center near Watkinsville, GA on a Cecil sandy loam soil. In all years of the study, rye was planted in the fall after fall tillage operations (disk harrowing and paraplow). The rye cover crop was killed with paraquat applied at 0.5 lb/A when approximately 3000 lbs dry matter/A was present. Cotton was planted shortly after the rye cover crop was killed. The field plots were arranged in a split-split-block design with tillage regimes as whole block split for weed management and variety studies. The whole blocks were five tillage regimes which consisted of conventional-tillage (fall disk harrow followed by spring disk harrow), four conservation-tillage regimes of fall paraplow followed by planting with a fluted coulter or in-row chisel at planting, and fall disk-harrowing followed by planting with a fluted coulter or in-row chisel. These whole tillage blocks were split into weed management and cotton varietal sub-blocks. The weed management consisted of no inputs, preemergence only system consisting of norflurazon plus fluometuron applied at 1.0 lb/A, postemergence only system consisting of a split application of MSMA applied post-directed at 6-8 inch cotton and 10-12 inch cotton at 1.5 lb/A and sethoxydim applied broadcast at 0.20 lb/A, and a preemergence plus postemergence system consisting of norflurazon applied preemergence at 1.0 lb/A followed by a split application of MSMA applied post-directed at 1.5 lb/A at the 6-8 inch and 10-12 inch cotton height. The cotton varietal sub-block consisted of three cotton varieties (DS119. DPL90, and Tifcot 56). Visual weed control ratings were taken 10 weeks after planting and seed cotton yields were taken.

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Seed cotton yields were converted to fiber yields for an economic analysis based on a Crop Enterprise Cost Analysis developed by the Georgia Cooperative Extension Service (Givan and Shurley, 1993) Data were analyzed by computer using ANOVA procedures (SAS, 19851.

RESULTS AND DISCUSSION

Differences in tillage were specific among weed management systems and varieties. In weed management systems without postemergence weed control, tillage differences were not observed. Sicklepod and smooth pigweed control were greater than 80% 10 weeks after planting (WAP) in all tillage systems in which a post-directed application of MSMA was applied. In the weed management system in which no postemergence herbicides were used, sicklepod and smooth pigweed control ranged from 60 to 75% 10 WAP. When a preemergence only weed management system was utilized, cotton grown in the conventional-tillage system yielded higher than other conservation-tillage systems. Under weed management systems utilizing postemergence only weed control, cotton yielded higher than the other tillage systems when the paraplow followed by an in-row chisel planter was used. Under weed management system utilizing preemergence plus postemergence weed control, cotton yields were equivalent between fall paraplow followed by spring planting with fluted coulter and fall paraplow followed by spring planting with an in-row chisel, and conventional-tillage.

DS119 cotton yielded higher than the DPL9O and Tifcot 56 in plots in which cotton was planted with a in-row chisel either behind fall paraplow or disk-harrow. Varietal differences were not observed when a fluted coulter was used to plant cotton. In the conventional-tillage system, DPL9O yielded higher than DS119 and Tifcot56. Economic analysis showed that net returns were greater with DS119 at the two higher weed management systems under all tillage regimes.

Economic analysis revealed that positive net returns resulted when the weed management system consisted of a residual preemergence followed by postemergence herbicide and the cotton variety DS119 was planted under all five tillage systems. The highest net returns among the five tillage systems were with the fall disk-harrow followed by spring in-row chisel for cotton planting ($50 dollars/A). The lowest net returns were from the conventional-tillage system ($12/A). When DSI19 cotton variety and a postemergence only weed management system were utilized, positive net returns were observed from the fall paraplow followed by spring in-row chisel ($108/A), fall disk-harrow followed by spring in-row chisel ($24/A) or fluted coulter ($11/A), but not the conventional-tillage system. In plots in which DPL9O cotton was planted positive net returns were observed in the conventional-tillage plots with weed management systems that contained a postemergence herbicide.

These data indicate that conservation-tillage cotton requires intensive weed management to be successful. A postemergence weed management system is requisite. Among cotton varieties examined, DS 119 seemed best suited to conservation-tillage while DPL 90 is best suited to conventional-tillage. Among tillage systems examined, the spring in-row chisel preceded by either a fall paraplow of disk-harrowing operation seemed to perform better.

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USE OF LEGUME WINTER COVER CROPS IN COTTON PRODUCTION SYSTEMS

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INTRODUCTION

Cover crops historically were widely grown in the southeastern United States, with an estimated 13 million acres of cover crops grown in this region in 1940 (Rogers and Giddens, 19571. Cover crops were incorporated as green manures prior to planting a summer or cash crop in an effort to maintain soil productivity in the absence of inexpensive inorganic fertilizers. Recently there has been a resurgence in research and interest in winter cover crops, especially legumes IHoyt and Hargrove, 1986; Smith et al., 19871. These crops are being evaluated for their effectiveness in reducing soil erosion and nitrogen contribution to the subsequent cash crop. Estimates of nitrogen (N) contribution from a hairy vetch (Vicia villosa Roth) cover crop for a subsequent cotton (Gossypium hirsutum L.) crop ranged from 6-60 lb N/A (Brown et al., 1985; Melville and Rasbury. 1980; Scott et al., 1990, Touchton et al., 1984). In addition to nitrogen, a number of soil properties are improved by cover crops including increased soil organic matter, saturated hydraulic conductivity, and water infiltration rates (Scott et al., 1990).

Long-term studies have demonstrated the feasibility of a legume cover crop-cotton production system. In a study conducted since 1972 at the Delta Branch Station, Clarkedale, Arkansas, hairy vetch plus rye (Secale cereale L.) or hairy vetch cover crop treatments significantly increased seedcotton yields by 263 and 145 lb/A, respectively, compared with winter fallow (Scott et al., 19901. Annual seedcotton yields in a long-term study (1955-1980) at the Red River Research Station near Bossier City, Louisiana, were 2152 lb/A following hairy vetch compared to 2120 lb/A for cotton monoculture with 60 lb/A of supplemental nitrogen (Dawkins and Paxton, 1983).

One of the concerns with the use of cover crops has involved a perception that pest problems in the cash crop would increase due to the cover crop. However, there is limited data on the impact of cover crops on pest populations and pest damage for the subsequent cash crop. This information is critical for cotton, a crop in which profitability is determined in large part by pest damage and pesticide use. Seven sites were examined for the benefits and risks from pests as a result of the use of winter legume cover crops in cotton production systems as part of a Sustainable Agriculture Research and Education Grant. All sites had the cover crop treatments hairy vetch and winter fallow. Two long-term sites were included; Clarkedale, Arkansas, established in 1972, and Bossier City, Louisiana, established in 1955. Tillage comparisons, conservation vs. conventional, are included at four sites. The entomology sites, Edisto. SC and Foreman, AR ,included two hairy vetch treatments; 1) all of the cover crop incorporated, and 2) strips of hairy vetch allowed to mature. This report will focus on the impact of legume cover crops on seedling diseases of cotton.

MATERIALS AND METHODS

Field sites

Field studies on seedling diseases of cotton were conducted in 1992 and 1993 at 5 locations (Table 1). Timing of some field operations are listed in Table 1. Cotton stands were determined by counting seedlings in two 20 ft sections of row per plot. Sites were managed according to current University Cooperative Extension Service recommendations.

Soil Populations

Soil samples, 0 to 6 in., were taken along diagonals on the bed or within the row at three times; prior to planting cotton, at approximately cotton planting, and 6 weeks postplanting. Samples were refrigerated at 2 to 5 C and mixed thoroughly prior to assaying. Twenty-five grams of soil (oven dry weight1 were suspended in sufficient

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Table 1. Experimental outline for cover crop sites.

Site component	Clarkedale	Rohwer	Lewisville	Bossier City	Springfield
Plot design	Split plot	Split-split-split plot	Split plot	Split plot	Split-split plot
Cover crop treatments	Hairy vetch Winter fallow Hairy vetch +rye Crimson clover + rye	Hairy vetch Winter fallow Rye Wheat Crimson clover	Hairy vetch Common vetch 'Cahaba White' Winter fallow	Hairy vetch Winter fallow	Hairy vetch Common vetch 'Cahaba White' Fallow
Tillage treatments	Conventional Conservation	Conventional Conservation	Conventional Conservation	Conventional	Conventional Conservation
Other treatments		Irrigation +/- "Burndown" +/-		Nitrogen level	Aldicarb +/-
Replications	4	4	4	4	6
Plot size	8 rows x 100 ft	4 rows x 40 ft	6 rows x 50 ft	6 rows x 210 ft	8 rows x 50 ft
Soil type	Dubbs/Dundee silt loam	Hebert silt loam	Caspianna silt loam	Norwood very fine sandy loam	Lucy loamy sand
Cover crop killed	4/8/92 4/14/93	3/16/92 3/28/93	3/27/92 4/7/93	4/16/92 4/21/93	4/28/92 6/21/93
Cotton planted	5/12/92 5/26/93	5/2/92 5/6/93	5/8/92 5/3/93	5/5/92 5/7/93	5/26/92 6/21/93

0.2% water agar to make 250 ml. The sample was shaken on a wrist action shaker for 20 min prior to assaying populations or making additional dilutions. The spread plate method was used for estimating populations of Pythium spp. on P_6ARP (Jeffers and Martin, 1986). Populations of Thielaviopsis basicola were determined by the pour-plate method in TB-CEN (Specht and Griffin, 19851. Soil populations of Rhizoctonia spp. were determined by the soil-pellet method with a multiple-pellet soil sampler (Henis et al., 1978) on Ko and Hora's medium (Ko and Hora, 1971).

Seedling disease and pathogen isolation

Cotton seedling samples were collected approximately three weeks after planting from five random one foot sections of row. Seedlings were rinsed for 45 minutes in running tap water and rated for seedling disease symptoms. The hypocotyl disease severity index was 1=no symptoms, 2=few pinpoint lesions or diffuse discolored areas, 3=distinct nongirdling necrotic lesion, 4=girdling lesion, and 5=seedling dead. The root disease index was 1=no symptoms, 2=1-10% of the root system discolored, 3=11-25% of the root system discolored, 4=26-50% of the root system discolored, and 5>50% of the root system discolored. Seedlings were surface disinfested by immersion for 1.5 min in 0.5% NaClO and plated on water agar (2%). Resulting colonies were transferred to PDA and identified to genus. Seedlings were subsequently transferred to the Thielaviopsis selective medium to determine isolation frequency for T. basicola.

RESULTS AND DISCUSSION

Plant Stand

Cotton plant stands were similar over all winter cover crop treatments for 1992 and 1993. The conservation tillage treatment resulted in lower plant stands compared to conventional tillage at Rohwer in 1992 and Clarkedale in 1992 and 1993 (data not shown).

Soil populations

Differences were observed among treatments for soil populations of selected fungal genera. Pythium populations were significantly greater for the plots containing hairy vetch for most of the sites sampled compared to winter fallow (Table 2). In addition, the other winter cover crops at Clarkedale crimson clover + rye and hairy vetch + rye also increased populations of Pythium spp. in soil. A rye winter cover crop at Rohwer did not elevate Pythium populations. The elevation of soil populations of Pythium spp. following winter legume cover crops has been reported previously (Rothrock and Hargrove, 1988). Populations of Pythium spp. also were greater under the conventional tillage treatment at Rohwer (Table 2) and Clarkedale (data not shown) than under the conservation tillage treatment.

Thielaviopsis basicola populations were only detected in appreciable numbers at the long-term Clarkedale site. Soil populations were significantly lower following the cover crop treatments hairy vetch and hairy vetch + rye compared to the winter fallow treatment (Table 2). Evidence for the suppression of T. basicola populations from the incorporation of hairy vetch also has been shown in controlled environmental studies (Rothrock and Kendig, 1991).

Soil populations of Rhizoctonia spp. did not differ with cover crop treatment (Table 2) for the at planting sample in 1992 or 1993. Greater populations were found in the conventional tillage treatment at Springfield, SC than the conservation tillage treatment in 1992. Tillage did not significantly influence Rhizoctonia populations at the other sites.

Seedling disease

Seedling diseases were more severe at Clarkedale in 1992 and Lewisville. Seedling disease severity was not consistently influenced by cover crop or tillage treatment. Cotton seedlings showed slightly greater root and hypocotyl disease symptoms in the hairy vetch treatment than the winter fallow or common vetch treatments at Springfield in 1992 (Table 3). However, a rye cover crop increased root disease severity at Rohwer in 1993 and the winter fallow treatment had the greatest root disease severity at Clarkedale in 1993. Conventional tillage decreased root disease severity compared to the conservation tillage treatment at Rohwer in both 1992 and 1993 (Table 3) and Clarkedale in 1993, but increased disease severity at Clarkedale in 1992 (data not shown).

Table 2. Influence of winter cover crop and tillage treatments on soil populations of selected plant pathogenic genera at cotton planting.’

			Rhizoctonia spp.	Pythium spp.		Thielaviopsis basicola
Location/Treatment	1992	1993	1992	1993	1992	1993
Clarkedale, AR						
Cover crop						
Hairy vetch	35.4 a[z]	0 a	864,562 a	562,010 a	5,715 b	5,080 b
Winter fallow	55.8 a	0 a	175,543 c	258,098 c	30,391 a	25,401 a
Rye + crimson clover	19.5 a	8.2 a	762,068 ab	606,463 a	18,235 ab	23,224 a
Rye + hairy vetch	7.7 a	0 a	603,742 b	413,683 b	15,649 b	6,441 b
Lewieville, AR						
Tillage						
Conservation	6.8 a	0 a	107,503 a	184,615 a	0 a	0 a
Conventional	8.2 a	0 a	152,410 a	139,255 a	0 a	0 a
Cover crop						
Hairy vetch	8.6 a	0 a	224.078 a	217.274 a	0 a	0 a
Winter fallow	14.1 a	0 a	64,411 b	102,060 b	0 a	0 a
Common vetch	0 a	0 a	102,060 b	166.471 ab	0 a	0 a
Rohwer, AR						
Tillage						
Conservation	42.6 a	6.4 a	203,213 b	315,706 b	0 a	363 a
Conventional	62.6 a	2.3 a	529,351 a	372,859 a	91 a	816 a
Cover crop						
Hairy vetch	83.5 a	0 a	619,614 a	349.726 a	91 a	91 a
Winter fallow	45.4 a	10.0 a	253,109 b	351,540 a	45 a	181 a
Rye	29.5 a	3.2 a	226,800 b	331,582 a	0 a	953 a
Springfield, SC						
Tillage						
Conservation	28.6 a		59,422 a		0 a	
Conventional	68.9 b		50,803 a		0 a	
Cover crop						
Hairy vetch	74.4 a		92,081 a		0 a	
Winter fallow	40.4 a		35,834 b		0 a	
Common vetch	32.2 a		54,432 b		0 a	
Bossier City, LA						
Cover crop						
Hairy vetch	172.4 a	74.8 a	8,165 a	108,864 a	0 a	0 a
Winter fallow	127.0 a	57.6 a	11,340 a	109.771 a	0 a	0 a

[y] Propagules per lb of soil. Zero = populations below the detectable level.

[z] Means within a column and location and main effect are not significantly different if they are followed by the same letter, LSD ($P = 0.05$).

Table 3. Influence of cover crop and tillage on seedling diseases and isolation frequency of pathogens.

	Isolation frequency (%)[v]						Diseases severity index			
	Rhizoctonia solani		Pythium spp.		Thieleviopsis basicola		Hypocotyl[w]		Root[x]	
Location/Treatment	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Clarkedale										
Cover crop										
Hairy vetch	7.8 a[y]	9.0 a	23.6 a	35.0 b	19.2 c	1.0 a	2.4 a	2.0 a	3.0 a	1.5 b
Winter fallow	12.3 a	6.2 a	10.6 ab	30.2 bc	76.0 a	5.8 a	2.3 s	2.2 a	3.2 a	2.1 a
Rye+ clover	4.3 a	3.0 a	17.1 ab	66.0 a	58.7 b	5.0 a	2.6 a	2.0 a	3.6 a	1.6 b
Rye+ vetch	1.7 a	10.0 s	4.1 b	15.0 c	44.8 b	2.0 e	2.2 a	2.1 a	3.4 a	1.6 b
Lawisville										
Tillage										
Conservation	6.7 a	1.0 b	32.0 a	8.0 a	0 a	0.3 a	2.0 a	2.0 s	2.5 a	3.2 a
Conventional	13.2 a	3.3 a	25.0 a	6.4 a	o s	0.0 e	2.1 a	1.8 a	2.9 a	3.5 a
Cover crop										
Hairy vetch	6.8 a	3.5 s	29.8 e	9.0 a	o s	0.0 a	2.0 a	1.9 a	2.3 a	3.3 a
Winter fallow	9.5 a	3.0 a	23.8 e	4.5 a	0 a	0.5 a	2.1 s	1.9 a	2.9 a	3.4 a
Common vetch	13.5 a	O b	31.9 a	8.0 a	0 a	0.0 a	2.1 e	1.9 a	2.9 e	3.4 a
Rohwer										
Tillage										
Conservation	8.3 a	2.5 b	5.2 a	12.2 a	0 a	1.5 b	1.6 e	2.4 a	2.5 a	2.9 a
Conventional	17.8 a	6.9 a	10.1 a	18.5 a	0 a	11.8 a	1.7 a	2.2 a	1.9 b	2.5 b
Cover crop										
Hairy vetch	18.9 a	7.5 a	13.9 a	10.3 a	o s	10.6 a	1.7 a	2.3 a	2.1 a	2.6 b
Winter fallow	6.5 b	3.2 s	3.6 b	18.0 a	0 a	1.7 e	1.6 a	2.2 a	2.1 a	2.4 b
Rye	13.7 ab	3.2 s	5.3 b	17.8 a	0 a	7.7 a	1.7 a	2.4 a	2.3 a	3.1 a
Springfield										
Tillage										
Conservation	22.9 a		nc[z]		0 a		2.4 a		2.6 a	
Conventional	38.3 a		nc		0 a		2.3 a		2.3 a	
Cover crop										
Hairy vetch	27.1 a		nc		0 a		2.5 a		2.7 a	
Winter fallow	29.2 a		nc		0 a		2.2 b		2.3 b	
Common vetch	35.5 e		nc		0 a		2.2 b		2.3 b	

[v] Isolation frequency is based on seedlings from 5 random 1 ft sections of row, <= 25 plants.

[w] Hypocotyl disease index: 0 = no symptoms, 5 = seedling dead.

[x] Root disease index; 0 = no symptoms, 5 = greater than 50% root discoloration.

[y] Means within a column and location and main effect ara not significantly different if they are followed by the same letter. LSD ($P = 0.05$).

[z] Identification not completed. However, percent isolation was very low at this site.

Isolation frequency of pathogens varied among locations (Table 3). T. basicola was one of the major components of the cotton seedling disease complex at Clarkedale in 1992. The importance of reduced populations of this pathogen following a hairy vetch cover crop was indicated by the low incidence of black root rot, isolation of T. basicola, on cotton for these treatments (Table 3). Differences in isolation frequency of Pythium spp. from cotton seedlings were found among the cover crop treatments in 1992 and 1993, but results were not consistent. A hairy vetch cover crop tended to increase isolation frequency of R. solani at Rohwer in 1992, but hairy vetch did not influence isolation frequency in other years or locations (Table 3). Tillage influenced isolation frequency significantly at three sites. Conservation tillage decreased isolation frequency of Pythium spp. at Clarkedale (data not shown), T. basicola at Clarkedale in 1992 and Rohwer in 1993. and decreased R. solani at Rohwer and Lewisville in 1993 (Table 3).

SUMMARY

These results suggest that winter cover crops influence some cotton seedling diseases to a greater degree than others. Because several pathogens may be responsible for seedling disease, it is important to know which diseases are important in each field. Legume cover crops may reduce seedling disease in situations where T. basicola is an important pathogen. In contrast, when R. solani is an important component of the seedling disease complex, disease severity may increase. The data stress that the impact of cover crops on individual pests and pest damage will have to be understood before integrated crop management systems that include cover crops can be developed. An interdisciplinary team is addressing a number of aspects of the use of cover crops in cotton production, including the impact of cover crops on insects, nematodes. and weeds. Research suggests that the environmental sound production practice of the use of winter legume cover crops does not increase pest problems and may reduce specific problems such as black root rot. Initial results indicate the profitability of the production system varies dramatically over sites.

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EVALUATION OF A BLADE CULTIVATOR FOR CONSERVATION TILLAGE COTTON FOLLOWING CRIMSON CLOVER

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ABSTRACT

Shallow subsurface tillage can control weeds and maintain surface residues in conservation tillage systems. Our objective was to determine the efficacy of using subsurface tillage for weed control in cotton (Gossypium hirsutum L.) grown in a reseeding crimson clover (Trifolium incarnatum L.) winter cover production system. Treatments in the study were planting date (15 April, 29 April, and 24 May), winter cover (fallow or 'Dixie' crimson clover), and midrow weed control method (V-blade cultivator and glyphosate application). Soil type was Norfolk loamy sand (fine, loamy, siliceous, thermic, Typic Kandiudult). Weed control methods were compared in the first two planting dates in late May. At one week after treatment, weed control in the mid-rows was similar between glyphosate application and subsurface tillage in both planting dates and both winter cover treatments. Subsurface tillage reduced residue cover in the midrows by 8%. Weed control treatments were applied to all planting dates in late June. Clover successfully reseeded following both weed control methods. These preliminary data suggest that further investigation of subsurface tillage in reseeding crimson clover cotton production systems is warranted.

INTRODUCTION

Winter cover crops can be used for soil improvement and erosion control in cotton fields. Of the legume cover crops, crimson clover may be especially suitable in the southeastern USA because of its ability to provide adequate fall growth and abundant residues (Hoyt and Hargrove, 1984). Crimson clover can also provide all the N needed by a succeeding cotton crop on sandy Coastal Plain soils (Bauer et al., 1993; Touchton et al., 1984). The ability of some crimson clover cultivars to mature and reseed prior to a mid- to late-May cotton planting increases the potential for utilizing this legume in conservation tillage production systems.

Weed control in strip- or no-till systems is accomplished primarily with herbicides. In the pre-herbicide era, mechanical devices were developed to control weeds in row middles of crops growing in mulch-type cultural practice (Chase, 1942). This technology is again being evaluated for modern crop production. Cultivators are currently available to growers that will control weeds between rows when large amounts of surface residues are present.

In order for these cultivators to be most effective in a reseeding crimson clover conservation tillage system, crimson clover seeds must be left near the soil surface after cultivation. The optimal seeding depth for small seeded legumes like crimson clover is 0.5- to 1.5-cm (Decker et al., 1973). Therefore, secondary cultivation devices which cause significant soil mixing may bury clover seeds and result in reduced clover stands the following fall.

We used a set of V-blade sweeps to determine the efficacy of using this weed control method for cotton grown following crimson clover on a sandy Coastal Plain soil. In this report, we present the 1993 results from our comparison of these sweeps with a directed application of glyphosate in strip-tillage cotton grown after a crimson clover cover crop.

MATERIALS AND METHODS

Five independantly acting V-blade cultivator units were assembled. Each V-blade and a smooth coulter were attached to a lower parallel linkage frame of a Case-IH Model 183 cultivator utilizing a gauge wheel for depth control. The standard gauge wheel attachment was reversed to give the desired placement between coulter and V-blade.

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V-blade construction consisted of removing the stem from a 30 inch sweep and replacing the stem by welding a short flat bar attachment, beveled on the front, to the front portion of the sweep. The ends of the sweep were cut off to give a 26-in cutting width. The wings have a slightly beveled cutting edge. Nominal dimensions for the blade-wings are 0.25-in thick and 2-in wide.

The framework was constructed to provide a relatively simple means for accomplishing the following functions: 1. attaching to the Case-IH frame; 2. attaching the V-blade over a range of fixed distances from the Case-IH support frame with an adjustable pitch angle; 3. adjusting coulter depth; 4. aligning V-blade and coulter with each other and travel direction; 5. replacing parts for repairs and future investigations.

We evaluated this V-blade cultivator on a Norfolk loamy sand soil at Clemson University's Pee Dee Research and Education Center in Florence, SC. In this investigation, the V-blade and coulter nominal operating depths were 2 and 3-in, respectively, with the V-blade set parallel with the soil surface.

The treatments in the experiment were winter cover (crimson clover and fallow), planting date (15 April, 29 April, and 25 May). and midrow weed control method [V-blade cultivator and a directed application of glyphosate (Brewer, 1993) to the midrowsl. Experimental design was randomized complete block in split plot arrangement with the winter cover and planting date combinations as main plots and midrow weed control method as subplots. The experiment had four replicates.

In the fall of 1992, the experimental area was disked and harrowed. The cultivar 'Dixie' was seeded into the crimson clover plots at a rate of 20 lb seed ac^{-1} with a grain drill on 14 October, 1992.

At two weeks before the April planting dates, glyphosate was applied in 12-in strips to kill vegetation where the cotton rows were to be. A broadcast application of glyphosate was made at one week before the May planting date. All plots were in-row subsoiled before planting to a depth of 18 in. Cotton ('DES 119') was planted with a four row no-till planter in 38-in rows.

Total N applied to the cotton in the winter fallow plots was 70 lb ac^{-1}. No N was applied in the crimson clover plots. Lime and other plant nutrients were applied based on soil test results. Insecticides were used at planting to control thrips and in late June, late July, and early August for <u>Heliothis virescens</u> and <u>Helicoverpa</u> control. Pre- and post-emergent herbicides were applied with a directed sprayer for in-row weed control. A traveling gun irrigation system was used to apply 0.5 in of water to the plots on 29 and 30 April and again on **3** and 4 June.

Aboveground biomass of the winter covers (winter weeds in the fallow plots or the crimson clover) was determined by collecting and drying (70" C) a 10.8-ft^2 sample from each subplot on May 17. On 20 May, midrow weed control treatments were applied on the subplots in the first two planting dates. On 27 May, the amount of residue cover and live weeds in the treated areas were measured by using a' two dimensional transect. A 39-in long and 24-in wide frame was constructed from 1 inch PVC pipe. Four parallel strings were streched across the frame and attached to the 24-in sides. Six parallel strings were across the 39-in side. On each side, strings were spaced 6 inches apart. Residues and weeds [mainly crabgrass (<u>Digitaria</u> spp.)] were determined at the 24 intersections of the strings. Six determinations were made in each plot. The weed control treatments were applied to all three planting dates on 21 June. The cotton and weeds were severely water stressed at that time, so residue and weed determinations were not made.

Clover cover in early December was measured in two replicates of the study by using a line-transect of 45 ft with 39 evaluation points. Data was collected from midrows that had and did not have tractor wheel traffic during the growing season.

All data collected were subjected to analysis of variance. Mean separations were made by calculating a least significant difference.

RESULTS AND DISCUSSION

The biomass of the crimson clover and winter weeds on 17 May are given in Table 1. Values for clover in the first two planting dates were low, compared to the May planting date, because the clover in the crop rows was killed with glyphosate two weeks before each planting date in April. Also, wheel traffic from cotton planting and applying herbicides (in-row) in the April planting dates reduced clover production in the traffic

Table 1. Clover and winter weed biomass levels measured on May 17, 1993.

cotton Planting Date	Winter Cover Clover	Winter Cover Fallow
	lb/ac	
April 15	860	451
April 29	1009	243
May 24	2301	343
$LSD_{(0.05)}$	241	

midrows. Winter weed biomass was similar in the three planting dates (Table 1).

A severe drought occurred during the cotton growing season in 1993 and limited the value of our evaluation of the V-blade for weed control. The amount of weed control (measured on 27 May) at one week after treatment with the V-blade cultivator was the same as for the glyphosate application (data not shown). Both had very low live weed (mainly Digitaria spp.) populations. Like the weed control methods, neither winter cover treatment nor planting date influenced the amount of live weeds.

The amount of residue cover on 27 May was influenced by planting date, winter cover, and midrow weed control method, but interactions between these production practices did not occur. Residue cover was about 15% lower for the 29 April planting than the 15 April planting. Crimson clover provided 16% more residue cover than did winter weeds (74% for clover vs. 58% for fallow).

The V-blade cultivator exposed a small amount of soil. Residue cover in the mid-rows on 27 May was 62% in the V-blade plots and 70% in the glyphosate plots. Most of the soil exposed was in a line down the middle of the mid-row where the shank holding the V-blades entered the soil. Little or no soil was exposed near the end of the blades.

The lack of soil surface disturbance with the V-blade cultivator apparently kept enough of the clover seed in a zone where it could readily emerge and become established. In general, soil cover in the fall by live clover plants following use of the V-blade cultivator was only slightly less than when glyphosate was used to control weeds in the cotton row middles (Table 2). In the 15 April planting date, the amount of reseeded clover in the V-blade cultivator non-wheel mid-rows was less than the herbicide plots (Table 2). When the clover was allowed to fully reseed before planting cotton (24 May planting date), soil cover by live clover plants was greater than 90% for both the V-blade and glyphosate weed control methods (Table 2).

Table 2. Reseeded crimson clover cover in non-wheel and wheel mid-rows in late November, **1993.**

cotton Planting Date	Weed Control Method	Mid-Row Non-Wheel	Mid-Row Wheel
		%	
April 15	V-Blade	36	54
	Glyphosate	57	48
April 29	V-Blade	59	62
	Glyphosate	60	63
May 24	V-Blade	90	91
	Glyphosate	95	95
$LSD_{(0.05)}$		10.6	

In summary, surface residues were retained and crimson clover successfully reseeded following the use of the V-blade cultivator for weed control in 1993. These data suggest that further investigations of the V-blade cultivator in reseeding crimson clover cotton production systems are warranted.

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ADJUSTING GRAIN YIELD OF BIRD DAMAGED PEARL MILLET

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ABSTRACT

Pearl Millet [Pennisetum alaucum (L.) R. Br.] is a potentially-productive, high-quality grain crop that is highly susceptible to bird damage in small plots and in areas around the outside of large fields. Treatments that change the physiological maturity (specifically the soft dough stage which red winged blackbirds [Aaelaius phoenicens] seem to prefer and seek out) of small plots within a large field will result in their destruction. Our objective was to relate pearl millet grain yields to head length and seed size measurements of undamaged panicles. This research was conducted on a Norfolk sandy loam located on the North Florida Res. and Educ. Ctr., Quincy FL with HGM-100 pearl millet hybrid. Three hundred and sixty HGM-100 panicles that were not damaged by birds were selected at random for three different lengths of panicle (15, 12, and 9 inches in length) for grain yield and linear regression analysis. The simple linear regression equation for predicting grain yield per head of bird damaged pearl millet research plots was: $Y = -0.0317 + 0.0048\,X$, where Y = pearl millet head yield (lb/head) and X = head length (inches), $R^2 = 0.92$.

INTRODUCTION

Pearl millet is a potentially productive high-quality grain or silage crop (Burton et al., 1986 and Kumar et al., 1983). It is grown under low-input management conditions (noncrusting sandy soils with little fertilizer and limited water: Payne et al., 1990) and fits the summer growing season presently occupied by crops such as soybean IGlvcine max (Merr.)], peanut IArachis hyopgeae L.], sorghum [Sorghum bicolor L. (Moench)I, tropical corn [Zea mavs L.], bahiagrass IPaspalum notatum (Flugge)], and bermudagrass [Cvnodon dactvlon L. (Pers.)] in year-round multiple cropping systems of the southeastern United States.

Two major problems have been demonstrated in research with this potential new crop (Wright et al., 1993). First, the commercially available hybrid grain-type pearl millet, HGM-100 is a small seeded crop. This necessitates the need for uniform depth of planting which can be remedied by improved planter engineering and careful planter adjustment. Second, is the problem of the crops susceptibility to extensive bird damage to maturing panicles (the milk stage is the most susceptible stage). particularly in small plots (Wright et al., 1993).

Wright et al. (1993) experienced extensive bird damage to pearl millet in small plot research in 1992 and used a grain/silage-without grain ratio from an undamaged pearl millet herbicide study to estimate grain yield from other bird damaged research plots. This estimate was better than nothing, but a better predictor of bird damaged pearl millet yield was needed.

Estimating grain and forage crop yields has been demonstrated to be a function of the equation: $D = M/V$, where D = a measure of bulk density, M = mass, and V = volume (Teare and Mott, 1965 and Wilson and Teare, 19721.

The objective of this study was to find a pearl millet parameter, persistent after bird damage, for accurately predicting pearl millet grain yields from small-plot research to finish the research that had been successfully conducted up to the milk stage and bird predation.

MATERIALS AND METHODS

These studies were conducted in 1993 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 in this study was HGM-100. developed as a grain pearl millet by W.W. Hanna (1991). Tifton. Georgia. Pearl millet seed was no-till planted in a weed fallow field with a Brown Ro-Til implement with KMC planters in a

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Table 1. Pearl millet grain yield, and grain size for six replications of each head length (9. 12, and 15 inch); Quincy, FL. 1993.

Rept.	Head length’ (inch)	Grain (lb/1000 seeds)	Grain (lb/head)
1	15	0.0150	0.0467
2	15	0.0139	0.0377
3	15	0.0139	0.0398
4	15	0.0142	0.0452
5	15	0.0146	0.0382
6	15	0.0135	0.0410
$\bar{x}$		0.0142 A	0.0414 A
1	12	0.0122	0.0225
2	12	0.0120	0.0220
3	12	0.0132	0.0221
4	12	0.0130	0.0218
5	12	0.0143	0.0299
6	12	0.0133	0.0314
$\bar{x}$		0.0130 B	0.0250 B
1	9	0.0109	0.0130
2	9	0.0086	0.0144
3	9	0.0102	0.0154
4	9	0.0109	0.0111
5	9	0.0095	0.0112
6	9	0.0090	0.0096
$\bar{x}$		0.0098 C	0.0124 C

[1] Three specific head lengths selected at random from non-bird-damaged pearl millet. Each replication is the mean of 20 pearl millet heads.

[2] Grain size (seed weight (lb/1000 pearl millet seed) of the three specific head lengths.

[3] Grain yield was collected for each 20 heads per replication, divided by twenty and expressed as yield/head.

• Mean values in columns followed by the same letter are not significantly different at the 5% level of significance.

completely randomized block design with six replications on 29 May 1993. Before the millet was planted, weeds were burned down with applications of Round-up (7 May) at 2 pt/A and Gramoxone (21 May) at 3 pt/A. Seed were planted 3/4" deep at 4 lbs/A (322 000 seeds/A planted) with an emergence of approximately 177 000 plants/A (55% emergence). Plots were 24' X 30' with eight rows 36" apart.

Five hundred lb of 5-10-15 fertilizer/A was applied on 15 May before planting. Ammonium nitrate was sidedressed to the side of the row at 120 lb N/A on 16 July. Prowl @ 1 qt/A + Atrazine @ 2 qt/A was used for weed control (Wright et al., 1993). Herbicides were applied between stage 1 (three leaf stage) and 2 (five leaf stage), about 12 days after planting when millet was between 3 and 5 inches tall.

Pearl millet heads were measured from top to bottom of panicle as illustrated in Fig. 1. Twenty pearl millet heads were carefully selected for each of three specific head lengths (9, 12, and 15 inch) and replicated six times. Concomitant measurements of head grain yields and counts of heads per unit area were then used for regression analysis. Pearl millet heads were harvested on 28 Sept, dried in a greenhouse, and threshed with a clover threshing machine that required 20 pearl millet heads per sample for the threshing operation.

Little rain occurred throughout the growing season for this rainfed experiment. A total of 19.0 inches of rainfall was recieved during the pearl millet growing season from 29 May to 28 Aug, 1993. Rainfall events and amounts are shown in Fig. 2.

RESULTS AND DISCUSSION

The null hypothesis that pearl millet grain yield per head could be predicted from head length measurements was tested in 1993. Six replications of 20 non-bird damaged pearl millet grain heads of specific lengths (15, 12, or 9 inches) were carefully threshed and grain yield per head and grain weight per seed were found to be significantly different for each head length (Table 1).

A simple linear regression equation was developed to predict head yield from head length: Y = - 0.0317 + 0.0048 X, where Y = pearl millet

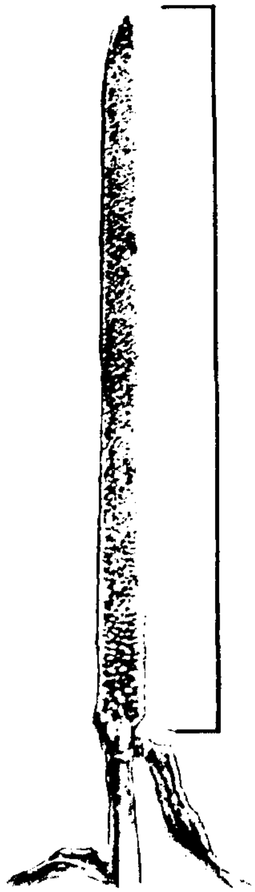

Figure 1. Length of pearl millet head measured as illustrated.

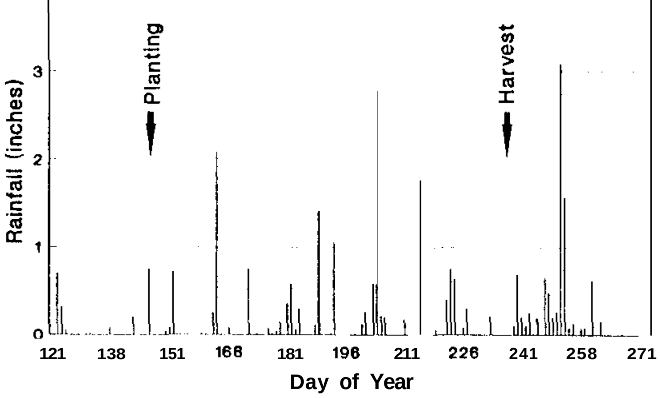

Figure 2. Rainfall during the 1993 pearl millet season in relation to rainfall amounts and dates of events.

grain yield (lb/head) and X = head length (inches) with a coefficient of correlation (r) = 0.96 and $\underline{P} < 0.0001$. A simple linear equation was also developed to predict head yield from grain size (lb/1000 seeds): $Y = -0.0421 + 5.5408X$, where Y = pearl millet grain yield (lb/head) and X = lb/1000 seed with a coefficient of correlation (r) = 0.89 and $p < 0.0001$.

Grain size (Y) was also predicted by head length: $Y = 0.0037 + 0.0007X$ with a coefficient of correlation (rl = 0.90 and $P < 0.001$.

When grain size (lb/1000 seed) and head length (inches) were used in a multiple regression analysis, the equation developed was: $Y = -0.0344 + 0.0043 X$, $+ 0.7630X_2$, where Y = pearl millet grain yield, X, = head length (inches) and X_2 = grain seed size (seed/lb) with a coefficient of determination (R^2) = 0.92 and $\underline{P} < 0.0001$.

We agree that the best measure of grain yield is from undamaged pearl millet heads per unit area, but using predictions of head grain yield from head length measurements of a specified unit area can salvage time-consuming small plot research that is more susceptible to bird depredation in the soft dough stage than when the pearl millet is grown in large fields. The most useful equation for predicting head grain yield is the simple linear regression where head length explains 92% of the variation in head grain yield. If all the head lengths are measured and number of heads counted in a unit area, then grain yields (bu/A) can be predicted from

$$\frac{\text{lb grainlhead x heads/A}}{\text{56 lb/bu}}$$

This equation is useful for salvaging valuable small plot research that has been subject to bird depredation.

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PHYSIOLOGICAL DEVELOPMENT OF HGM-100 TO PLANTING DATE AND AVAILABLE WATER

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ABSTRACT

Physiological status in plants is dynamic with soil water, atmospheric conditions, and ontogeny of the plant (indicated by stage of growth). Pearl Millet [Pennisetum glaucum (L.) R. Br., hybrid HGM-1001 is a new crop in the Southeast suitable for grain or silage. Our objective was to describe stage of development of HGM-100 in relation to date of event and available water for four planting dates through the summer growing season. This research was conducted on a Norfolk sandy loam located on the North Florida Res. and Educ. Ctr., Quincy FL with HGM-100. Stage of development and rainfall/irrigation events and amounts are described for four planting dates in 1993 for HGM-100. Seed size and predicted grain yields were related to amount of available water and planting date. The 17 May planting date produced the highest predicted grain yield (19.1 inches) and the 15 June planting date produced the lowest grain yield. The low yield may have been due to lack of pollinators (bumble bees, Bombus spp.) and not lack of water (18.2 inches). The 5 May planting recieved the least water (16.4 inches).

INTRODUCTION

Knowledge of plant, insect and disease ontogeny in relation to date of planting date as a function of growth stages and environmental parameters make it possible to compare or to combine limited bits of knowledge from all over the world to explain yield phenomena.

HGM-100 pearl millet synchrony with date of planting and expected environmental changes, such as, available water, day length and temperature; and the interactions with insect and disease cycles must be understood to obtain successful crop yields. These interactions have been defined as Systems Agriculture (Teare et al., 1992) in recent years.

Pearl millet is a potentially-productive high-quality grain or silage crop (Burton et al., 1986 and Kumar et al., 1983). It is grown under low-input management conditions (noncrusting sandy soils) with little fertilizer and limited water (Payne et al., 1990).

Hattendorf et al. (1988) report that pearl millet had the greatest daily water use rate of the crops studied {pearl millet, sunflower IHelianthus annuus L1, sorghum [Sorghum bicolor (Moench), corn (Zea mays L), and soybean [Glycine max (Merr.)]}. This and the knowledge that pearl millet also had the greatest leaf area index of these crops suggest that pearl millet has the capacity for deep rootedness, a greater number of roots and/or the attribute for increased rooting density (Davis-Carter, 1989).

Timing, intensity and duration of water stress accounted for 70 to 85 % of the variation in pearl millet grain yields within and across years in other studies (Mahalakshmi et al., 1985, 1987, and 1988). Critical growth stages identified as being sensitive to water stress were flowering and grain filling.

The objective of this study was to determine the impact of date of planting on HGM-100 pearl millet phenological events in relation to insect activity and available water during the 1993 summer growing season.

MATERIALS AND METHODS

These studies were conducted in 1993 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 in this series of experiments was HGM-100, developed as a grain pearl millet by W.W. Hanna (1991). Tifton, Georgia. Pearl millet seed was no-till planted (in-row subsoiled strip tillage) with a Brown Ro-Til implement with KMC planters.

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Table 1. Planting date, stage of development, and 112" irrigation for calendar date and day of year at Quincy, FL, 1993.

Stage	Description	Calendar date	Day of year	Amount Irrigation (inches)
PI	Preirrigation	30 April	120	1/2
PD_1	Planting date	5 May	125	
I	Irrigation	7 May	127	1/2
O	50% Emergence	10 May	130	
I	Irrigation	14 May	134	112
I	Third leaf visible	15 May	135	
1	Irrigation	17 May	137	112
2	Fifth leaf visible	21 May	141	
I	Irrigation	27 May	147	1/2
3	Panicle initiation[1]	30 May	150	
4	Flag leaf visible	5 June	156	
		8 June	159	112
5	Boot stage	12 June	163	
I	Irrigation	17 June	168	112
I	Irrigation	22 June	173	1/2
6	50% stigma emerged	25 June	176	
7	Milk stage, 1/2 length	10 July	191	
8	Dough stage, 1/2 length	19 July	200	
9	Black layer, 1/2 length	30 July	211	—
			86[2]	4.0[3]
TR	Total rainfall			12.4[4]
				16.4'

Table 1. Continued

Stage	Calendar date	Day of year	Amount Irrigation (Inches)
PI	14 May	134	112
PD_2+I	17 May	137	1/2
O	22 May	142	
I	27 May	147	1/2
I	30 May	150	
I	8 June	159	1/2
2	9 June	160	
3	14 June	165	
I	17 June	168	112
4	21 June	172	
I	22 June	173	1/2
5	25 June	175	
6	14 July	195	
7	3 Aug	215	
8	12 Aug	224	
9	16 Aug	226	—
		89	3.0[3]
TK			16.1[4]
			19.1'

[1] Panicle initiation occurs when fifth leaf fully extended.

[2] Days from planting to black layer formation at 1/2 length.

[3] Total irrigation.

[4] Total rainfall during growing period: PD, (1 May to 30 July). PD_2 (14 May to 16 Aug), PD_3 (11 June to 5 Sept), PD_4 (12 July to 30 Sept)

[5] Total water during growing period.

Table 1. Continued.

Stage	Calendar date	Day of year	Amount Irrigation (inches)
PI	8 June	159	1/2
PD_3	15 June	166	
0	20 June	171	
I	22 June	173	1/2
1	26 June	177	
2	30 June	181	
3	4 July	185	
4	14 July	195	
5	20 July	201	
6	5 Aug	217	
7	17 Aug	229	
8 & I	24 Aug	236	1/2
9	2 Sept	245	—
		86^2	1.5’
TR			17.2^4
			18.7’

Table 1. Continued.

Stage	Calendar date	Day of year	Amount Irrigation (inches)
PD_4	15 July	196	
O	21 July	202	
I	26 July	207	
2	30 July	211	
3	5 Aug	217	
4	12 Aug	224	
5	19 Aug	231	
I	24 Aug	236	II2
6	27 Aug	239	
7	15 Sept	258	
a	21 Sept	264	
9	28 Sept	271	—
		79‘	0.5’
TR			17.7‘
			18.2’

The pearl millet date of planting study was a split plot design with planting dates as whole plots and stages of development determined for six replications in relation to calendar date, development period. and total water for each plot. Planting dates, stages of development, and date of irrigation are shown in Table 1. Plots were eight rows wide (rows were 36 inches apart) and 30 feet long. Seed of pearl millet were planted 3/4" deep at 4 lbs/A 1302 667 seeds/A). This resulted in approximately 166 467 plants/A, or 55 % emergence.

Fertilizer (5-10-15 at 500 lbs/A) was applied three days before planting. Nitrogen was sidedressed to the side of the row at 120 lbs/A at boot stage. Prowl @ 1 qt/A + Atrazine @ 2 qt/A was used for weed control (Wright et al, 1993). Prowl and Atrazine were applied between stage 1 and 2 (Table 1, 10 to 15 days after planting when pearl millet was 3 to 5 inches tall).

Little rainfall occurred throughout the early growing season for this experiment. One half inch applications of irrigation were scheduled in response to paucity of rainfall (Table 1). Rainfall events and amounts are shown in Fig. 1.

RESULTS AND DISCUSSION

Four pearl millet planting dates, maturity dates and water (rainfall/irrigation) events are shown in Fig. 1 in relation to time. Note the lack of rainfall throughout the season. Total water available (rainfall and irrigation) from planting to maturity for each planting date (PD) was: PD, = 16.4 inches, PD, = 19.1 inches, PD, = 18.7 inches. and PD, = 18.2 inches (Table 1). Physiological stage of development for each planting date is shown in relation to calendar date and day of year (Table 1). Days between stages 0 to 3 were 20, 23, 14, and 15; stages 3 to 6 were 26, 30, 32, and 22; and stages 6 to 9 were 35, 31, 28, 32 for PD1, PD2, PD3, and PD4, respectively (Table 1).

Pearl millet head lengths; shown to be related to grain yield by Pudelko et al., 1994; are shown for each planting date (Fig. 2) (columns topped with the same letter are not significant at the 5 % level of significance). Head lengths for 5 May, 17 May, and 15 June plantings accurately predicted grain head yields $\underline{P} < 0.0001$) by the equation: $Y = -0.0317 + 0.0048 X$ (Pudelko et al., 1993). However, the 15 July planting date produced very little seed. The average number of

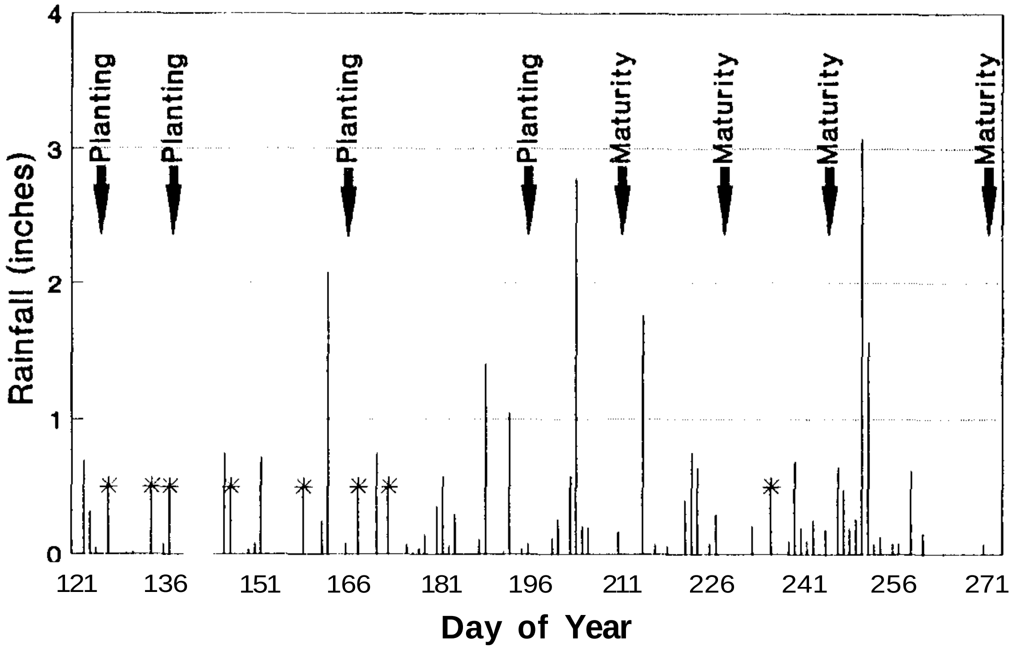

Figure 1. Rainfall during the 1993 pearl millet growing season for four planting dates in relation to rainfall amounts and dates of events.

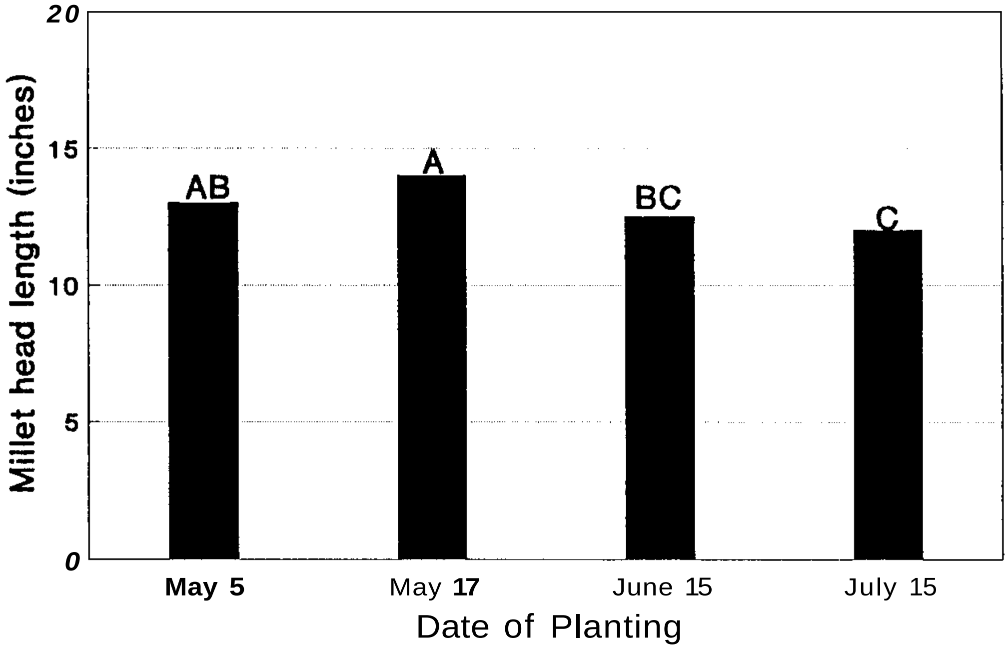

Figure 2. Pearl millet head lengths in relation to date of planting. Columns topped by the same letter are not different at the 5% level of significance.

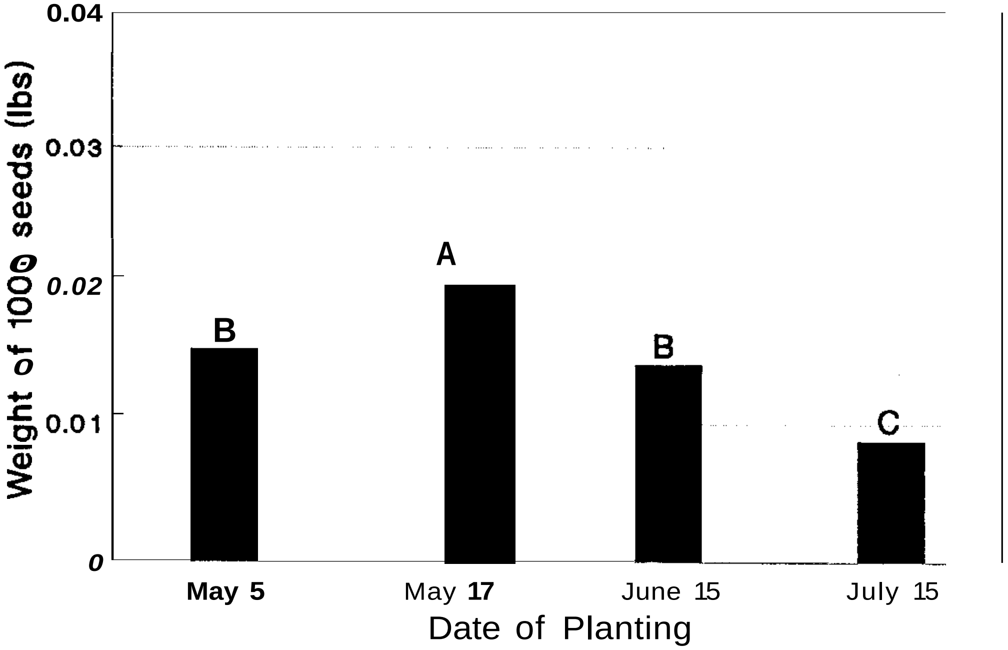

Figure 3. Pearl millet seed size (weight of 1000 seeds in relation to date of planting. Columns topped by the same letter are not significantly different at the 5% level of significance.

seeds per 20 non-bird damaged heads was only 105. This may have been related to environmental changes, i.e., reduced length of day, or paucity of pollinators. Bumble bees, the primary pollinators for the first three planting dates, were essentially absent during flowering of PD,. It probably wasn't lack of available water (18.2 inches compared to 16.4 inches for PD_1).

Contrary to Mahalakshmi et al. (1988). we found differences in seed size (lb/1000 seed) due to planting date (Fig. 3). Seed size in relation to planting date indicates that environment affected grain yield. One would expect that the 15 July planting date, with only 105 seeds per 20 heads, should have large seeds like PD, or at least seeds the same size as PD, and PD„ but the seed size was smaller than the earlier plantings. Grain yield (predicted by head length, Fig 2.) and seed size (lb/1000 seed, Fig. 3) are increased by increased water (19.1 inches for PD„ Table 1) (Mahalakshmi et al., 1987 and 1988). Thus, PD, (17 May) may be the optimum planting time for pearl millet in the Southern Coastal Plain.

CONCLUSIONS

1. Physiological growth stages from planting to black layer formation are shown in relation to calendar date and date of year for four planting dates.
2. The 17 May planting date recieved the most rainfall (19.1 inches) and produced the highest grain yields.
3. Head lengths for 5 May, 17 May, and 15 June plantings accurately predicted pearl millet head yields ($\underline{P} < 0.05$) with equation $Y = -0.0317 + 0.0048 X$.
4. The 15 July planting date produced very little seed although head lengths averaged over 12 inches long.
5. Bumble bee pollinators were essentially absent during flowering of the 15 July planting date.
6. The 17 May planting produced grain with the largest seed size and 15 July, the smallest seed size.

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PEARL MILLET HEAD LENGTH IN RELATION TO INDUCED STRESS

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ABSTRACT

Pearl Millet [Pennisetum glaucum (L.) R. Br., hybrid HGM-1001 panicle length is highly correlated with grain yield. Our objective was to relate pearl millet head length with two induced stressors: 1) herbicide stress, and 2) plant density stress (row width/seeding rate). This research was conducted on a Norfolk sandy loam located on the North Florida Res. and Educ. Ctr., Quincy FL. Preplant applications of Dual with 2,4-D or Atrazine, Ramrod alone or with Atrazine significantly ($P < 0.05$) increased head length in till and no-till treatment. Prowl and Atrazine increased head length in till treatment only. The mean head length across row widths for the 6 lb/A seeding rate was significantly shorter than the 2 and 4 lb/A seeding rate. The mean head length across seeding rates for the 5 inch row width was significantly greater than the 15 and 30 inch row width. This information helps evaluate whether pearl millet head lengths should be used to predict grain millet yield under certain imposed stress treatments.

INTRODUCTION

Pearl millet is a potentially-productive high-quality grain or silage crop (Burton et al., 1986 and Kumar et al., 1983). It is grown under low-input management conditions (noncrusting sandy soils) with little fertilizer and limited water (Payne et al., 1990).

Teare et al., 1994, describe physiological stage of development for each of four planting dates and related planting date and water availability to predicting grain yield from head length measurements. They found that head lengths for 5 May, 17 May, and 15 June plantings accurately predicted grain head yields, but 15 July planting produced less seed and smaller seeds with moderately long heads which was probably related to absence of pollinators (bumble bees, Bombus spp.) and lateness of the season. Timing, intensity and duration of water stress accounted for 70 to 85 % of the variation in pearl millet grain yields within and across years in other studies (Mahalakshmi et al., 1988). Critical growth stages identified as being sensitive to water stress were flowering and grain filling.

Two preplant herbicides, Pursuit and Accent, have been reported to reduce grain yield of pearl millet (HGM-100) 60 and 100 percent compared to a handweeded check (Wright et al., 1993). However, the effect of herbicide stress has not been reported in relation to head length [suggested by Pudelko et al. (1993) for estimating pearl millet grain yields in small research plots after bird predation].

The objective of this study was to determine the impact of certain induced-stresses [herbicide stress, and plant density stress (row width/seedling rate)] on pearl millet to head length, which has been used for predicting pearl millet head yields.

MATERIALS AND METHODS

These studies were conducted in 1993 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 in this series of experiments was HGM-100, developed as a grain pearl millet by W.W. Hanna (1991). Tifton, Georgia. Pearl millet seed was no-till planted (in-row subsoiled strip tillage) in a weed fallow field with a Brown Ro-Til implement with KMC planters.

Herbicide Study

A herbicide study on pearl millet was conducted on a very weedy field. Before it was planted, the field was mowed and divided into two equal parts. One halve for conventional tillage-planting and the other for no-tillage-planting. The conventional halve was subsoiled to 12-inch depth on 12 May and S-tine harrowed 2 June. The no-till part was sprayed with Gramoxone on 2 June at the rate of 3.0 pt/A primarily for nutsedge control.

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Table 1. Pearl millet head length in relation to weed control on Till and No-Till system.

	Treatment	Rate per A	Till System Head Length[1]		No-Till System Head Length[1]	
1.	Atrazine without oil	1.5 lbs	0.918	FGHI	0.875	FG
2.	Atrazine without oil	2.0 pt	0.930	FGH	0.900	FG
3.	Atrazine with oil	1.0 lb + 1 qt	0.870	HI	0.878	FG
4.	Atrazine with oil	1.5 lbs + 1 pt	0.870	HI	0.945	EF
5.	Dual + 2,4 D	1.0 pt + 0.5 lb (a.i.)	1.072	BC	1.100	AB
6.	Dual + 2,4 D	1.5 pts + 0.5 lb (a.i.)	1.070	BC	1.120	AB
7.	Dual + 2,4 D	2.0 pts + 0.5 lb (a.i.)	0.948	EFG	1.085	B
8.	Ramrod (42%) + 2,4 D	3.0 qt + 0.5 lb (a.i.)	1.010	CDE	0.990	DE
9.	Ramrod (42%) + 2,4 D	4.5 qt + 0.5 lb (a.i.)	1.017	CD	1.005	CDE
10.	Prowl + 2,4 D	1.0 pt + 0.5 lb (a.i.)	0.910	GHI	0.882	FG
11.	Prowl + 2,4 D	1.5 + 0.5 lb (a.i.)	0.880	HI	0.938	EFG
12.	Dual + Atrazine with oil	1.0 pt + 1.0 lb	1.253	A	1.075	BC
13.	Dual + Atrazine with oil	1.5 pt + 1.0 lb	1.058	BC	1.173	A
14.	Ramrod + Atrazine with oil	3.0 qt + 1.0 lb	1.102	B	0.888	FG
15.	Ramrod + Atrazine with oil	4.5 qt + 1.0 lb	0.948	EFG	1.058	BCD
16.	Prowl + Atrazine with oil	1.0 pt + 1.0 lb	0.918	FGHI	0.865	G
17.	Prowl + Atrazine with oil	1.5 pt + 1.0 lb	0.975	DEF	0.900	FG
18.	Check hand weed control		0.858	I	0.889	FG
19.	Check without weed control		0.900	GHI	0.897	FG
20	Check without weed control		0.908	GHI	0.905	FG
Mean[2]			0.971 z		0.968 z	
21.	On till only Ramrod + Atrazine with oil and Prowl postemer 4.5 qt + 1.0 lb		0.895	GHI		
22.	On till only Prowl + Atrazine with oil and Prowl posteiner 1.0 pt + 1.0 lb		0.898	GHI		

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[1] Mean values in columns followed by the same letter are not significantly different at the 5% level of significance.

[2] Mean values in row followed by the same letter are not significantly different at the 5% level of significance.

Cultural practices common to both tillage systems were: 1) the application of 500 lb/A of 5-10-15 fertilizer 21 June, 2) pearl millet seed treatment with Concep to "safen" herbicide application (particularly Dual). 3) planting on 23 June followed by irrigation with 3/4 inch of water on the day of planting, 4) seeding rate of 4 lb/A in plots 12 feet by 25 feet in 36" rows (plant density of 166 000 plants per acre), 5) band application of 80 lb N/A as ammonium nitrate applied two inches to the side of row on 21 July, 6) spraying with Lannate for control of corn earworm on 8 July, and 7) all plots were sprayed with 2.4-D for broad leaf weed control on 16 July.

Seventeen pre-emerge herbicide treatments were applied in different herbicide combinations (Dual (Metolachlor), Ramrod (Propachlor), Prowl (Pendimethalin). Atrazine, and 2,4,-D) on 25 June (Table 1). Two postemergence treatments of Prowl were applied following pre-emerge applications of Atrazine, plus either Ramrod or Prowl in the till system only. One hand weeded treatment and two treatments without weed control completed the 22 treatments used in this study (Table 1).

The experiment was a split plot design with tillage systems as whole plots and herbicide treatments as sub-plots. All treatments were replicated four times. Results were subjected to analysis of variance and means were separated using Fishers Least Significant Difference Test at the 5 % level of probability.

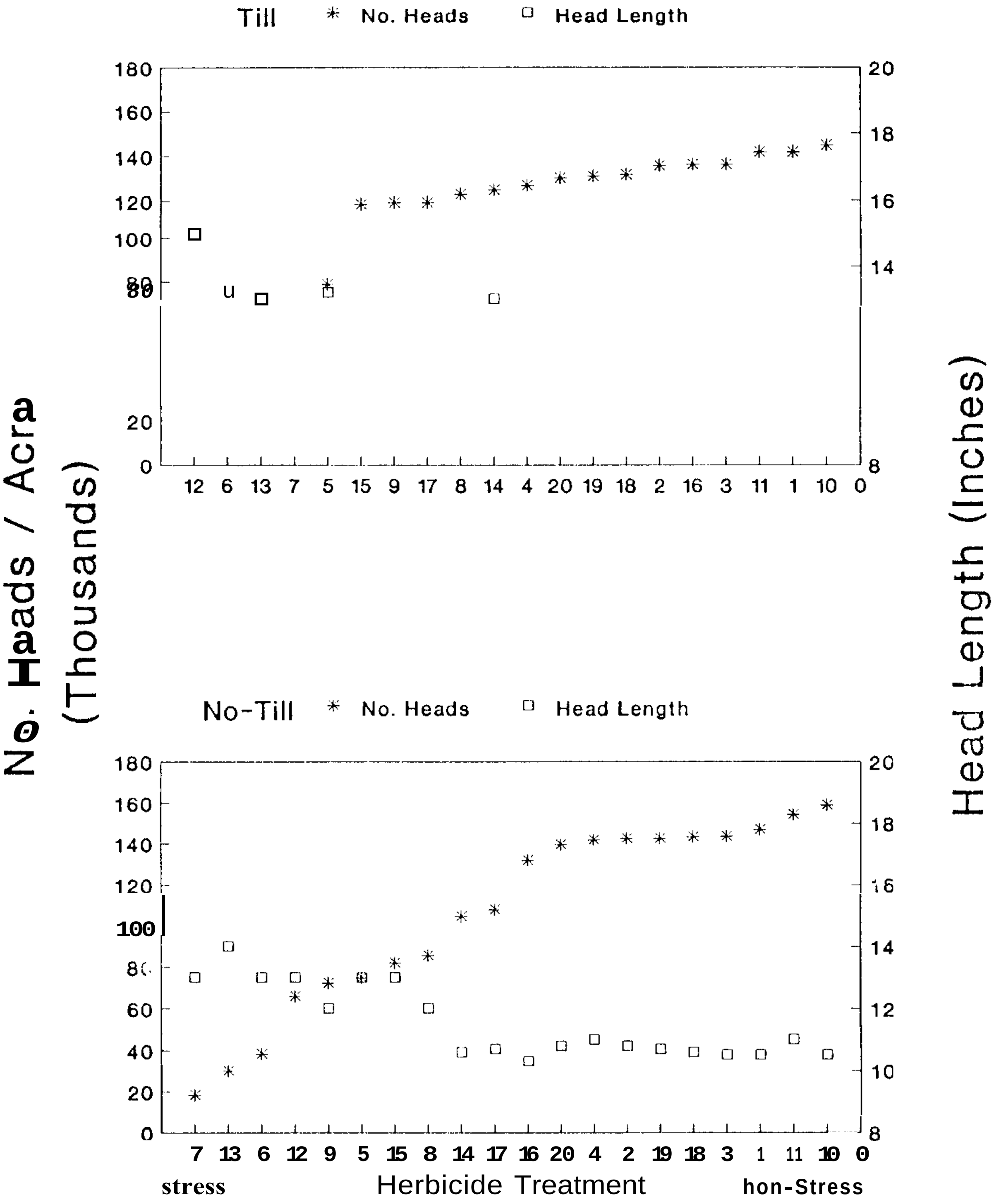

Figure 1. Herbicide stress indicated by number of heads/A in relation to herbicide treatment and head length (inches) of till and no-till systems.

Row Width/Seeding Rate Study

The row width-seeding rate study was planted on 28 June. Row widths and seeding rates used in the study are shown in Table 2. Plot size was 5 feet wide X 25 feet long.

Cultural practices common across all row widths and seeding rates were: 1) application of 500 lb/A of 5-10-15 before planting on 25 June; 2) application of ammonium nitrate banded beside row at **50** lb N/A at 5th leaf stage **(10** July), boot stage (31 July), and milk stage (27 Aug) (total N applied, 150 lb/A); and application of Prowl + Atrazine at 1.0 and 1.5 lb/A, respectively on 30 June after planting and before emergence (3 July).

Plant population density (plants per acre and plants per linear foot of row) are shown in Table 2 for each seedling rate and row width. Note the uniform plant population density across row widths (columns) and the increased number of plants within the row as row width increased for each seeding rate.

RESULTS AND DISCUSSION

Herbicide Study

Tillage systems had no effect on pearl millet head length ($\underline{P} < 0.051$ (Table 1). Number of heads/A is an indication of herbicide treatment stress. Figure 1, with herbicide treatments ordered in relation to number of heads/A, shows the lowest number of heads/A or greatest herbicide stress at the left of the X axis and least herbicide stress at the right of the X axis. Herbicide treatments and their numerical codes are shown in Table 1. In the till system (Fig. 1), ,head lengths were significantly longer ($\underline{P} < 0.05$)with Dual and 2.4-D treatment at the two lower rates Itrt **6** and **7),** Ramrod and 2,4-D (trt 8 and 9). Dual and Atrazine (trt 12 and 13). Ramrod and Atrazine at the lower rate (trt 13). and Prowl and Atrazine Itrt **17)** than with the no-herbicide application trt 18, 19, 20). In the no-till system (Fig. 1) seed head lengths were significantly ($\underline{P} < 0.05$) longer for Dual and 2.4-D at all rates Itrt 5, 6, and 7). Ramrod at all rates Itrt 8 and 9). Dual and Atrazine (trt 13 and 14), and Ramrod and Atrazine (trt **15)** than for the no-herbicide application. With the exception of trt 14 (Ramrod @ 4 qt/A and Atrazine with oil @ 1 lb/A). Dual and Ramrod increased head lengths and reduced number of heads/A.

The two post emergence treatments in the till system, of Ramrod and Atrazine (trt 21) and Prowl and Atrazine (trt 22). had no effect on pearl millet head length ($\underline{P} < 0.05$).

Row Width/Seeding Rate Study

The effect of pearl millet population density (plants/A and plantsllinear foot of row) for each combination row widthlseeding rate are shown in Table 2. Population density increased in rows from left to right according to seeding rate, but population density in columns from top to bottom across row widths remained constant. Plants/linear foot of row increased for each row width from left to right and from top to bottom for all seeding rates across rbw widths (Table 3). Population density effects on pearl millet head lengths are shown in Table 3. The mean head length across row widths (Table 4) for the 6 lb/A seeding rate was significantly shorter than the 2 and 4 lb/A seeding rate ($\underline{P} < 0.051$. The mean head length across seeding rates (Table 4) for the **5** inch row width was significantly greater than the 15 and 30 inch row widths ($\underline{P} < 0.05$).

CONCLUSIONS

1. Tillage systems had no significant effect on head length.
2. Pre-emerge applications of Dual and 2,4-D; Ramrod; Dual and Atrazine: Ramrod and Atrazine increased head length in till and no-till systems. The Prowl and Atrazine treatment increased head length in the till system only.
3. Post emergence treatments of Ramrod and Atrazine and Prowl and Atrazine had no effect on head length ($\underline{P} < 0.05$).
4. The mean head length across row widths for the 6 lb/A seeding rate was significantly shorter than the 2 and 4 lb/A seeding rates ($\underline{P} < 0.051$.
5. The mean head lengths across seeding rates for the 5 inch row width was significantly greater than the 15 and 30 inch row widths($\underline{P} < 0.05$).

This knowledge is useful for assessing the value of the predictive equation (Pudelko et al., 1993) for estimating pearl millet head yield of small

Table 2. Plant population density (plants/A) and plants/linear foot of row[1] are shown for each combination seeding rate and row width.

Row width (inches)	Seeding Rate' (lb/A) 2	4	6
5	**89,000 (0.85)**	**172,000 (1.65)**	**264,000 (2.53)**
15	**88,000 (2.54)**	**176,000 (5.06)**	**266,000 (7.64)**
30	**88,000 (5.08)**	**177,000 (10.16)**	**265,000 (15.23)**

[1] Plants/linear foot of row in brackets

'Emergence rate approximately 55% of seeding rate

Table 3. Pearl millet head lengths' in relation to row width and seeding rate.

Row Width (inches)	Seeding Rate (lb/A) 2	4	6	$\bar{x}$
5	**1.013**	**0.995**	**0.998**	**1.002** A
15	**0.975**	**0.992**	**0.848**	**0.938 B**
30	**0.970**	**0.955**	**0.895**	**0.940 B**
$\bar{x}$	**0.986 A**	**0.981 A**	**0.913 B**	

[1] Mean values followed by the same letter are not significantly different at the 5% level of significance.

research plots after bird predation. In the decision making process, it is important to know that Dual and Ramrod increase head length more than Prowl, that high seeding rates shorten head lengths, and that narrow rows lengthen heads lengths.

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